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THE TRANSITION OF CHINESE S&T INSTITUTES SINCE 1980s: POLICY, PERFORMANCE AND IMPLICATION

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Abstract

In 1985 China began its reform on the Science & Technology (S&T) sector which was inherited from a planned economy. The reform over the past 20 years is deemed to be a decisive factor in China's science and technology progress. The paper first argues that two fundamental tasks of China's S&T sector reform are to enhance scientific productivity and strengthen the industry-academic relationships. Subsequently, the reform policies are outlined within three categories: 1) reforming the funding system, 2) improving R&D management 3) strengthening industry-academic relationships.

The evolution of S&T institutes such as the Chinese Academy of Science is examined to provide micro-level evidence of policy impacts. The scientific output of China's S&T sector did achieve the remarkable improvement in the reform period, but we also observe the rapidly growing investment from the governments flew into the sector. The evaluation of the performance of the reform needs to examine the scientific productivity of the sector. Therefore, we proceed to measure the scientific productivity of China's S&T institutes based on the R&D input and output data in the aggregate and provincial level. The Polynomial Distributed Lag model is utilized to uncover the structure of the lag between R&D input and output. The findings based on the aggregate data and provincial data confirm that the scientific productivity of China's S&T institutes has been decreasing since 1990s. These results call for the future actions that can contribute to enhancing the scientific productivity of China's S&T institutes.

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Section 1: Introduction

China’s science and technology (S&T) has achieved impressive progress in the past two decades. Shown in Table 1, over the period of 1991-2002, the ratio of Chinese “Science Citation Index (SCI)” papers to the world total increased from 1.07 percent to 4.18 percent.[1] The patent application of the S&T institutes almost doubled. The contract value of technology transfer projects in 2002, measured by 1990 constant price was two and a half times of the figure in 1991. In a global context, the number of Chinese SCI papers soared at a two-digit speed from 1998 to 2002, far surpassing its counterparts in the world as seen in Table 2. In 1998, China ranked 9th in the world in terms of the number of SCI papers, but in 2002 its position ascended to 5th. The citation count of China’s SCI papers also shows an upward trend. The count number in the period of 1993-2003 was 30 percent greater than those in the period of 1992-2002 (Figure 1).

(Here insert Table 1)

(Here insert Table 2)

(Here insert Figure 1)

The increasing budget appropriation and outlay from various government levels played an overwhelming role in the rise of China’s S&T sector. Reform in China’s S&T institutes, beginning in 1985 is deemed to be a decisive factor in the progress of the entire

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[1] Science Citation Index, Science Citation Index Expanded, Engineering Index and Index to Scientific & Technical Proceedings are widely used academic publication index systems, which are developed by Thomson ISI, based in US.

sector. Drastic sector reorganization, unprecedented government investment, and sharply increasing scientific output have all resulted in much attention which are directed toward China's S&T institutes from the international scientific community (Mervis and Yang, 2003).

In this paper, the so-called "China's S&T institutes" are defined to include three groups of R&D organizations: the sub-institutes of the Chinese Academy of Science; the institutes affiliated with various ministries and other central governmental agencies; and the institutes affiliated with local governments. Taken together, these three groups of R&D institutes amounted to 5,793 in 1986, though they decreased to 4,347 in 2002. According to the various versions of *China Statistical Yearbook on Science and Technology*, in 1995, the aforementioned institutes hired 1.01 million staff; however, in 2002 only 590 thousand employees remained on their payrolls.

The Chinese S&T reform system dates back to 1985 when "The Resolution of the Central Committee of the Communist Party of China on the Structural Reform of the Science and Technology System" was issued. By launching this reform, Chinese leaders were eager to expand the successful changes in the agriculture sector that took place in the late 1970s to the industrial and S&T sectors. One of the direct impacts of this S&T system reform is that many new R&D units had been established and developed inside the universities and other enterprises after 1985. Accordingly, the S&T institutes which formerly had undertaken almost all the R&D activities in the planned era have been losing their dominance in the country's innovation system. Table 3 shows the declining importance of the S&T institutes vis-à-vis the universities and the enterprises in the period of 1987-2002. This dynamic change is the outcome of the government's policy that seeks to strengthen industrial R&D. It is important to notice that the growth of the R&D capability in industry and academia did not come as a sacrifice in the development of S&T institutes. The growth of R&D input and output of the S&T institutes in the 1990s, measured by the absolute value is evident in Table 3.

(Here insert Table 3)

The transformation of the S&T system in the post-socialist countries has been discussed in literature in the context of the Central and Eastern European Countries (CEECs). The representative works were written by Dyker and Radosevic (1999), Meske (2002), Radosevic and Auriol (1999), Jasinski (2003), Radosevic (2003), and Mirskaya and Rabkin (2004), etc. The same issue in the context of China was analyzed by Cao (2002), Fischer and von Zedtwitz (2004), Gu (1995), Huang, et al. (2004), IDRC (1997), Liu and White (2001a), OECD (2002), Suttmeier and Cao (1999), US Embassy Beijing (2002), World Bank (2001), and Xue (1997), etc. In these works, the drawbacks of the so-called "centrally planned S&T system" were highlighted. The corresponding remedy policies implemented in these transitional countries were also emphasized. In this paper, we would like to go further to identify which drawbacks are the most fundamental and what are the priority issues of the S&T system reform in the post-socialist countries such as China.

The low efficiency of the planned S&T system was widely criticized by the works such as Hanson and Pavitt (1987), Meske (1998), OECD (1969) and Radosevic (1999). It is believed that before the S&T system reform, the scientific productivity of China's S&T institutes also remained at a low-level. In this paper, the scientific productivity is measured based on inputs such as R&D expenditure and outputs such as patent application or publication. If a low scientific productivity prevailed in the planned system in China, it is inquisitive to ask whether on-going reform has enhanced the efficiency of S&T institutes in China. Is the explosive increase of China's scientific publications in recent years ascribed to the scientific productivity augmentation or only because of the larger amount of the governmental investment? In order to answer these questions, we follow the pioneer ideas appearing in Adams and Griliches (1996a, 1996b) and Crespi and Geuna (2004) to measure the scientific productivity of China's S&T institutes. The result from this empirical exercise not only serves to evaluate the policy performance of the S&T system reform in the past two decades, but also helps to point out the focus of future efforts.

In short, the remaining parts of the paper are organized to achieve its objectives. Section 2 identifies the fundamental tasks China needs to accomplish in its S&T system reform; Section 3 categorizes the complex reform policies during the past decades; Section 4 provides two case studies to observe the micro-level impacts of S&T system transformation; Section 5 conducts the empirical analysis to measure the scientific productivity of China's S&T institutes and Section 6 concludes the paper.

Section 2: Fundamental tasks of the S&T system's transformation in China

The discrepancies of the S&T systems in centrally planned economies and in market economy countries were identified early in the works of OECD (1969) and Hanson and Pavitt (1987).[2] It was already proved by the history of the 20th century that the capitalist system made better use of the human and physical resources to promote innovation than the centrally planned system. Higher labor productivity and better welfare were also achieved by the former (Kornai, 2000). In terms of S&T, the higher performance was achieved in the west industrialized countries, which made the governments in China and the CEECs gradually recognize the institutional constraints of the planned S&T system. Some remedy initiatives were subsequently designed and launched in the late 20th century. The reform in China was put on agenda in the middle of the 1980s. The similar transformation also began in the CEECs before their "velvet revolution" in 1989, but was only completely launched after the beginning of the 1990s (Radosevic, 2003).

(Here insert Table 4)

The objective of the transformation was to transform the rigid, segmented and inefficient plan-oriented S&T system into a highly dynamic, interactive and efficient system such as those in the leading industrialized countries. The two Figures (2 and 3) describe the objective of Chinese S&T system's transition, which is analogous to the case of East Germany (Meske, 1994). Among the numerous missions that China needed to

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[2] The summary of their findings is in Table 4.

concentrate on during the two decade long reform, two fundamental tasks had always been considered critical. The first was establishing an effective linkage across the agents inside the S&T system, especially the link between R&D institutes and enterprises. The second vital task was enhancing the scientific productivity of the S&T system. Whether the two tasks had been accomplished and how well they had been achieved in a large degree decided the performance of the S&T system reform in China.

(Here insert Figure 2)

(Here insert Figure 3)

The new linkages among the agents of the innovation system surely need to be re-established in the transformation from linear planned system to the interactive system. Therefore, the importance of first task, i.e. linking the agents in the innovation system, is self-evident. As far as the second task, we are not the first ones who noticed that lower scientific productivity existed in the centrally planned economies. Dyker and Radosevic (1999) and Meske (2002) already questioned the relevance of the bulky S&T system in the post socialist countries. The S&T sector built in the planned era were considered as a "liability" instead of as "asset" in the economic transition. Here, further evidence is provided to show the seriousness of the low efficiency of planned S&T system (see Figure 4 and 5).

(Here insert Figure 4)

(Here insert Figure 5)

In Figure 4 and 5, the CEECs and China placed themselves below the fit line, which reveals their low productivity of producing the "triadic" patent families. The triadic patent families are the proxy variable of a country's R&D output, representing the technological competitiveness of the country (OECD, 2001, 2004). The post socialist countries truly devoted the abundant capital and human resources into the R&D activities, but the achievement measured by the invention in the international frontier level were relatively less. The low input-output ratios of the most post socialist countries are impressive because after one decade of reform, their S&T systems still showed the low efficiency of producing high value R&D output. It is necessary to note that because of the lag between the R&D capital and human resource input and the output, the input in 1999 can only account for little or nothing of the output in 1999. Linking them together is just for simplifying the analysis and would not harm the consistence of the conclusion.

Section 3: Policies and the performance of the S&T institutes' transformation in China

In the past 20 years, various policies regarding S&T system transformation have been implemented in China. The trial-and-error reform process makes the policy issue vague and hard to discern. However, given the fundamental tasks of China's S&T system reform in the previous section, we are able to classify the reform policies into three groups, which are 1) reforming the R&D funding system, 2) improving R&D management in the S&T institutes and 3) strengthening the industry-academic relationship. The classification reduces the complexity of the policy issue and helps us grasp the far-reaching change of China's S&T system in the past two decades.

3.1 The reform of the S&T funding system

At the beginning of the reform, the Chinese government quickly realized that increasing the budget appropriations of the S&T institutes would not solve the efficiency problem completely. The centrally planned funding mechanism based on scale of the institutes or number of the staff would squander much of the resource invested towards the S&T sector. By recognizing it, shortly after issuing "the resolution" in 1985, the government transferred the responsibility of allocating the S&T funding from the Ministry of Treasure to the State Science and Technology Commission, which later turned into Ministry of Science and Technology (MOST). In the following years, while China's government steadily increased the S&T budgetary appropriation, a series of programs were developed to manage the R&D projects under the leadership of MOST.[3] In addition, the National Natural Science Foundation of China (NSFC) was established to manage the funding to basic research, based on evaluating the merit of research proposals (Xue, 1997). The annual growth rates of the central government's appropriation to S&T activities were significantly higher in the 1990s than in the 1980s. Since the second half of the 1990s, the budgetary support had even rocketed at a two-digit speed (Table 5). The strengthened governmental R&D inputs contributed to the growth of China's ratio of Gross Expenditure on R&D expenditure/GDP in the recent years (Figure 6).

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[3] The description of Chinese S&T programs is available in Huang, et al. (2004).

(Here insert Table 5)

(Here insert Figure 6)

Currently, the 863 Program, 973 Program and Key Technology R&D Program (*Gong Guan* Program) consisted of three major funding programs managed by MOST. The budgets of the three programs reached 5.5, 0.9, 1.5 billion RMB in 2004, respectively.[4] In 2004, the budget of NSFC amounted to 2.246 billion RMB. The number of the received research proposals by NSFC topped 42,984, increased by 21.8 percent from the figure in 2003 and were around four times of the figure in 1987 (State Science and Technology Committee, 1988). The merit-based public R&D funding system was the major achievement of China's two decade long S&T system reform. Its establishment ensured the improvement of scientific productivity, which has never been given emphasis in the planned era.

3.2 The improvement of the R&D management in the S&T institutes

Improving the management in the S&T institutes is another measure that China's government embraced in an effort to enhance scientific productivity. Between 1985 and 1987, the system of "working position title" such as "Professor, Associated Professor, Researcher, Associated Researcher, etc." was established. The position system coupled with the salary differentiation policy motivated the research staffs and encouraged the mobility of human resources. After the late 1980s, the directors of the S&T institutes were obliged to sign working contracts with the governments. At the same time, they

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[4] The exchange rate of US Dollar to RMB was 1:8.27 at the end of 2004.

were granted more autonomy for personnel, finance, property management and international cooperation.

The more ambitious reform known as the "Knowledge Innovation Program" was launched in 1998 in the Chinese Academy of Science. The program aimed to consolidate the Academy through reducing the 68,000 permanent positions to 30,000 by 2010 via retirements and re-assigning people to alternate positions. The remaining positions were given to the most productive staff (*Science*, 2001). While the emphasis was given to reducing redundant personnel, the efforts were also made to recruit the overseas Chinese scientists. According to the US National Science Foundation (2001), more than 21,600 Chinese earned Science and Engineering (S&E) Doctorates at US universities over the period of 1986-98, which is around 7.5 percent of all S&E Doctorates in US universities. The large scale "brain drain" in China has decreased in recent years largely through active expatriate scientist recruitment programs (Cao, 2002; Huang et al., 2004). Since the 1990s, the modern R&D management experience in advanced countries has been introduced to China (Zhao, 2003). The attention of the policy-makers was also drawn to some issues currently debated in the west countries, such as the intellectual property right. Through learning from the West, China's institutes modernized their R&D management and better exploited the value of the abundant S&T human resources in the sector.

3.3 Strengthening the academy and industry relationship

Strengthening the industry-academic relationship was given emphasis in the “Resolution” of 1985 in China. The government designed a two-fold policy, push-side and pull-side, to build the linkages between industry and academia.

On the one hand, the “push-side” policy executed in the 1980s gradually reducing the government’s budgetary appropriation to the S&T institutes. This strategy succeeded to force institutes to turn towards enterprises to earn revenue. The technical service provided to the enterprises and the joint R&D projects financed by the industry became more important to the S&T institutes because they brought in an increasing proportion of the total revenue of the institutes. Xue (1997) reported that the ratio of government appropriation to the budget of the S&T institutes decreased by 5 percent on average each year from 1986 to 1993. After 1985, S&T institutes, especially those doing experiment and development were encouraged to merge into enterprises. The newest round of reform after 1999 even went further to transform hundreds of S&T institutes into enterprises or non-profit organizations. Meanwhile, the government concentrated its funding on the unchanged institutes that primarily conduct basic research (Huang, et al., 2004).

On the other hand, the “pull-side” policy focused on the establishment of the “technology market” which facilitated the technology transfer from academic to industry. The transfer was promoted by the “Technology Contract Law” taking effect on Nov. 1, 1987 and the subsequent relevant regulations. The registered contract value of the technology transfer projects achieved the remarkable growth during 1990s.[5] In addition, the spin-off enterprise was also strongly promoted by the government. Gu (1995) reported that the

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[5] See Table 1.

first spin-off enterprise from Chinese S&T institutes was set up in 1980, but the strong promotion led by governmental “Torch Program” only initiated in 1998. The program supported hundreds of Science Park and incubators across the country (Huang et al., 2004). Promoted by the government’s S&T policy, Chinese spin-off enterprises showed the dynamism in their access to new technology, efficient corporate governance, aggressive business strategy and strong learning capability (Lu, 2001). Some spin-off companies have grown up to compete in the international market, such as the computer company Lenovo. It was spun off from the Institute of Computing Technology, Chinese Academy of Science in 1984 and in late 2004 acquired the IBM personal computing division to create the world's third largest PC business with approximately US$12 billion annual revenue in 2003 (Lenovo, 2004).

Section 4: Transformation of S&T institutes in Chinese Academy of Science: Two cases

In this section, the micro-level impacts of China’s S&T institute reform are presented by the following two case studies. The two chosen institutes, namely, Institute of Chemistry (ICCAS) and former Beijing Scientific Instrument R&D Center were both affiliated with the Chinese Academy of Science (CAS) before the transformation. The study only focuses on their transition starting in 1998 in the framework of “Knowledge Innovation Program”.

ICCAS was founded in 1956. It employed 448 staffs, including 90 professors and 129 associate professors by the end of 2003. 380 PhD students and 220 Master students enrolled in the institute (Institute of Chemistry, 2004a). It hosts three National Key Laboratories, four Key Laboratories of the Academy and one National Center for Chemical Analysis and Testing. It has been undertaking a variety of large R&D projects funded by the 973 Program, 863 Program and NSFC, etc. Its scientific publications measured by Science Citation Index papers ranked first among the S&T institutes in China in 2002. Because of its predominant role in the Chinese chemistry research community, it has been selected to implement the pilot reform led by "Knowledge Innovation Program" in 1998.

With the support of the "Knowledge Innovation Program", the following institutional reform took place in ICCAS after 1998. First, the executive power was fully assigned to the director of ICCAS. A council composed of the representatives from the governments, NSFC, CAS and scientists, was established to review the development strategy, the general operation, and the annual budget, revenue and expenditure of the institute. Second, an international evaluation committee was organized to appraise the development objective and research performance of the institute. Third, the new salary system was established to motivate the staff to become more productive. In the new system, the salary of staff consisted of three parts: basic salary, position allowance and performance allowance. Fourth, the human resource development strategy was modified. The new objective was increasing the proportion of the young staff (age below 45) to 75 percent and augmenting the ratio of the mobile researchers (visiting, post doctoral,

doctoral and master researchers) to the permanent staff to 150 percent. In sum, these policy actions successfully boosted the R&D output of the institute, which is proven by the growing publication and patent application (Figure 7 and 8).

(Here insert Figure 7)

(Here insert Figure 8)

Before 1998, ICCAS had already co-founded four high technology companies, which were engaged in producing new materials such as nano-polymer and functional nano-interface materials. It is easier for ICCAS to transfer the new technology generated from its successful R&D projects to these partly owned high-tech companies. The innovation demand is also easily transmitted from these subsidiary companies to the ICCAS. After 1998, by selling some shares of these companies to the strategic collaborator, ICCAS transformed its subsidiary companies into stock companies. It is expected that the new stock companies with a clear ownership structure can establish effective corporation governance and achieve rapid growth in the future.

The former Beijing Scientific Instrument R&D Center was established in 1958. It not only conducted scientific research but also produced scientific instruments. In 1999 the center employed 348 S&T staff and owned two branch companies. The revenue was a little more than 10 million RMBs. Although the two branch companies already attempted to sell their products in the market before 1999, the performance was severely weakened by the rigid management structure and poor corporation governance of the enterprise.

At the end of 1999, the whole center was transformed into a new company named KTD, in the framework of "Knowledge Innovation Program". The new company was jointly owned by CAS and its employees. In CAS's report, the advantages of the transformation were explicitly summarized as follows. First, the reform facilitated the new company to establish effective corporation governance. Under the condition of a clear-cut ownership structure, economizing the resources and pursuing better performance became the natural principles of the daily operation. These basic business principles had never been implemented in the former center without the ownership reform. Second, the staff joined in the social insurance system through the support of CAS, which unloaded the financial burden of the new company. Third, managers and employees were better motivated by the rule of market economy, such as larger return associated with higher risk. Fourth, the R&D managers in the new company paid more attention to the commercial value of the R&D projects instead of merely focusing on their pure technological advance. In all, the transformation policy liberalized the growth potential of the former R&D center. In 2002, KTD achieved revenue of 96 millions RMB, or 9 times the figure in 1999. The profit reached 18 million RMB in 2003. In such a short period, KTD successfully transformed itself from a small S&T institute without patch production capacity into a high-tech company with market-oriented R&D capabilities.

Section 5: Scientific productivity of Chinese S&T institutes during the reform period

As we discussed previously, during the reform period, various policies have been put into effect to improve the scientific productivity of China's S&T institutes. This initiative has been fundamentally imperative for China that it has become a priority for the past two decades. However, few attempts have been made to measure the change of scientific productivity of China's S&T institutes, or namely evaluate the reform policy performance. Previous works such as Liu and White (2001b) analyzed the regional innovation productivity in China by evaluating patent data from the periods of 1985-1995, but their arguments were weakened by the ad-hoc treatment of the lag structure of inputs and outputs. In this paper, we intend to fill the vacancy of that literature.

Additionally, the R&D investment from the Chinese government has increased in an unprecedented rate recently (Table 3 and 5), reflecting the leaders' will of building the long term economic prosperity on the increasing S&T contribution. The utilization of the growing governmental R&D funding has been widely debated inside China, and even in the international science community.[6] Whether the R&D output has increased proportionally with the recent fast growing R&D input or whether the governmental R&D investment has been best utilized is the focus of the debate. Our measurement of the scientific productivity can provide the convincing answer to these questions.

5.1 Method

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[6] See two issues of *Nature* Special Edition, *China Voice I and II*. We cite several articles from these two supplements in the following discussion.

Following Adams and Griliches (1996a, 1996b), we adopt a scientific production function (function (1), log-linear form) to estimate the scientific productivity.

(1) $$y = \alpha + \beta W(r) + \gamma X + u$$

where y is logarithm of the research output which can be measured by paper, citation or patent, $W(r)$ is the logarithm of a distributed lag function of the past R&D expenditure, representing the stock of R&D investment, X is a set of control variables, normally including a time trend variable t to control the changes of the variables over time, wheres u represents all the other unaccounted factors contributing to the output. The key issue of this function is the specific form of the $W(r)$ and its estimation.

Crespi and Geuna (2004) utilized the polynomial distributed lag (PDL) model as the form of $W(r)$ to analyze the data of the 14 OECD countries in the period of 1981-2002. The proper lag structure can be seearched through various information criteria in the PDL model. Thus, the method is able to trace the full impact of past R&D input on output, which can not be found completely through the ad hoc lag structure proposed by Adams and Griliches (1996b) and Liu and White (2001b). Following Crespi and Geuna (2004), we base our analysis on the following polynomial distributed lag model (Quantitative Micro Software, 2002) as

(2) $$y_t = \alpha + \sum_{j=0}^{k} \beta_j r_{t-j} + \lambda t + u_t$$

(3) $$\beta_j = \delta_0 + \delta_1(j-c) + \delta_2(j-c)^2 + \ldots\ldots + \delta_p(j-c)^p \, (j = 0,1,\ldots k > p)$$

where c is a pre-specified constant given by

(4) $$c = \begin{cases} (k)/2 & \text{if p is even} \\ (k-1)/2 & \text{if p is odd} \end{cases}$$

When running the regression, the function (2) is substituted by

(5) $$y_t = \alpha + \delta_0 z_0 + \delta_1 z_1 + \ldots + \delta_p z_p + \lambda t + u_t$$

where

(6) $$\begin{aligned} z_0 &= r_t + r_{t-1} + \ldots + r_{t-j} \\ z_1 &= -cr_t + (1-c)r_{t-1} + \ldots + (j-c)r_{t-j} \\ &\cdots \\ z_{p+1} &= (-c)^p r_t + (1-c)^p r_{t-1} + \ldots + (j-c)^p r_{t-j} \end{aligned}$$

Once the δ is estimated from the function (5), β can be recovered straightforward through function (3) since β is a linear transformation of δ. The constant *c* is included only to avoid numerical problems that arise from colinearity and does not affect the estimates of β. The minimal value of Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) indicates the appropriate lag length *j* of the model (Brockwell and Davis, 1991; Crespi and Geuna, 2004). The definitions of the AIC and SIC are given in the following equations

(7) $$\text{AIC} = -2(l/n) + 2(s/n)$$

(8) $$\text{SIC} = -2(l/n) + s\log(n)/n$$

where l is the value of the log of the likelihood function with the s parameters estimated using observations n (Quantitative Micro Software, 2002). Based on the equation (5), here $s = p+3$. Knowing that the full effect of R&D expenditure in the higher education sectors of the 14 OECD countries take 6 years to occur, i.e. j=6 (Crespi and Geuna, 2004), we start to search the lag length from a lag of 6 years in our analysis on China. We look for the right polynomial degree p by testing sequential unit reduction of its value from the initial value of 5.

After the βs are obtained from the estimation of the function (2), we proceed to calculate the growth of scientific productivity between the period t and $t-1$ according to the following equation

(9) $$\text{Scientific Productivity Growth} = (y_t - y_{t-1}) - \sum_{j=0}^{k} \hat{\beta}_j (r_{t-j} - r_{t-1-j})$$

where $\hat{\beta}_j$ is the estimated coefficient of the function (2).

When reporting the growth of scientific productivity, we may present the annual scientific productivity growth rate. The growth rate from time t to time $t+1$ is commonly taken to be (Scientific Productivity $_{t+1}$ – Scientific Productivity $_{t}$)/ Scientific Productivity $_{t}$. Since $ln(1+r)$ is approximately equal to r for small r, the scientific productivity growth rate can be approximated by the difference in logarithms, i.e. ln Scientific Productivity $_{t+1}$ – ln Scientific Productivity $_{t}$. Therefore, the average annual scientific productivity growth rate between the period s and t is obtained by (ln Scientific Productivity $_{t}$ – ln Scientific Productivity $_{s}$)/(t-s).

5.2 Data

The data of Chinese S&T institutes are from two sources: 1) *China Statistical Yearbook on Science and Technology* (*Zhong Guo Ke Ji Tong Ji Nian Jian,* hereafter it is called “Yearbook”) and 2) *Data Set of S&T Organizations* (*Ke Ji Ji Gou Tong Ji Shu Ju Ji*, hereafter called “Dataset”). The first *China Statistical Yearbook on Science and Technology* was published in 1991, covering the data of 1990. The *Data Set of S&T Organizations* was firstly issued in 1986, publishing the annual statistic data of China’s S&T institutes.

It is worth noting that the Chinese S&T statistics system was established less than 20 years ago. The early S&T data were more problematic than the recent ones, which poses difficulty to our analysis based on time series. Moreover, the early versions of the data sources only included fewer statistical indicators. For instance, the usual R&D input indicator such as R&D intramural expenditure was not reported in the early period. Therefore, we have to adopt the more consistent “expenditures of R&D projects”, instead of “R&D intramural expenditure” as the R&D input data in the analysis. The R&D output is measured here by “the count of papers published in the international journals, books and conference proceedings” (*Ke Ji Lun Wen, Guo Wai Fa Biao*, hereafter called “international paper”) and “the count of the patent applications in Chinese patent office” (hereafter called “patent application”). The papers published abroad are considered with higher equality than those published in the domestic journals and proceedings. Their quality is more stable than that of the domestic publications as well (Moed, 2002; Ren and Rousseau, 2002).

To estimate the function (2), the R&D project expenditure and patent application data are taken from the “yearbook”. The international papers data are from “dataset”. All of data series cover the period of 1986-2003. These data are aggregate data in the country level, collected from all the S&T institutes in China. Utilizing the coefficients of βs obtained from the estimation result of the function (2), we can calculate the aggregate scientific productivity of China’s S&T institutes through the equation (9).

In order to test the robustness of the aggregate scientific productivity, we take advantage of the provincial level data in the “dataset” to re-calculate the scientific productivity of the S&T institutes in some provinces. The comparison of the aggregate data result and the provincial data result would reach a robust conclusion of the scientific productivity of China’s S&T institutes in the past decades. The provincial R&D project expenditure data and publication data in the “dataset” cover the period of 1991-1995 and 1997-2003. The provincial patent data solely cover the period of 1992-1995 and 1997-2003. This means all 1996 data in the “dataset” are missing. Taking account of the fact that these three data series are rather smooth, namely, without much variation between two neighboring years, we fill the vacancy of the 1996 data with the average of 1995 and 1997 data.

All the expenditure series are converted by China’s GDP deflator into 1990 constant price. Figure 9 displays the aggregate data from the “Yearbook” for estimating the function (2). All three data series show the evident upward trend. Before running the function (2), we need to test whether the data series are with unit roots or with deterministic time trends. If the test rejects the hypothesis of unit root, it would justify our including a time trend variable *t* into the function (2), otherwise, we have to differentiate the data before the estimation.[7] However, the limited number of the available observations makes it impossible to achieve the accurate result by means of some unit root test methods, including Augmented Dickey-Fuller (1979), Phillips-Perron (1998) and GLS-detrended Dickey-Fuller (Elliot et al., 1996). Fortunately the method of KPSS (Kwiatkowski et al., 1992) was not affected by this difficulty. Based on the result of KPSS method (Table 6), the judgment whether the data series are with unit roots depends on the level of significance we choose. This means we can not safely reject or accept the null hypothesis on the basis of the limited observations.

(Here insert Figure 9)

(Here inset Table 6)

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[7] There is detailed discussion of this issue in Hamilton (1994).

Because of the ambiguity in the econometric result, we would like to examine this issue from the realistic perspective. The reality is that the Chinese government did attempt to increase R&D funding and improve the performance of the S&T sector in the past years. Therefore, the R&D data series, having an obvious stable upward trend would be better analyzed with the deterministic time trends, instead of with the unit roots. Likewise, the similar inference that the country's aggregate R&D input and output data series are with the deterministic time trends were also made based on the data of the OECD countries. Crespi and Geuna (2004) rejected the unit root hypothesis in their test on the 14 OECD countries’ R&D input and output data. All in all, we do not differentiate the data before running the function (2).

Table 7 provides some general information of the provincial level data from the “dataset”. It demonstrates that the eleven out of thirty one provinces in China (hereafter called “top eleven” provinces), spent around 80 percent of national R&D project expenditures in 1991 and 2003. About 80 percent of China’s international paper publications and patent application were also concentrated in these eleven provinces. These mean that the “top eleven” provinces absorbed the majority of R&D resources in China and produced a significant proportion of R&D output in the country. Furthermore, the ranks of these provinces varied little between 1991 and 2003. Thus, we simplify our calculation of the scientific productivity in the provincial level by focusing on these eleven provinces instead of presenting a result embracing 31 provinces.

(Here insert Table 7)

5.3 Result

In the estimation result of function (2) (Table 8), by examining the AIC and SIC values we choose the 7 lags and 5 lags as the optimal lag structures for the publication and the patent data, respectively. The proper polynomial degree of the model for publication is 3rd because the F-statistic value turned to be significant when the degree is reduced from 3rd to 2nd. Likewise, the right degree of the model for patent is determined to be 1st. This proper function form reveals that in China's S&T institutes the full effect of the R&D investment on the international publication takes 7 years to occur and its total effect on patent application lasts 5 years.

(Here insert Table 8)

The sum of lags represents the long term elasticity of the R&D output and input. Our result shows the long term elasticity of publishing international papers and R&D project expenditure in China's S&T institutes is around 0.8 and the elasticity of patent application and R&D investment is approximately 2. That is, a 1 percent increase of the R&D investment in China's S&T institutes leads to 0.8 percent growth of the international papers and 2 percent growth of the patent application.

With the βs obtained from the function (2), we calculate the aggregate scientific productivity growth rate through the equation (9) (Table 9). By measuring the output as patent application, we can trace the scientific productivity growth rate of China's S&T institutes until the early period of 1991/1992. But when output is measured by publication, we only can find the scientific productivity as early as in the period of 1993/1994 because of the difference of lag structure. The average annual scientific productivity growth rate in terms of publication is -2.9 percent and in terms of patent it is -9.5 percent.

(Here insert Table 9)

The finding of the deteriorating scientific productivity in China's S&T institutions in 1990s from the aggregate data is confirmed by the provincial data result in Table 10. The weighted averages of the scientific productivity growth rates of the "top eleven" provinces are negative, whenever the output is measured by the publication or patent data. It is important to remember that the reporting period of the provincial data result is different from that of the aggregate data result, because the early period provincial data are not available in the "dataset". For this reason, we modify the reporting period of the aggregate data result to form a comparison with the provincial data result in Table 10. The "top eleven" provinces' performance in terms of international publication was worse then the national average level in the period of 1998-2003, but if we measure the scientific productivity by patent application, the S&T institutes in these provinces outperformed those in the other regions in the period of 1996-2003. It is worth noting the exceptional performance was achieved by the S&T institutes in Shang Hai and Gan Su.

The scientific productivity of the S&T institutes in these two provinces, measured by the publication or patent data, did achieve a continuous improvement. The enhanced performance of the S&T institutes in Shang Hai (ranked 2nd among the 31 provinces in 2003 in terms of R&D input scale) and Gan Su (ranked 10th) is worthy of the further research, which could point out a possible direction of future reform actions.

(Here insert Table 10)

5.4 Discussion

The worsening scientific productivity of China's S&T institutes certainly casts doubt on the policy performance of the on-going S&T system reform. As we discussed previously, a well-functioned funding system and efficient R&D management are crucial to the success of R&D activities in a transitional country such as China. If these systems failed to perform well, the best R&D proposal would not be supported and excellent scientists would lose their motivation to pursue first class research, which would be reflected by declining productivity in the long run.

Our concern resulted from the quantitative analysis is neither astonishing nor "first time invention". The critical viewpoints of China's recent S&T system's reform were summarized by various authors in the two series of supplement of *Nature- China Voice I* and *II* in 2003 and 2004. Most of those authors attained their basic education in China and received their Doctoral degree abroad. They are active in the international scientific community and also acquainted with China's S&T system.

Poo (2004) judged that the reform of the administrative structure and establishment of a merit-based system for staff evaluation and resource allocation is crucial for Chinese S&T institutes' development in the next stage. He wrote down: "I am not aware of any research institutions in China that has terminated the contract of a scientist simply because of poor research performance – a common practice in major research institutions elsewhere." Wu (2004) and Rao et al. (2004) also criticized that "the system for evaluating research proposals and distributing funds is far from ideal, and does not promote innovative research". To support the judgment, they cited a popular saying in China: "Small grants, big review; medium grants, small review; big grants, no review." In Wu's opinion, this happened simply because the research project evaluation was limited by very low proportion of the outside reviewers and the serious cronyism, especially for the big projects. He also pointed out that China's low-level output is related to the inadequate and short-term nature of its research funding, which pressed the scientists to produce quick results that lack novelty and creativity. Additionally, many researchers were worried about the misconduct inside the Chinese scientific community, such as fabrication, falsification and plagiarism, etc. (Li, 2004; Wang, 2004)

Unlike the anxiety of the expatriate and domestic Chinese scientists about the recent S&T system reform, our concern is deduced from the quantitative economic analysis. However, our finding resonates with the cited criticism mainly originating from the subjective observation of China's S&T institutes. The worsening scientific productivity of China's S&T institutes since 1990s obviously requests the greater efforts of the future reform policy, which is expected to emphasize the continuous improvement of the funding system, strengthening the internal management and fighting misconduct activities.

Section 6: Conclusion

The "Resolution" issued in 1985 launched the reform of China's centrally-planned S&T system. The objective of the reform was to transform the rigid, segmented and inefficient plan-oriented S&T system into a highly dynamic, interactive and efficient system such as those in the leading industrialized countries. In this transformation, two fundamental tasks need to be well accomplished, namely, 1) establishing the effective linkage across the agents inside the S&T system and 2) enhancing the scientific productivity of the S&T system. Whether the two tasks have been accomplished and how well they have been achieved in a large degree is decided by the reform performance in China.

In the past 20 years, numerous policies regarding S&T system transformation have been implemented in China. The analysis of the successful policies are centered on three policy groups, i.e. reform the R&D funding system, improve R&D management in the S&T institutes and strengthen the industry-academy relationship. The study of two institutes affiliated to the Chinese Academy of Science examines the impacts of the reform policy in the micro-level. The performance improvement of the two institutes after 1998 is well explained by the successful policy measures in the framework of "Knowledge Innovation Program".

In order to evaluate the policy performance during the reform period, we calculate the scientific productivity of China's S&T institutes based on the data from two different sources. The result reveals in China's S&T institutes the full effect of the R&D investment on the international publication takes 7 years to occur and its total effect on patent application lasts 5 years. The long term elasticity of publishing the international papers and R&D project expenditure is around 0.8 and the elasticity of patent application and R&D investment is approximately 2. That is, a 1 percent increase of the R&D investment in China's S&T institutes leads to 0.8 percent growth of the international papers and 2 percent growth of the patent application.

The most important finding in this paper is the deteriorating scientific productivity in China's S&T institutes since 1990s. The result based on the aggregate data shows the average annual growth rate of scientific productivity is -2.9 percent when the output is measured by the publication data, and is -9.5 percent when the output is measured by the patent data. This result is confirmed by the analysis based on the provincial data. We calculate the scientific productivity of the S&T institutes in the eleven provinces, which concentrated around 80 percent of national resources invested to the S&T institutes. The weighted average growth rates are negative, whenever the output is measured by the publication or patent data.

The deteriorating scientific productivity certainly casts doubt on the policy impacts of the on-going Chinese S&T system reform. This finding resonated with the anxiety of some expatriate and domestic Chinese scientists about the drawbacks of the current S&T reform. The evidence of the declining scientific productivity of China's S&T institutes since 1990s obviously requests greater efforts of the future reform policy, which is expected to emphasize the continuous improvement of the funding system, strengthening the internal management and fighting misconduct activities.

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Table 1: Output Indicators for Chinese S&T System: 1991 – 2002

Year	Number of China's "Science Citation Index" (SCI) Papers[1]	Ratio of China's SCI Papers to World Total SCI Papers	Patent Application of China's S&T Institutes[2]	Contract Value Registered in Technology Markets (Sellers are S&T Institutes) (Unit: 1,000 RMB, 1990 Constant Price)[2]
1991	6,630	1.07%	2,385	4,167,097
1992	6,224	0.92%	2,541	6,078,776
1993	9,617	1.28%	2,636	6,353,850
1994	10,411	1.32%	2,540	5,629,851
1995	13,134	1.54%	2,345	5,961,984
1996	14,459	1.62%	2,835	5,942,453
1997	16,883	1.84%	2,829	6,310,247
1998	19,838	2.13%	2,872	8,141,753
1999	24,476	2.51%	3,048	8,981,310
2000	30,499	3.15%	4,122	9,028,356
2001	35,685	N/A	4,360	9,745,492
2002	40,800	4.18%	5,373	10,094,857

Source: 1, Institute of Scientific and Technological Information in China (2000, 2001, 2002, 2003).
2, *Chinese Statistical Yearbook on Science and Technology 2003.*

Table 2: S&T Papers Included in *Science Citation Index Expanded*, *Engineering Index* and *Index to Scientific & Technical Proceedings*: China and Several Countries

Country	Rank of the Number of Total S&T Papers in the World in 2002	Ratio of the Country's S&T Papers to the Total in the World in 2002	Annual Growth Rate of the Country's S&T Paper			
			1999/1998	2000/1999	2001/2000	2002/2001
UK	3	7.95%	N.A.	N.A.	N.A.	-4.36%
Germany	4	7.35%	N.A.	N.A.	5.29%	-4.41%
China	5	5.37%	31.95%	7.56%	29.89%	19.94%
France	6	5.13%	N.A	N.A	4.63%	-4.25%
Italy	7	3.84%	-2.21%	-2.86%	9.69%	-1.55%
Canada	8	3.62%	4.07%	-4.46%	2.08%	0.20%
Russia	9	2.89%	1.06%	-1.60%	-5.82%	11.83%

Source: Institute of Scientific and Technological Information in China (2000, 2001, 2002, 2003).

Table 3: S&T Institutes in China's Innovation System: 1987-2002

	Year	S&T Institutes	Ratio of value of S&T Institutes to the Sum	Universities	Ratio of the value of Universities to the Sum	Enterprises	Ratio of the value of Enterprises to the Sum
R&D Personnel (Thousand Person Year, Full Time Equivalent)	1987[1]	385.86	47.23%	178.29	21.82%	252.78	30.94%
	1995	345.00	44.86%	144.00	18.73%	280.00	36.41%
	2002	206.00	25.40%	181.00	22.32%	424.00	52.28%
R&D Expenditure (Billion RMB, Current Price)	1987[2]	10.68	60.72%	0.70	3.98%	6.21	35.30%
	1995	14.64	44.30%	4.23	12.80%	14.17[4]	42.89%
	2002	35.13	33.71%	13.05	12.52%	56.02[4]	53.76%
Invention Patent Application in State Intellectual Property Office of P.R. China (Items)	1987[3]	1,844	29.35%	1,360	21.65%	3,078	49.00%
	1995	865	34.26%	574	22.73%	1,086	43.01%
	2002	3,429	15.33%	4,282	19.14%	14,657	65.53%
Science Citation Index Papers (Number) [5]	1999	3,927	29.84%	9,214	70.03%	17	0.13%
	2002	8,036	25.80%	23,028	73.94%	82	0.26%

Source: Data of 1995 and 2002 are from *China Statistical Yearbook on Science and Technology 2003*.

Note: 1, Data of 1987 are from Xue (1997). The data are the head count data.

2, Data of 1987 are from Xue (1997).

3, Data of 1987 are from Shen (1997). The data not only include the invention patent application, but also the utility model and the design patent application. Therefore, their values are larger than those of the year 1995 in the table.

4, Data are specified in *China Statistical Yearbook on Science and Technology 2003* as "R&D Expenditure". Their values are supposed to be larger than those of "Intramural R&D Expenditure" data.

5, Data are from Institute of Scientific and Technological Information in China (2000, 2001, 2002, and 2003). Data of 2002 are for "Science Citation Index Expended" papers. Data of 1999 are for "Science Citation Index" papers.

Table 4: The Discrepancies of the S&T System in Centrally Planned Economies and Market Economy Countries

S&T System in the Centrally Planned Economy	S&T System in the Market Economy
• Strong influence from the political hierarchy and control;	• Dynamic and interactive innovation system; o High mobility of the human resources, knowledge, capital inside the innovation system; o Demand for innovation comes from not only the "push side" such as the R&D institutes, but also the "pull side" such as the users and enterprises;
• Linear innovation model: o Innovation process is vertically segmented as basic research, applied research and experiment and development; o Innovation system is horizontally segmented by ministerial R&D branches; o Innovation push comes from the externalized R&D towards production; o Users are not the source of improvement and innovation;	
• Enterprises are only production units instead of being the center of the innovation; o R&D is "outsourced" to ministries or other organizations instead of being organized as an "in-house" activity; o Knowledge is accumulated more in design and engineering institutes than in enterprises; o Links between R&D and production are generally weak;	• Industrial R&D is the driving force of the innovation activities; o Technology is firm-specific assets; o Enterprises accumulate the embodied knowledge through learning-by-doing in the specific organizational contexts; o Enterprises create the pull-demand for innovation;
• R&D fund is distributed on the basis of institutional (per personnel) funding instead of depending on the merit of the projects;	• R&D project is financed through the competitive selection of the proposals based on the merit of the project;
• "Soft Budget Constrain" prevails inside the R&D units; o Low efficiency of the R&D activities; o Overstaffing is a serious problem.	• "Hard Budget Constraint" guarantees the efficiency in the daily operation and management of the R&D units.

Source: Hanson and Pavitt (1987), Meske (1998), OECD (1969) and Radosevic (1999)

Table 5: Chinese Central Government's Budgetary Expenditure and Appropriation for S&T: 1980-2002[1]

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Budgetary Appropriation for S&T (Billion RMB. Constant Price. 1990=100)	10.91	10.17	10.80	12.94	14.78	14.54	15.25	14.67	13.93	13.51	13.91	15.06
The Annual Growth Rate of Budgetary of Appropriation for S&T		-6.8%	6.2%	19.8%	14.3%	-1.7%	4.9%	-3.8%	-5.1%	-3.0%	3.0%	8.2%
The Ratio of the Budgetary Appropriation for S&T to the Total Budgetary Expenditure	5.3%	5.4%	5.3%	5.6%	5.6%	5.1%	5.1%	5.0%	4.9%	4.5%	4.5%	4.7%
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
Budgetary Appropriation for S&T (Billion RMB. Constant Price. 1990=100)	16.43	17.10	16.96	16.89	18.39	21.39	23.51	29.80	31.25	37.73	44.04	
The Annual Growth Rate of Budgetary of Appropriation for S&T	9.2%	4.1%	-0.8%	-0.4%	8.9%	16.3%	9.9%	26.8%	4.8%	20.8%	16.7%	
The Ratio of the Budgetary Appropriation for S&T to the Total Budgetary Expenditure	5.1%	4.9%	4.6%	4.4%	4.4%	4.4%	4.1%	4.1%	3.6%	3.7%	3.7%	

Source: *China Statistical Yearbook on Science and Technology 2003*.

Note: 1, The original data are current price data. The constant price transformation is based on the GDP deflator provided by the World Bank.

Table 6: Unit Root Test of the Aggregate Data Series: Kwiatkowski-Phillips-Schmidt-Shin Method[1]

Null Hypothesis: The Data Series are Stationary	Kwiatkowski-Phillips-Schmidt-Shin Test Statistic	Asymptotic Critical Values		
		1% level	5% level	10% level
Logarithm of R&D Project Expenditure 1990 Constant Price	0.129737	0.216	0.146	0.119
Logarithm of International Paper	0.161040			
Logarithm of Patent Application	0.133574			

Note: 1, The exogenous variables in the regression include the constant term and linear trend.

Table 7: R&D Input and Output of China's S&T Institutes in Provincial Level

Province	Ratio of R&D Project Expenditure of Each Province to National Total				Ratio of International Papers of Each Province to National Total		Ratio of Patent Applications of Each Province to National Total	
	1991		2003		1991	2003	1992	2003
	Ratio	Ranking	Ratio	Ranking	Ratio	Ratio	Ratio	Ratio
Bei Jing	31.7%	1	41.8%	1	42.0%	47.8%	23.7%	29.8%
Liao Ning	5.5%	3	4.9%	3	7.6%	5.4%	9.4%	10.1%
Ji Lin	5.4%	5	4.4%	5	4.9%	4.0%	4.1%	7.1%
Shang Hai	12.3%	2	10.6%	2	12.1%	13.4%	7.5%	17.1%
Jiang Su	4.4%	6	3.7%	6	3.5%	4.0%	4.2%	2.6%
Shan Dong	2.3%	11	3.0%	9	1.6%	1.6%	6.3%	3.5%
Hu Bei	2.8%	10	3.4%	8	2.0%	2.3%	3.2%	2.3%
Guang Dong	3.1%	8	4.4%	4	4.9%	3.0%	2.7%	4.5%
Si Chuan	5.5%	4	3.5%	7	1.9%	0.8%	4.7%	2.4%
Shaan Xi	3.0%	9	1.5%	14	1.5%	0.8%	2.4%	1.5%
Gan Su	3.1%	7	2.5%	10	3.6%	2.3%	2.4%	2.9%
Sum of Total Thirty One Provinces' Original Data[1]	1,258,153.74		3,809,492.93		7,425	10,884	2,007	4,377
Sum of "Top Eleven" Provinces' Original Data[1]	993,539.24		3,176,766.26		6,351	9,294	1,420	3,668
Ratio of "Top Eleven" to Sum Total	79.0%		83.4%		85.5%	85.4%	70.8%	83.8%

Source: *Data Set of S&T Organizations*

Note: 1, Unit for "R&D Project Expenditure": Thousand RMB, 1990 constant Price; Unit for "International Papers": Piece of Paper; Unit for "Patent Application": Piece of Patent Application.

Table 8: Estimation Result of Function (2): International Papers and Patent Application

	International Papers			Patent Application		
	8Lags	7 Lags	6 Lags	6 Lags	5 Lags	4 lags
Expenditure $t_0(\beta_0)$	0.05927	0.04184	-0.02903	0.26160**	0.20100***	0.19033**
t_{-1} (β_{-1})	-0.11599**	-0.09994**	-0.10137*	0.28676***	0.25203***	0.25715***
t_{-2} (β_{-2})	-0.13319**	-0.11333**	-0.11543**	0.31193***	0.30306***	0.32397***
t_{-3} (β_{-3})	-0.05024	-0.03743	-0.07361**	0.33710***	0.35409***	0.39079***
t_{-4} (β_{-4})	0.07499	0.08863**	0.02170	0.36226***	0.40512***	0.45761***
t_{-5} (β_{-5})	0.18459**	0.22574***	0.16810**	0.38743***	0.45615***	
t_{-6} (β_{-6})	0.22068**	0.33478***	0.36321**	0.41260***		
t_{-7} (β_{-7})	0.12536	0.37662**				
t_{-8} (β_{-8})	-0.15926					
Sum of Lags	0.20620	0.81692**	0.23356	2.35968***	1.97143***	1.61987***
Constant	7.309209	2.555524	7.054632***	-11.16723***	-8.125046***	-5.367869***
Time Trend Variable t	0.009567	-0.026481	0.015873	-0.118476***	-0.093469***	-0.072193***
AIC	-3.474260	-3.719499	-3.193782	-2.063941	-2.967998	-2.100132
SIC	-3.292709	-3.502465	-2.951328	-1.902306	-2.794168	-1.917544
Polynomial Degree Reduction Wald Coefficient Test (P value of F-statistics)						
5 to 4		0.9957				
4 to 3		0.5668				
3 to 2		0.0747*			0.6493	
2 to 1					0.5802	
1 to 0					0.0364**	

Note: * : Significant at 0.1; **: Significant at 0.05; ***: Significant at 0.01.

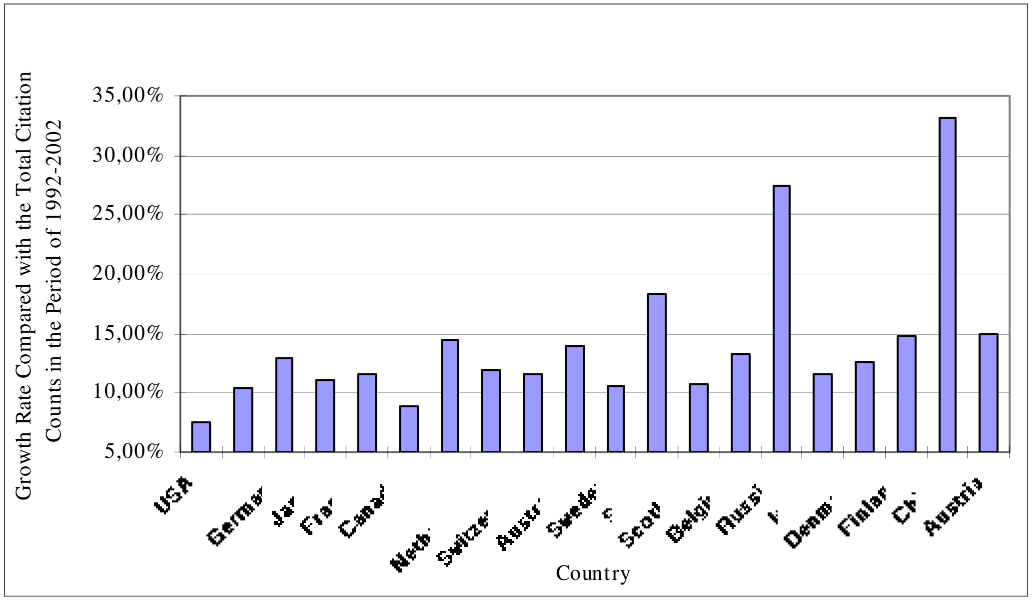
Table 9: Scientific Productivity Growth Rate of China's S&T Institutes: Aggregate Data

	Scientific Productivity Growth Rate in terms of International Paper	Scientific Productivity Growth Rate in terms of Patent Application
1991/1992	N.A.	-15.3%
1992/1993	N.A.	-6.6%
1993/1994	-4.8%	-11.2%
1994/1995	-3.5%	-15.7%
1995/1996	-0.2%	5.9%
1996/1997	-7.3%	-15.0%
1997/1998	4.4%	-11.9%
1998/1999	-3.9%	-11.8%
1999/2000	-8.2%	0.0%
2000/2001	1.5%	-18.4%
2001/2002	-1.6%	-9.5%
2002/2003	-5.5%	-4.2%
	Average Annual Growth Rate	
1991/2003		-9.5%
1993/2003	-2.9%	

Table 10: Average Annual Scientific Productivity Growth Rate of the S&T Institutes in the “Top Eleven” Provinces:

Province	Average Annual Scientific Productivity Growth Rate in terms of International Paper	Average Annual Scientific Productivity Growth Rate in terms of Patent Application
	1998-2003	1996-2003
Bei Jing	-5.0%	-7.1%
Liao Ning	-2.8%	-4.2%
Ji Lin	0.9%	-2.1%
Shang Hai	2.3%	3.6%
Jiang Su	-9.4%	-18.5%
Shan Dong	-7.4%	-23.0%
Hu Bei	-11.7%	-7.2%
Guang Dong	-9.6%	-6.6%
Si Chuan	-12.4%	1.3%
Shaan Xi	-16.1%	-5.8%
Gan Su	0.2%	1.4%
Weighted Arithmetic Average[1]	-4.8%	-5.7%
Result of Aggregate Data		
1998/2003	-3.5%	
1996/2003		-10.1%

Note: The weight is the ratio of the each province’s “R&D Projects Expenditure” to sum of “top eleven” provinces’ “R&D Projects Expenditure”.



Source: Institute of Scientific and Technological Information in China (2003).
Note: 1, The ranks of the countries descend from the left to the right. For instance, US ranked in 1st and Austria ranked in 20th.

Figure 1: Ranking of the Total Citation Counts of the Countries (Regions)' *Science Citation Index Expanded* Papers: 1993-2003[1]

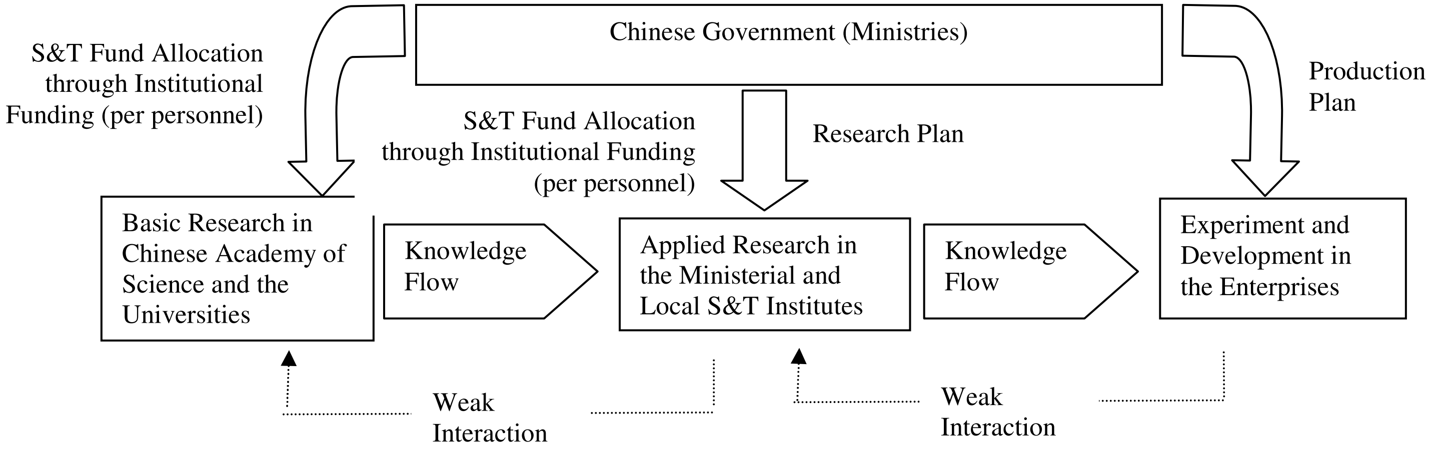


Figure 2: Chinese S&T System in the Planned Economy

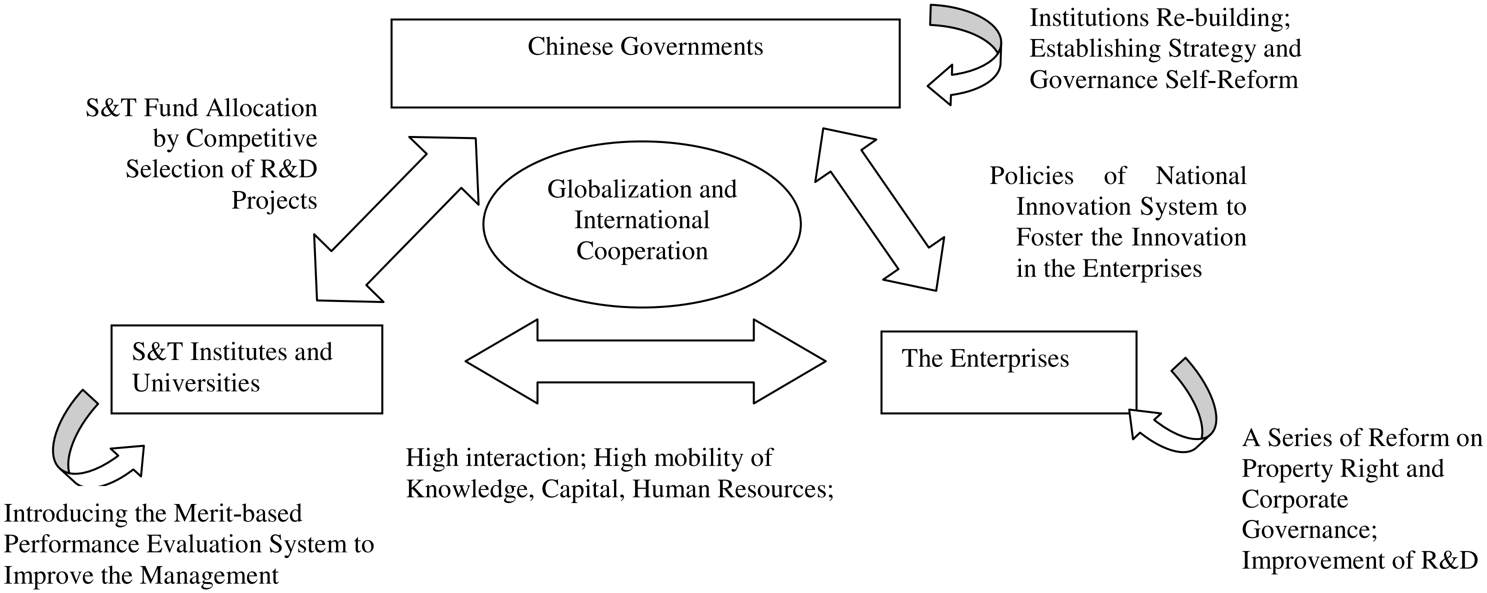
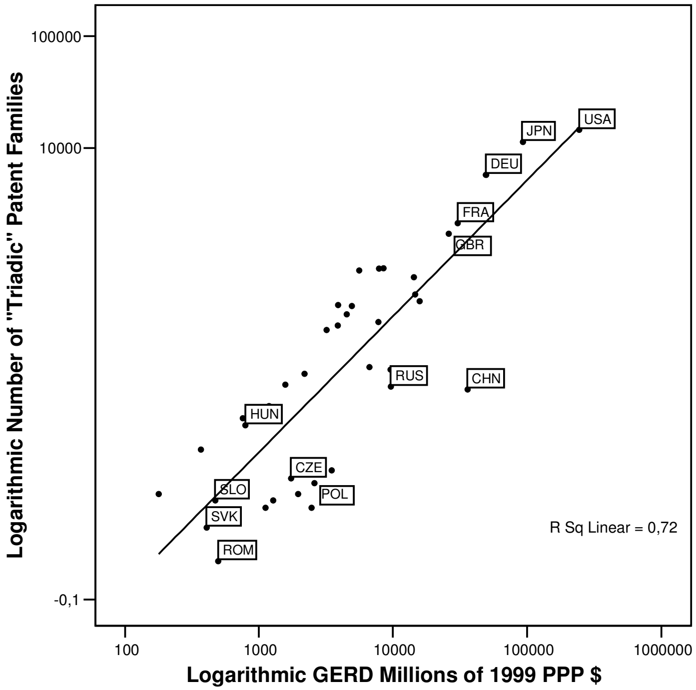


Figure 3: Chinese S&T System in the Market Economy



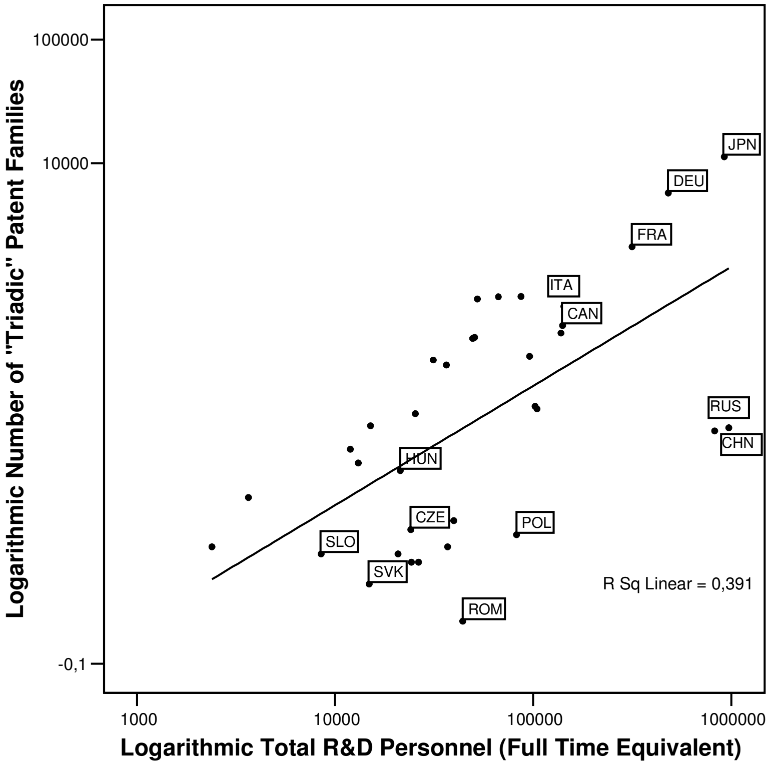
Data Source: OECD (2003).

Note:

1, The OECD countries include: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Japan, Korea, Luxembourg, Mexico, New Zealand, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States. The selected non-OECD countries and regions include: Argentina, China, Israel, Romania, Russian Federation, Singapore, Slovenia, Chinese Taipei.

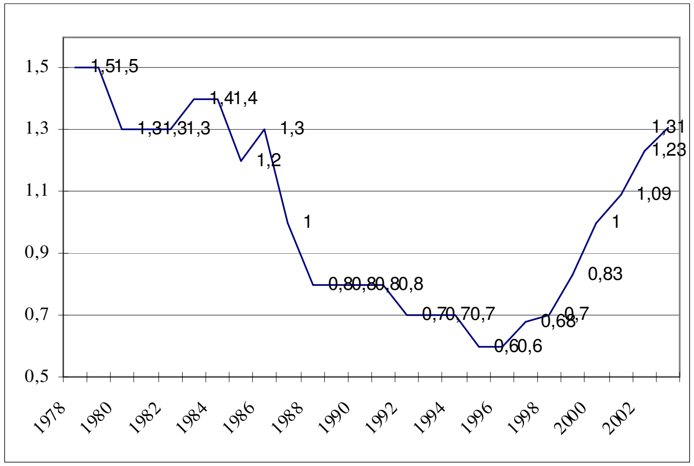
2, Countries Label: USA-United States; JPN- Japan; DEU-Germany; FRA-France; GBR- United Kingdom; RUS-Russian Federation; CHN-China; HUN-Hungary; CZE- Czech Republic; POL-Poland; SLO-Slovenia; SVK- Slovak Republic; ROM-Romania.

Figure 4: The “Triadic” Patent Families and Gross Expenditure on R&D in the OECD and Selected Non-OECD Countries and Regions (1999 Data)



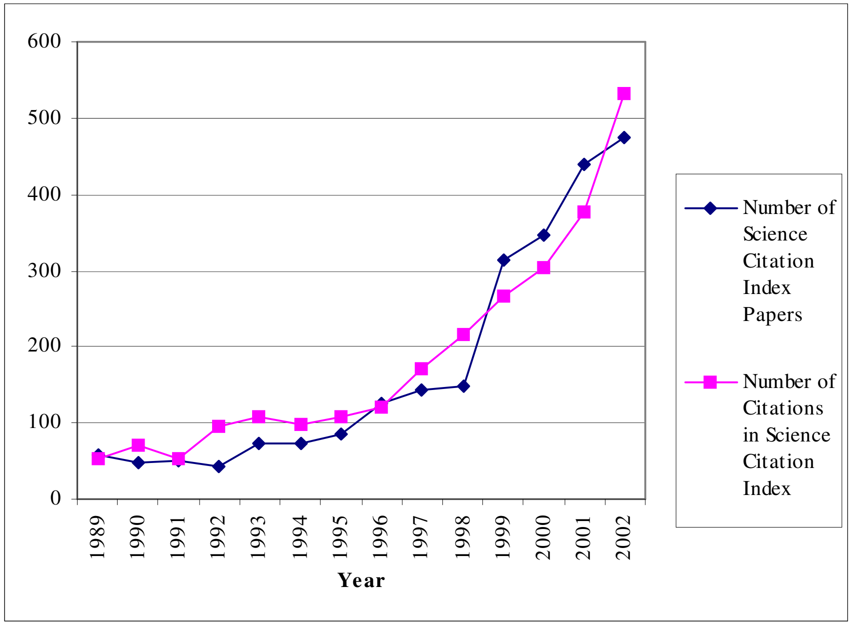
Data Source: OECD (2003).
Note:
1, The included OECD and non-OECD countries are the same as those in Figure 4.
2, Countries Label: JPN- Japan; DEU-Germany; FRA-France; ITA-Italy; CAN-Canada; RUS-Russian Federation; CHN-China; HUN-Hungary; CZE- Czech Republic; POL-Poland; SLO-Slovenia; SVK- Slovak Republic; ROM-Romania.

Figure 5: The “Triadic” Patent Families and Total R&D Personnel in the OECD and Selected Non-OECD Countries and Regions (1999 Data)



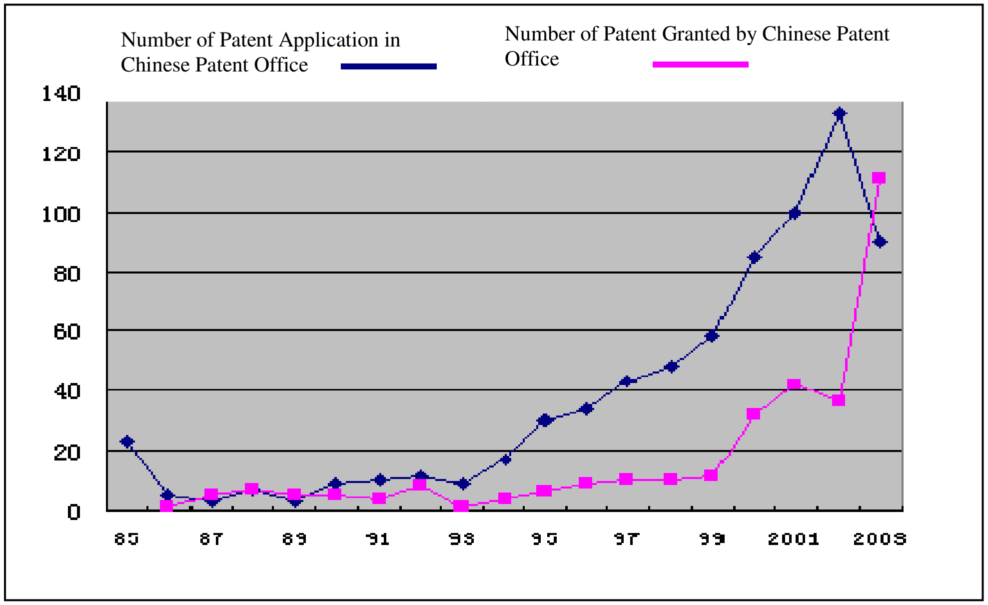
Source: Various versions of *China Statistical Yearbook on Science and Technology*.

Figure 6: China's Gross Expenditure on R&D / GDP Ratio: 1978-2003



Source: Institute of Chemistry (2004b).

Figure 7: Publication in Institute of Chemistry, Chinese Academy of Science: 1989-2002



Source: Institute of Chemistry (2004b).

Figure 8: Patent Application and Patent Grant in Institute of Chemistry, Chinese Academy of Science: 1985-2003

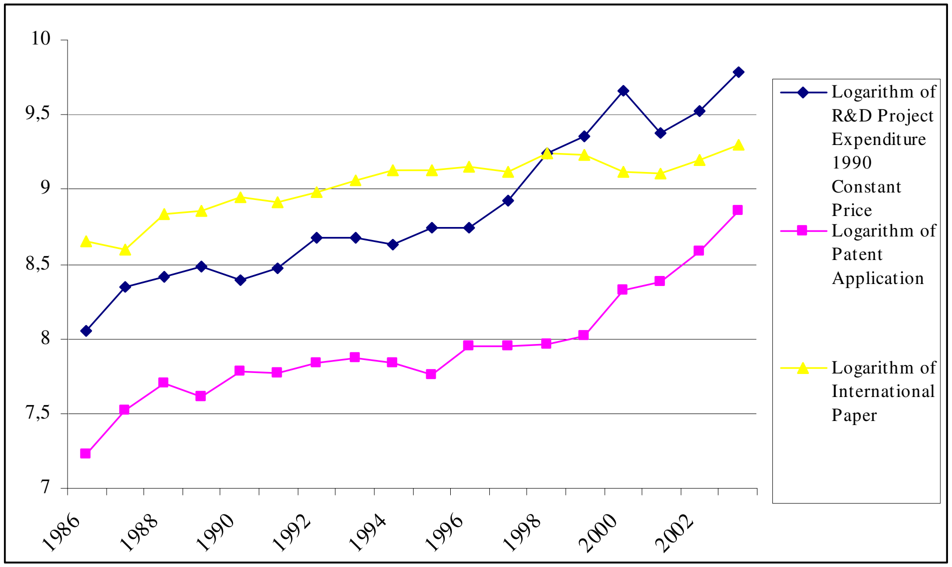


Figure 9: R&D Input and Output in Chinese S&T Institutes: Aggregate Data