Innovation, Patenting, and International Competitiveness: Empirical Evidence from China

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As an integrated part of its overall economic reforms, China's innovation system is apparently becoming increasingly efficient. The orientation of research and development has shifted to activities more applied in nature as reflected in the patent data. Combining this with data measuring China's R&D inputs, we present evidence supporting the hypothesis that the patent production function is characterized by constant returns to scale. Moreover, accumulation of patents, which is the source of intertemporal technology spill-overs, contributes significantly to the creation of new knowledge. Technological capability as measured by the ratio of number of patents to the population of a region appears to correlated with enhanced international competitiveness of the non-state industrial sectors. (*JEL* classification: O31)

I. Introduction

One of the most remarkable phenomena in Asia's economic development in the last decade is the rapid economic growth in China and its increasing competitiveness in the international market. China has been experiencing a fundamental transformation of its economic system during the past 17 years. As an integrated part of the overall economic

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reform, changes in the innovation system have been fundamental. This paper looks at the changes in China's innovation system in general and its patent system in particular and to analyze the relationship between these changes and the improvement in its international competitiveness. We will address the following questions: what has happened in China's innovation systems since the reform? What are the characteristics of the innovation sector in China today? Have changes in the nation's innovation system influenced the international competitiveness of China's industries? By answering these questions, we can improve our understanding of the innovation system reforms in China in the transitional period and the impact of such reforms on its economic development and international competitiveness.

The relationship between economic development of nations and the technological progress has long been recognized. As has been shown in the endogenous growth literature, the rate of productivity growth is influenced by technological progress as well as accumulated human capital. In the theoretical literature, technological progress and knowledge accumulation are considered as two of the most important factors that explain the differences in both the levels and the rates of economic growth across nations (Lucas 1988; Grossman and Helpman 1991; Romer 1990). Undoubtedly, the rate of technological change and the level of accumulated knowledge influence the competitiveness of a nation. Despite the importance of this issue, it is not easy to measure accurately a nation's innovativeness and technology progress in an empirical study. Patent data, although not ideal, constitute a rough indicator of innovative activity and have been used more and more frequently in recent studies (Griliches 1984, 1990; Jaffe *et al.* 1993; Mansfield 1986). China re-established its patent system and started to publish its patent data in 1985. This data offers an opportunity for us to look at closely the mechanisms behind China's remarkable economic growth and its increasing international competitiveness. By examining China's patent data, including its composition and distribution, we may be able to gauge the scale and scope of China's invention and innovation and their contributions to economic development.

This paper is organized as follows. The next section provides a brief overview of the science and technology sectors in China, focusing on the reform measures and policies adopted in the last 17 years. In Section III, we discuss the patent system in China and use recently available patent data to study the evolution and structural changes in its innovation system during the reform process. Next, we look at the relationship between patenting and research and development efforts in a simple empirical model to identify the characteristics of the patent production function. We investigate the impact of patenting on the international competitiveness of non-state industrial sectors in Section V. Concluding remarks are presented in Section VI.

II. Innovation System in China

The current innovation system in China is the result of 17 years of reform. Although economic reforms have brought changes in many aspects of the innovation system, its basic organizational structure remains the same. China's innovation system is composed of five types of research organizations, each of which has certain specific tasks and objectives. First of all, in both prestige and number of researchers, the Chinese Academy of Sciences represents China's current status of scientific research. With 123 research institutes and 66,608 research scientists and engineers in 1992, it engages primarily in basic research although many of its research activities have become more applied in recent years. Second are the research institutes controlled by the central government ministries. Totalling 961, such institutes conduct industry-specific research and develop new products. Thirdly, large enterprises have their own R&D departments/divisions to develop new product models and to improve existing production processes. All higher learning institutions participate to some extent in R&D, and the participation is increasing, but most academic research is still concentrated in the so-called key universities. Finally, there is a defense-related research sector which carries out research for both military and civilian purposes (State Science and Technology Commission of China, 1993).

Reforms of China's innovation system are an integrated part of the overall economic reform which was initiated in 1978. The recognition of the importance of science and technology in economic growth prompted China's leaders to rethink the entire system. The main objectives of the reforms were two-fold: first, to upgrade technology overall so as to bring China closer to industrial nations; second, to improve links between the R&D sector and other sectors so as to let the R&D sector contribute more towards economic development. Major steps have been taken since then to transform the R&D sector. The State Science and Technology Commission was reinstated to coordinate planning and guidance, and programs for the development of science and technology were initiated. Scientific research organizations at various levels were rapidly restored and soon came into their own.

Because most of the research institutes were state-owned, they were used to relying on the state for allocation of funds. Now, following reforms of the country's fund distribution system, state-owned research institutes can no longer subsist on government appropriations. They must compete for the limited funds and be responsible for the output of their research. In addition to the direct allocation of funds from the government, (which only comprised about 27% of total R&D funding sources in 1993), a substantial proportion of funds must be raised by the institutes themselves, often supplemented by bank loans. When the total amount of funds allocated to R&D activities from the state budget increased, the way such funds were allocated altered fundamentally. The reform of the fund distribution system and the development of the technology market instilled new vitality into the efforts of the nation's research organizations to serve the nation in advancing economic development. A substantial number of government research institutes set up organizational or business ties with various enterprises and economic entities. Research and development activities also progressed in large and medium-sized industrial enterprises. In 1993, the nation's large and medium-sized industrial enterprises operated 12,499 technological development organizations employing 411,000 people, including 199,000 scientists and engineers (State Statistical Bureau of China 1995).

To foster integration between the otherwise fragmented parts of the innovation systems, policies were introduced to encourage technology-manufacturing-commerce cooperation. Research institutes or researchers themselves were allowed to set up or to lease small enterprises to commercialize their discoveries. The enterprises were encouraged and pressured by market forces to do more R&D. Outright merger between enterprises and research institutes has also become possible. To accelerate the process of commercialization of scientific discoveries and to facilitate technology transfers from research institutes to final users, China has established and developed several national and regional technology transaction centers in various regions (Baark 1991). The number of technology transactions increased rapidly. The total value of transactions reached RMB 22.9 billion in 1994 (State Statistical Bureau of China 1995).

Technology transfers were not limited to the civilian research institutes. Advanced technologies were transferred from defense-oriented research institutes to the civilian industrial sectors. These research institutes refocused themselves to both military and civilian purposes. Most importantly, these technology transfers and re-orientation were concentrated mainly in transport, telecommunications, nuclear energy and other sectors which were urgently needed for the development of the national economy. Despite these efforts, the magnitude of China's technology advances is limited by its level of overall economic development. The share of R&D expenditures in the GNP was 0.50% in 1994. (China Statistical Bureau of China 1995) It was much lower than that of the developed countries which averages 2.92% of GNP, and it was even below the developing countries' average, which was about 0.64% of the GNP in 1990 (UNESCO 1993).

III. Patent System in China

The purpose of the patent system is to provide inventors with exclusive right so that those who create new products or production processes can benefit from them and at the same time to encourage disclosure of innovations. The first legislation in China related to patents was "The Provisional Regulations on the Protection of the Invention Rights and Patent Rights" in 1950. This legislation established patent rights as understood in industrialized economies. However, in 1954 it was abolished and replaced by other regulations. The process of re-establishing the patent system started in 1978. In March 1984, the People's Congress passed the Patent Law of China. The Law was enacted in April 1985. The Patent Law of China, similar to the European Patent Convention, adopts a *First to File* system. This means priority is accorded to the inventor who is the first to file the patent application. The date of application establishes priority. This is different from the US patent system which adopts a *First to Invent* principle and priority is accorded to the person who is first to invent. Restoration of the patent system represents a major step in reform of the innovation system.

To encourage productive R&D activities which might lead to inventions, the Patent Law of China classifies all patents into three categories: creations and inventions; utility models; and designs. The *creation and invention* patent grants an inventor legal means to prevent others from copying or using the invention. To qualify as a creation and invention patent, the invention must be novel, useful and unobvious to practitioners skilled in the technology field. Utility model and design patents are judged by these same criteria but need to meet less stringent requirements. *Utility model* patents, also called *petty* patents, have a weak inventive step requirement, and in practical terms require novelty against national or regional inventions, but not always against world inventions. The advantage of the utility model patent is that it enables more people to participate in the innovation, thereby encouraging individuals and small firms to undertake R&D activities. *Design* patents do not require inventive steps and have a relatively weak usefulness requirement.

One measure of patent protection is the length of patent life. The differences in patent life create different degrees of incentive for inventors to patent their inventions. The shorter the period of patent protection, the weaker the incentive for inventors to have their inventions patented and the stronger the incentive to keep their inventions secret. As in many other countries, the patent protection period in China varies, depending on the type of patent: for creation and invention patents, the protection period is 15 years; for both utility model patents and design patents, the protection period is 5 years with the possibility of one 3-year extension. Because the Patent Law specifies that the maximum patent application examination period is 18 months, the *de facto* patent protection period for an invention patent can be as short as 13.5 years. Therefore, the protection period for invention patents is much shorter in China than in most other advanced countries. Under U.S. law, the exclusive right for an invention lasts 17 years following the date the patent is issued. Under the prevailing laws of most European nations, which were harmonized by the European Patent Convention in 1977, the exclusive rights they confer last for 20 years from the day of application (Scherer and Ross 1990).

A. China's Patent Applications and Patents Granted

The total number of patent applications and patents granted in China in the 9-year period from 1985 to 1993 are shown in Figure 1. As shown in the Figure, the numbers of patent applications and of patents granted both increased steadily after the introduction of the Patent Law. The figures for 1985 were smaller than subsequent years mainly for two reasons: the Patent Law was enacted in April of that year so the data only covers 9 months of that year; the patent examination created a time lag in patents awarded. The second reason can be used to explain the acceleration of the increases in patent applications and certified patents in each subsequent year. When comparing the trends of patent applications and patents granted, we observe that the

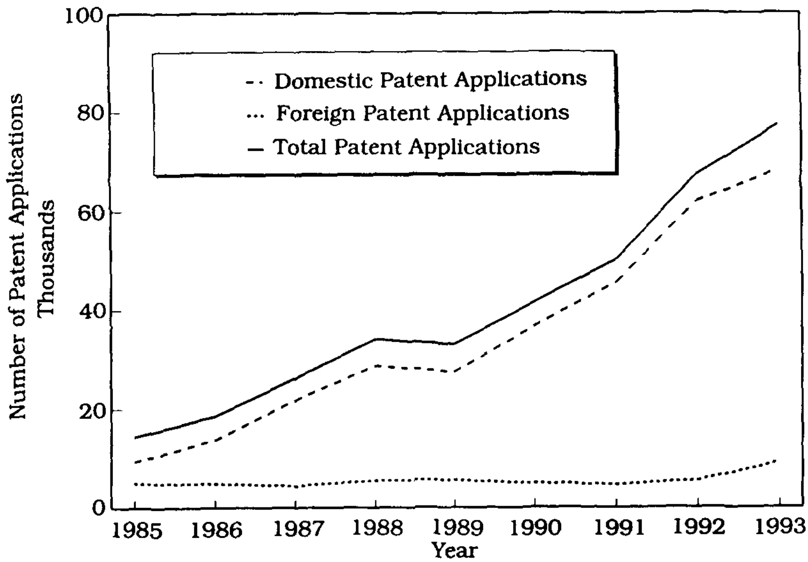
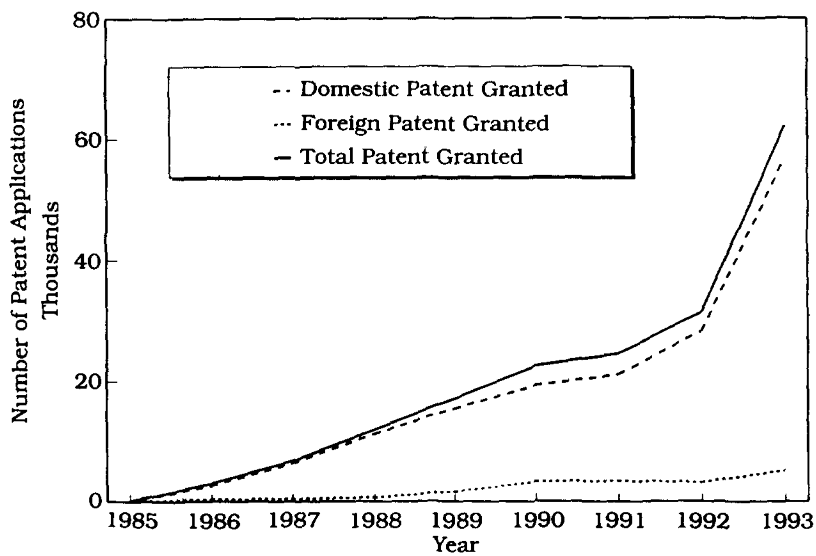


FIGURE 1A

PATENT APPLICATIONS MADE IN THE PEOPLE'S REPUBLIC OF CHINA (1985-93)



Sources: State Statistical Bureau of China. 1986-94.

FIGURE 1B

PATENT GRANTED BY THE PEOPLE'S REPUBLIC OF CHINA (1985-89) patent applications demonstrate more ups and downs than that of the patents granted. This is particularly obvious in 1989, when the national economy experienced some difficulties and in 1993, when the economy experienced an unprecedented boom.

Since patents are granted to inventors of devices or processes for both the novelty and the potential utility of such devices or processes, examinations must be carried out to verify these claims. According to the Patent Law, all patent applications must be filed with the State Patent Bureau in Beijing through local patent agencies. Thus, as each application must pass through a lengthy process of examination and certification, resources allocated to the national patent system become a critical factor determining how many patents can be successfully examined and certified in any given period. Despite such constraints, both patent applications and patents granted have generally increased in the past 9 years.

Of the total patents granted, about 10%, on average, are granted to foreigners. Although the number of foreign patents increased steadily in the 9-year period, the percentage of foreign patents out of total patents granted declined toward the end of the sample period to 8.4% from a peak of 14.5% in 1990. Comparable data from the U.S. shows that, in the 1950s, foreign inventors received only 7% of U.S. patents. By 1980-86, the share of foreign patents had increased to 42.6%. This increase of foreign patents supports the view that the U.S. patenting is becoming increasingly internationalized. To allay fears that the foreigners are taking the lion's share of the total patents, some researchers have suggested that some patents assigned to the foreigners were the inventions of the U.S. scientists employed by foreign companies; therefore, the decline in U.S. domestic patenting did not imply a weakening of the U.S. technological capability (Scherer and Ross 1990).

An indicator which represents efforts to uphold the standards of novelty and utility imposed in the granting of patent rights is the granting rate: *i.e.* the ratio between the total patent applications and the number of patents finally granted in each period. In most industrialized countries, about two-thirds of patent applications are eventually granted (Griliches 1990). From Table 1, we can see that the granting ratio in China in this 9-year period has been fluctuating with an increasing trend. In most years, the granting ratios for both the domestic and foreign patents were below two-thirds. It suggests relatively stringent examination standards adopted by the patent examiners in the review process.

TABLE 1
CHINA'S PATENT APPLICATION AND GRANTING RATIO

	Domestic Patents			Foreign Patents		
	Application	Granted	Ratio	Application	Granted	Ratio
1985	9,411	111	1.2%	4,961	27	0.5%
1986	13,680	2,671	19.5%	4,829	353	7.3%
1987	21,663	6,401	29.5%	4,414	410	9.3%
1988	28,582	11,292	39.5%	5,429	654	12.0%
1989	27,367	15,480	56.6%	5,538	1,649	29.8%
1990	36,585	19,304	52.8%	4,884	3,284	67.2%
1991	45,395	21,178	46.7%	4,645	3,438	74.0%
1992	61,788	28,311	45.8%	5,347	3,164	59.2%
1993	68,153	56,882	83.5%	9,123	5,245	57.5%
Sum	312,624	161,630	51.7%	49,170	18,224	37.1%

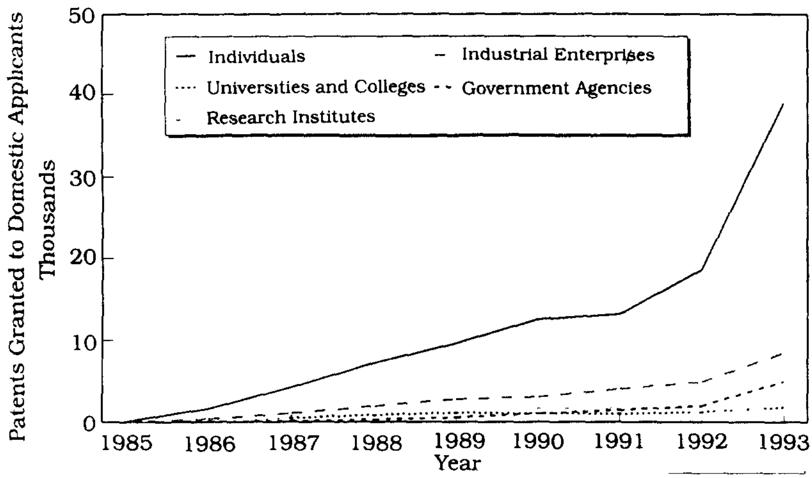
Sources: State Statistical Bureau of China, 1986-1994.

B. Classification of Domestic Patent Holders

The reform measures introduced in the R&D sector may have different impact on the different R&D organizations over time. Some organizations may respond relatively quickly with faster improvement in productivity, while others may not. Such differences are partly revealed in the patent data. The numbers of patents granted to the five types of domestic patent holders are classified into five groups and depicted in Figure 2.

As we can see in Figure 2, individual inventors hold most of the patents granted in the 9-year period under study. An interesting observation is the increase in relative importance of the industrial enterprises in patent holdings. As noted earlier, one of the weaknesses of the innovation system in the pre-reform period was the fragmentation of the innovation system and the separation between R&D and production stages.

From Figure 2, we can see that in the early stage of the economic reform, industrial enterprises accounted for a small share in the total domestic patents granted. In 1993, the share of domestic patents granted to enterprises increased significantly. The substantial increase in the patents granted to enterprises reflects success in efforts to integrate the previously-separated R&D and production stages have worked. Another striking trend to be seen in the patent statistics is the



Sources: State Statistical Bureau of China, 1986-1994.

FIGURE 2

PATENTS GRANTED TO DOMESTIC APPLICANTS IN CHINA (1985-94)

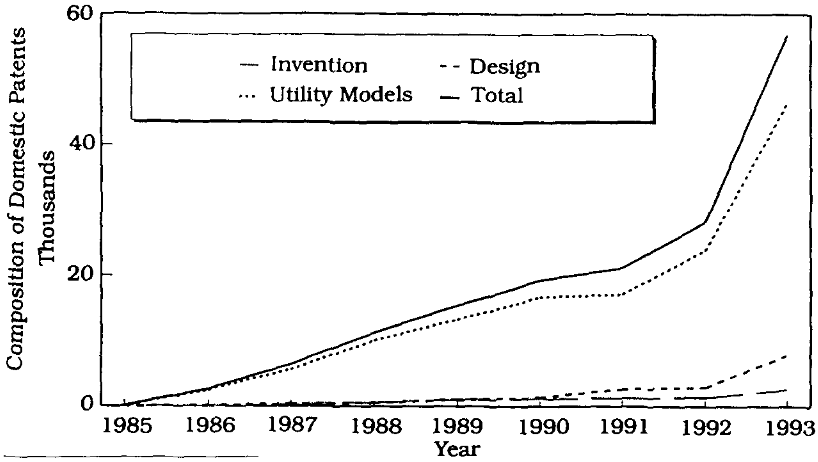
increase in number of patents granted to government research agencies. This has occurred even though direct government subsidies toward these types of research organizations have been reduced. This again shows that the incentive mechanism introduced in the innovation system has successfully motivated researchers to put more effort into invention and innovation.

C. Composition of Domestic Patents in China

As we noted earlier, total patents granted can be classified into three different categories. The efforts and inputs required to produce one type of patent are different from those required for another type of patent. Figure 3 shows the composition of the total domestic patents in the period of 1985-93.

We can see from Figure 3 that the utility models or petty patents represent the lion's share of the total number of patents granted. Given the fact that the requirements for utility model patents are lower than those for invention patents, we have to take into account the quality of the patents when interpreting the aggregated patent data.

According to a study based on a different sample of patents granted and patents in the examination, it is reported that about 30% of patents have been used in commercial activities (The China International



Sources: State Statistical Bureau of China, 1986-1994.

FIGURE 3
COMPOSITION OF DOMESTIC PATENTS IN CHINA (1985-94)

Trade Information Center 1991). This ratio is higher than the average patents' utilization ratio which is about 15% in the industrial countries. Given the fact that the majority of patents in China are classified as utility model patents, which in general require less novelty and are more applied in nature than the invention patents, this higher ratio of patent utilization is not surprising. The relatively low ratio of invention patents in both patent applications and patents granted indicates that there is still a long way to go if China wants to be a leading player in the international R&D competition.

IV. Estimating the Patent Production Function for China

Previous studies on the relationship between patents and innovation activities have tried to answer the following questions: what are the basic properties of the patent production function? Are there diminishing returns to scale in patent production? A variety of functional forms have been used in these econometric studies to test the properties of the patent production function (Griliches 1990; Scherer 1983; Acs and Audretsch 1989). To address these questions, cross-industry and/or cross-firm data have been used to establish the relationship between patents and R&D inputs. Instead, we use cross-regional and time series patent data recently available from China to further test the characteristics of this relationship. One of the advantages of such data is that industry-specific and firm-specific patent propensity errors may be aggregated out. Moreover, when compared with international comparative studies, cross-regional data provides more homogenous policy environments.

A. Basic Model

First, we consider a theoretical model of patent production. This model specifies the relationship between the productive resources required to generate new knowledge which leads to better production processes or new products and the output in terms of the number of patents produced. We characterize this relationship between R&D input and output as a Cobb-Douglas production function.

$$P = A\,S^{\alpha}\,X^{\beta}\,P_{-}^{\gamma} \tag{1}$$

where P depicts the R&D output, S and X denotes, respectively labour and capital as the R&D inputs. One feature of this model is that it explicitly incorporates the intertemporal externality of technology spillovers as one of the determinants of the R&D output. Following Romer (1987), we include in our model a variable, P_{-} to capture the intertemporal technology spillover effect. The cumulative innovative output becomes one of the determinants for knowledge production in the current period. New knowledge can be produced more effectively with a larger cumulative knowledge pool. Obviously, this model has omitted several factors which may affect knowledge production. The institutional changes introduced in China's innovation system and the increasing number of transfers of foreign technology certainly have impact on the productivity of the R&D sector. Because of data deficiency, we cannot model these factors explicitly.

The technical parameters in the model are α, β and γ. Whether the sum of these parameters is larger than, equal to, or smaller than one depends on the characteristics of the underlying patent production function. When the production function has diminishing returns to scale, we will see that the sum of these three parameters is smaller than one. When the sum is equal to one, we can infer that production function is characterized by constant returns to scale. Based on our theoretical model, we establish the following hypothesis:

Hypothesis 1: *The sum of α, β and γ is equal to 1.*

In our model, another important issue is whether the intertemporal externality of technology spillovers exists, and if so, how significant its effect would be. To test the existence of the intertemporal externality of the technology spillovers, we have the following hypothesis:

Hypothesis 2: *The parameter γ is positive.*

To carry out our test, we construct a regression equation based on the original theoretical model by taking the natural logarithm of both sides of equation (1) as follows:

$$\ln (P_{it}) = \ln (A) + \alpha \ln (S_{it}) + \beta \ln (X_{it}) + \gamma \ln (P_{it-}) + \varepsilon_{it}, \qquad (2)$$

where

P_{it} = number of patent applications for province i at period t
S_{it} = number of scientists/engineers in the R&D sector for province i at period t
X_{it} = R&D expenditures for province i at period t
P_{t-} = accumulative number of patents up to t-1 year
A = coefficient of total factor productivity
t = time period t = 0,... 7, covering 1986-93
i = a particular province i, i = 1,... 28.

In this regression equation, the number of patent applications is a dependent variable. One of the advantages of using the patent applications data is that such data can reflect the underlying research activities more accurately because they are free of bureaucratic constraints in the patenting process. Such constraints may induce distortion in the patent data. According to the hypothesis of bureaucratic constraints, the number of patents granted in a time period is limited by the resources allocated to the patent examination process. On the other hand, the granted patents data may also offer certain advantages. First, the quality of patents granted data is considered to be higher and more homogeneous than that of the patent applications because of the three criteria imposed for granting a patent. Secondly, the knowledge stock, appearing on the right-hand side of the estimation equation, can be better described by the cumulative number of patents granted. Certified patents are clearly better documented and more easily accessible for research than patent applications. Therefore, in the final

TABLE 2
DESCRIPTIVE STATISTICS OF THE KEY VARIABLES

Variables	Patent Applications	Patents Granted	Scientists/ Engineers	R&D Expenditures (Million Yuan)
Number of Observations	196	196	196	196
Mean	1,415	777	14,191	428.6
S.D.	1,274.15	893.37	16,234 7	608.6
Minimum	66	12	1,246	26.08
Maximum	6,972	5,806	98,317	4,302.0

regression exercise, we use both sets of data as dependent variables to estimate the underlying patent production function, although we do not expect significant differences because of the close correlation between patent applications and patents granted data.

B. Data

The data used in this test are the official statistics published from 1987 to 1994 by the State Statistical Bureau of China in its "Statistical Yearbooks", covering the period of 1986-93. The patent data and data of scientists/engineers and R&D expenditures were published each year at provincial level since the Patent Law went into effect. The patent data from 1985 are not included in the final sample for two reasons: first, the patent statistics only started from April of that year; second, 11 of 30 provinces did not report their patent statistics in that year. We also exclude 2 provinces from our province data sample. Hainan Province was only established in 1988, and Tibet did not report its data for some years in the sampling period. The final data sample, therefore, includes 196 observations with 28 cross-section observations for 7 years in a time series. Table 2 summarizes the characteristics of the key variables used in the test.

The column "scientists/engineers" represents the number of scientists/engineers engaging in research and development in each province. The "R&D expenditures" is measured by the total R&D expenditure, excluding the salary/wage payments. R&D expenditures are in constant yuan. We use the 1987 consumer price index as the base value to adjust all other years' R&D expenditures.

TABLE 3
PARAMETER ESTIMATES OF PATENT PRODUCTION FUNCTION IN CHINA

Parameter Estimates	Patent Applications	Certified Patents
Ln (A)	–0.89	–1.08
	(–3.54)	(–3.75)
α	0.07	–0.04
	(0.62)	(–0.29)
β	0.27	0.42
	(2.72)	(3.86)
	0.57	0.51
γ	(20.56)	(25.21)
R^2	0.91	0.91

Note: The numbers in parentheses are *t*-statistics.

C. Results

We apply the standard Ordinary Least Squares (OLS) method to equation (2) after pooling the time series and cross-section data. The regression results are summarized in Table 3.

Based on the results in Table 3, we make the following observations: first, the cumulative number of patents has a dominant effect on the patenting in the current period. We can reject confidently the hypothesis that γ is zero. The number of existing patents is interpreted in our model as an indicator of the accumulated knowledge. The larger such a patent base, the more effectively researchers can benefit from past experience in the production of new knowledge and subsequently new innovation. This result is consistent with Romer's theoretical argument that productivity improvement and economic growth are not solely determined by exogenously imposed technology and the current period innovation effort, but rather by endogenous factors such as the positive externality of accumulated knowledge. Secondly, the *F*-test does not allow us to reject the null hypothesis that the sum of the three technical parameters $\alpha + \beta + \gamma$ is equal to 1 with 90 percent confidence interval. Thirdly, the regression results and the *F*-test allow us to reject the hypothesis that the sum of α and β alone is equal to one. In other words, the patent production function would appear to be characterized with diminishing returns to scale should we use the current period innovation effort. Fourthly, When looking at each of the three R&D input factors, the estimate of α is not significantly different from zero. This is to say, the number of scientific personnel did not contribute significantly to patent production, which is obviously untrue. One plausible explanation may be that the bounding constraint in the patent production is capital input rather than labour. Finally, the explanatory power of the model is quite strong with adjusted R^2 of 0.91.

V. Patenting and Competitiveness of China's Non-State Sector

It is beyond the scope of this paper to discuss in detail all the driving forces for China's extraordinary growth in exports in the last decade. What concerns us here is how R&D efforts and technological capability, revealed by the growing number of patents, contribute to the international competitiveness of domestic firms in the sectors facing international competition. Given the nature and speed of China's economic transition, we need to identify carefully the portion of the economy which is mostly exposed to international competition with least distortion. The non-state manufacturing sector of the rural industry is a good candidate for our test.

The rural industry sector is sometimes known as the TVE sector, because it is mainly composed of the so-called township and village enterprises (TVE). According to a circular issued by the Chinese government, TVEs include four types of enterprises: enterprises owned by townships, enterprises owned by villages, partnerships formed by groups of individuals or families, and private entrepreneurs. While the first three categories include certain elements of collectives-remnants of the commune period, the last one is no different from private enterprises in a market economy. TVEs engage in almost all industrial activities in the economy. Statistics shows that TVEs mainly concentrate in five areas: manufacturing, construction, transportation, commerce and services, and agricultural products. Manufacturing represented 74.7% of total output value of the TVE sector in 1993.[1] According to the latest statistics, the total output value of TVEs in 1993 reached RMB 1,766 billion which accounted for about 32% of GDP (Agricultural Ministry of China 1993). Compared with the state sector, which is often directly or or indirectly assisted or protected by the government, the rural industry is considered to be the most dynamic sector in the non-state portion of China's economy. Hence, we use the manufacturing sector of

[1]A study by a team of researchers of the World Bank provides some first-hand and interesting findings on TVEs in China See Byrd and Lin (1990).

the rural industry as the subject of our empirical test.

To establish the relationship between the international competitiveness of a region and its determinants, we have to identify the proxies that can be used in the empirical investigation. The international competitiveness can be measured in different ways. One plausible measure is the export intensity , i.e. the proportion of the total output in a sector that is exported. The export intensity is determined by a number of factors. Among the factors contributing to the international competitiveness, the domestic technological capability is one of the most important factors. The stronger the domestic technological capability, the stronger the international competitiveness. In addition to that, the success of competition in the international market depends also on the foreign technology transferred into a region. Such technology inflows in the real world are often accompanied by foreign direct investments. To capture these features, we use a simple truncated empirical model expressed in the following regression equation:

$$\frac{EX_{it}}{GIOV_{it}} = \alpha + \beta_1 \frac{P_{it}}{POP_{it}} + \beta_2 \frac{FK_{it}}{K_{it}} + \varepsilon_{it} \tag{3}$$

where:

EX = direct export of the rural industrial sector
$GIOV$ = gross industrial output value of the rural industrial sector
P = number of patents granted
POP = total population in millions
FK = foreign direct investment in the rural industrial sector
K = total new capital inflows in the rural industrial sector
i = index for provinces, i = 1... 28
t = index for time periods, t = 87... 93.

The percentage of direct export in terms of the gross industrial output value, or the export ratio, is on the left hand side of the regression equation. It is supposed to measure the international competitiveness of the rural industrial sector. On the right-hand side, we include two variables which are expected to affect a region's export performance over time: first, the intensity of patenting which is measured by the number of patents per million population in each province; second, the percentage of foreign direct investment in total capital inflows into a region. We predict that the technological capability in a region, as a important input factor in determining the level of productivity, contributes positively to international competitiveness of the industry.

TABLE 4
PATENTING AND EXPORT PERFORMANCE OF TVE SECTOR IN CHINA

Variables	Estimates	S.D.	*t*-statistics
α	0.019	0.0040	4.82
β_1	0.008	0.0035	2.20
β_2	0.083	0.0125	6.62
R^2		0.22	

Therefore, we expect that the estimate of β_1 will have a positive sign and will be significantly different from zero. The foreign direct investment is used as a proxy for foreign technology inflows into a region because the technologies are often embodied in the capital investment when capital investment takes the form of advanced equipment or new production processes. Therefore, we predict the second variable is able to capture the foreign technology inflows, and we expect a positive sign for the coefficient, β_2.

Except for the patent data and the population data which come from "China's Statistical Yearbooks", all the data related to TVEs are from "China's Yearbooks of Township and Village Enterprises" published by the Ministry of Agriculture of China in various years. The standard OLS method is used to test the regression equation (3). The regression results are summarized in Table 4.

The regression results are consistent with both of our predictions. The coefficient of the patenting intensity is positive, implying the patenting intensity is correlated with the export performance of the TVE sector. The increases in R&D apparently strengthen the international competitiveness of the TVE sector. Foreign direct investments as a proxy of the foreign technology inflow are also found to be positively related to international competitiveness as reflected by the export performance of the non-state rural industrial sector.

VI. Concluding Remarks

Studies on issues related to R&D and nations' competitiveness are numerous. Most of these studies use data from industrial countries which differ substantially form the newly industrialized economies (NIEs) and developing countries in Asia. Using China as the research subject, this paper analyzes the reforms of China's innovation and patent systems and its impact on the international competitiveness of non-state rural industry sectors in the process of transition. As an integrated part of the overall economic reforms, China's innovation system is apparently becoming increasingly efficient. The orientation of research and development has shifted to activities more applied in nature as reflected in the patent data. Combining this with data measuring China's R&D inputs, we have found evidence supporting the hypothesis that the patent production function is characterized by constant returns to scale. Moreover, accumulation of knowledge, which is the source of intertemporal technology spillovers, contributes significantly to the creation of new knowledge. Technological capability as measured by the ratio of number of patents to the population of a region appears to enhance the international competitiveness of the non-state rural industry sectors. The foreign direct investment is also found to contribute positively towards the international competitiveness although the estimation of impact of technology transfers may have a upward bias because foreign direct investments are often accompanied by an influx of marketing information and management skills.

The results reported in this paper represent our first attempt to use patent data from China as an indicator of technological progress in China's transitional economy. Obviously, many interesting issues remain to be explored. The issues on patents applied and granted to foreigners and how foreign patenting relates to foreign direct investment in China are not analyzed. The impact of reform measures on the productivity of the R&D sector should also be carefully analyzed. These topics will certainly be addressed in our future research.

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Comment

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World economy is now confronted with the period of rapid change both externally and internally. The external change is mainly due to regional adherence and the internal one is caused by technological innovation. A trend of informationalization and softization by higher technologies pervasive in the world industries speeds up reforming the industrial structure on the one hand, and ties up the economic and technological relationship among neighbor countries on the other hand. Such a trend makes every country's comparative advantage change incessantly so that its economy cannot but be closely connected with other economies in the concept of horizontal specialization without considering country borders. In future, therefore, industrial competitiveness among countries will be determined not by comparative advantage based on factor endowment in a country but by how well connecting its own advantage with other countries' ones.

In this trend of change in world economic situation, the economic and technological cooperation comes to be more important among countries, especially among neighbor countries. In this point of view, Professor Wu's paper on China's innovation, patenting and international competitiveness is enough to attract our interests. As Professor Wu pointed out, China is enforcing its international competitiveness by reforming and restructuring technological system. It is well known that the Chinese competitive position in the labor-intensive industry on grounds of low wage, abundant labor force and natural resources has already overtaken Korea in the amount of exports in the world markets since 1991.

China's competitive power is not based on factor endowment alone. This country, despite its policies for science and technology were very unstable in the past, has developed advanced technologies in some fields such as space and aerial engineerings and its fundamental science like physics is considerable in the world level as well. After the Chinese government's launching reform policies, the policy achieve-

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TABLE 1
CHINA'S ASSIMILATION & LOCALIZATION OF IMPORTED TECHNOLOGIES (1990)

Technology	Assimilation & Absorption	Localization	Savings of Foreign Exchange
Number Controller	Production of machine tools	Machine: 90+% Number control: 80%	US$ 100Mil.
Color TV	Average Nontrouble working hours: 15,000+, Annual capability of assembly: 8Mil. sets	85%	US$ 300Mil. US$ 10/set
Exportable Ship & Ocean Ship Equipment	Production of Freighter of 10Mil. tons, container ship diesel engine & mobile communication tools of fairways	Ocean ship equipment & parts: 75%	US$ 200+Mil.
Synthetic Ammonia Processing Equipment	Energy-saving ratio 50%	82%	US$ 20+
Passenger Car	Production of Body, engine & transmission	60%	Foreign exchange saving rate: 60%
Filature Production Line	Production capacity attained to int'l level: 22lines	90%	Import-substitution: US$ 150Mil.

ments in science and technology are worthy of close attention. The patent data shown in Professor Wu's paper are a good indicator of the Chinese innovative activity after their launching reform policy of science and technology.

It is true that China has now not a few technologies to help its economic growth. However, it is well known that the Chinese technology is characterized by dual structure of advancement and backwardness. China is economically still a developing country demanding foreign technologies for its industrial development. Therefore the import of foreign technology is no less important than domestic invention and innovation. This means that foreign technologies imported to China have clearly contributed to the growth of its inventive output. Table 1 shows

TABLE 2

CHINA'S MAJOR ACHIEVEMENTS AND AWARDS GRANTED TO NATIONAL SCIENTIFIC AND TECHNOLOGICAL RESEARCH (1987-1993)

	Major Achievements	State Awards for Invention	State Awards for Scientific & Technological Progress
1985	10,476	185	1,761
1986	14,915	26	–
1987	11,800	225	806
1988	16,552	217	515
1989	20,278	150	504
1990	26,829	224	505
1991	32,653	209	502
1992	33,384	170	649
1993	33,000	175	441

Sources: Statistical Yearbook of China, A Statistical Survey of China.

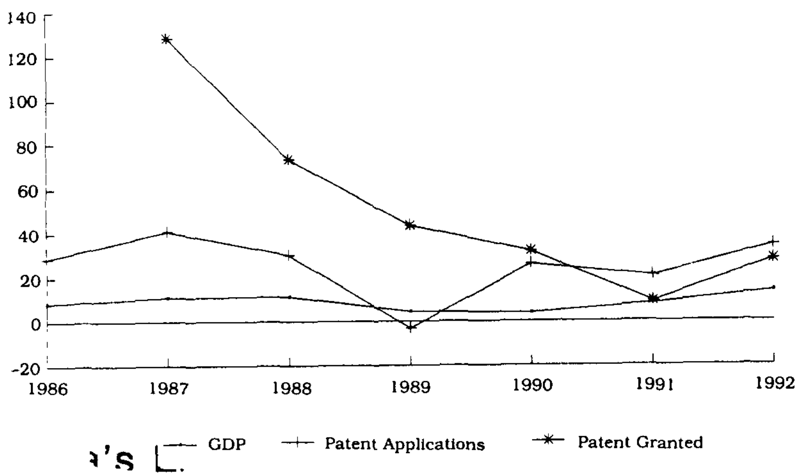

FIGURE 1

CHINA'S ECONOMIC AND PATENT GROWTH (%)

how much the imported foreign technologies contributed to the Chinese inventive output growth. So, if Professor Wu added a variable of imported technology cost in his Cobb-Douglas type production function, then it would reflect much more reality.

And also it is notable that China's state major achievements in scientific and technological research and awards granted to national scientific and technological research are recently depressive as shown in

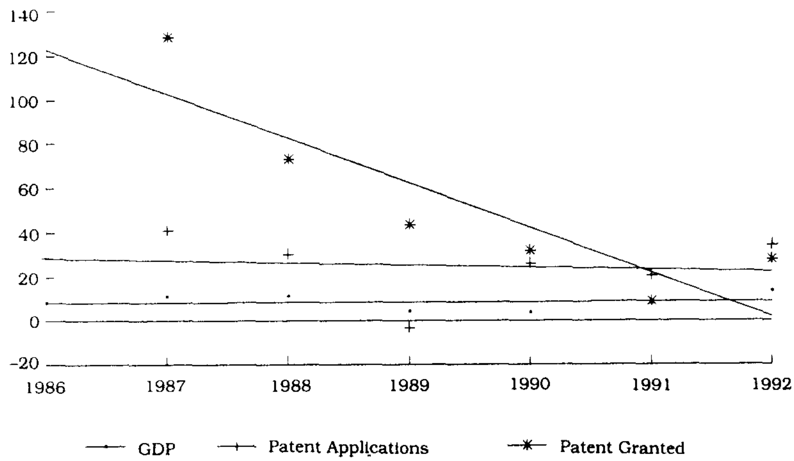

FIGURE 2
CHINA'S ECONOMIC AND PATENT GROWTH TRENDS

Table 2. This causes mainly from the social mood that there are no more important things than making money. Thus the Chinese scientists and technologists are also looking for the chances of money-making instead of looking for the state awards.

Professor Wu considered number of patents granted instead of patent applications as a variable in the model. But, drawing a simple trend of China's GDP growth rate, patent applications and patents granted from 1986 to 1992 on the basis of Figure 1A from Professor Wu's paper, we find an interesting result. Growth rates of GDP and patent applications show a very similar trend over time differently from that of growth rate of patents granted (See Figure 1 and 2). This implies, I think, that patent applications might be more meaningful in the model than patent granted. It cannot be deniable that the technological inventions applying for patents in China as well as in other countries can be used in productions even though they are not granted patents. If patent applications data were used, the low R^2 shown in Table 3 on Professor Wu's paper would be cured despite small observations of only four time periods from 1989 to 1992.