

China's National Innovation System Reform and Growing Science Industry Linkage

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Summary

In this paper, innovation policies for systems reform in China since the middle 80's are surveyed and its impacts on science industry linkage activities are investigated by looking into (1) technology market, (2) S&T outsourcing activities of firms and (3) co-invention patents by applicants in firms, universities and public research institutions. All of these findings suggest that the role of science sector in China's economic development process has become larger, and double skin problem (separation of science and industry sector) in China's innovation system has been gradually solved by a number of policy actions to facilitate science industry linkages.

Key Words: China, national innovation system, technology market, patent statistics, technology policy

1. Introduction

Technological progress is an important source of economic growth not only for developed countries, but also for developing countries. At micro level, economic growth is gained by value added growth by each firm. However, in a context of innovation system, not only firms are players, and but also universities and public research institutions are conducting R&D. The science sector, which includes universities and research institutes does not contribute to economic growth directly, but scientific outputs from this sector are served as important inputs to firm's innovation activities. Freeman (1987) pointed out science industry linkage is an important factor for economic performance of nations. Subsequently, the concept of national innovation system has been developed by empirical investigations into systemic interactions of various innovation players and socio-economic institutions facilitating such linkages (Nelson, 1993; OECD, 1999).

In China, a number of policy actions in order to reform its national innovation system have been taken for these 20 years. In 1985, the Resolution of the China Communist Party Central Committee (CCPCC) on the structural reform of the science and technology system was enacted. This is a cornerstone of departing from the Soviet model of innovation system, where S&T activities at public research institutes (PRIs) and production at state-owned enterprises (SOEs) were completely separated (Xue, 1997). It is clear that such science industry separation system does not work well, and the decision made in 1985 was for changing the direction of innovation policy toward science and industry linkage model.

In this paper, innovation policies for systems reform in China are surveyed and its impacts on science industry linkage activities are investigated. The remainder of this paper consists of five sections. The next section is for providing a survey of innovation policies to stimulate science industry linkages. In addition to direct measures such as public funding to linkage activities, institutional reforms of science sector by introducing market based incentive system are also important. This section is followed by three sections on quantitative studies about science and industry linkages, i.e., (1) investigating the role of technology market in China's innovation system reform, drawn some analytical findings in Men and Motohashi (2005) (2) understanding firm's S&T outsourcing activities by using S&T statistics from National Bureau of Statistics, from Motohashi and Xiao (2005) and (3) measuring co-invention activities of firms and universities by using patent database. All of these findings suggest that the role of science sector in China's economic development process has become larger since 1980's. Finally, this paper concludes with summary of findings and some policy implications.

2. Review of China's Innovation Policies for Science and Industry Linkage

Under the planned economic system based on the Soviet model that has been built in the 1950s, the science and technology activities and the industrial ones were separated. The transfer of technologies that were developing in public research institutions (PRIs) under this system was also controlled by the government. As a result, PRIs had no incentive to understand the needs of enterprises for technology. At the same time, state owned enterprises (SOEs) were supposed to concentrate on production activities by using PRIs' technologies, and did not have incentive for in-house R&D. Some scholars call this as double skins (*liangzhangpi*) to describe the separation between science and industry sectors. This is an initial condition of China innovation system reform, and major motivation of innovation policies in these 20 years is transforming

this separation system to linkage one.

In 1985, China Communist Party Central Committee (CCPCC) announced “Decisions on science and technology system reform” to solve the problem of double skins and lack of incentives for industry and science linkage. One of major policy instruments in the late 1980’s is an organizational reform of public research institutes (PRIs) which played a major role of R&D in China. The government classified all PRIs into three categories, i.e., type 1: ones focusing on basic research, type2: ones conducting research for public needs and type3; ones focusing on applied research. New policies required streamlining of all three types of PRIs. The most stringent decision was made particularly for type 3 PRIs, ordering stop of their operations within 5 years. Until 1995, 1181 PRIs out of 5074 had disappeared, but many institutes survived as private entities of technology services (NRCSTD, 2003). Such *ex*-PRI enterprises had played an important role to fill the gap between two sides of separated system at the beginning of China’s NIS reform (Motohahshi, 2004).

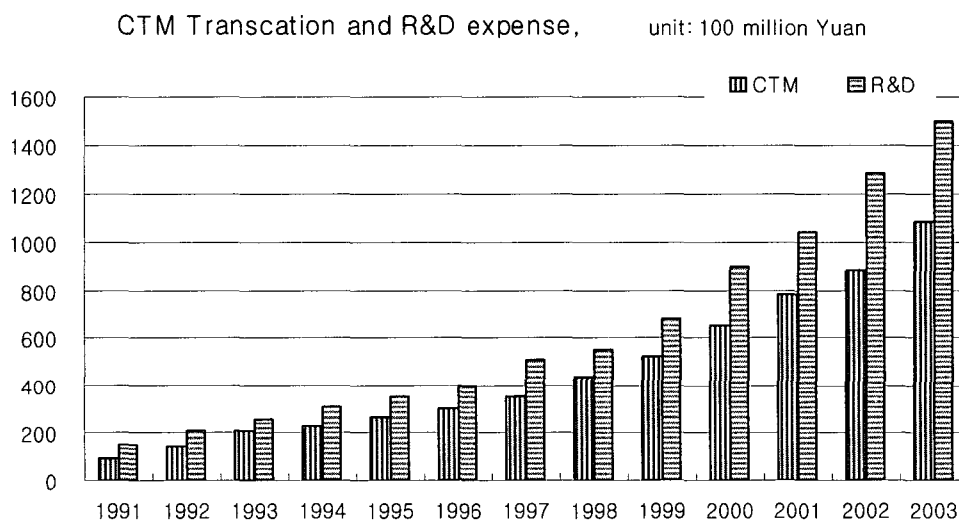
National innovation system reform entered a new era in 1992, when the market based economic reform has taken place seriously, based upon so-called Deng Xiaopin’s South Talk. Active interactions between science and industry sectors need proper incentive system for both sides. In this sense, market based economic reforms and open FDI policies induced better incentive mechanism for firms’ innovation activities and better performance. In 1993, “Technology Progress Law” was established, designating S&T developments as one of most important components in China’s economic development. Subsequently, Technology Transfer Law was enacted in 1996, which encouraged science sector to transfer its technology, and set some rules of technology market transactions. Under these initiatives, PRIs have been given more autonomy to technology transfer activities. At the same time, institutional funding to PRIs was reduced, so that PRIs were obliged to conduct technology licensing activities to survive. In this process, substantial number of PRIs became to be private technology service firms or be merged with large-medium size enterprises.

From 1998 when Jiang Zheming announced the “State Development through Promoting Science Technology and Education” (Kejiaoxingguo)¹ policy in the 15th CCPCC, the reforms of science and technology system have been further accelerated. The rules on property right of technology and technology transfer were established to facilitate market based technology transactions. For example, “Decisions on Technology Innovation, Development of High-tech, and Industrialization” was issued in 1999. In addition, the government set up public institutions to promote technology diffusion, such as productivity centers and engineering research centers (World Bank, 2001).

1) The first time of “State Development through Promoting Science and Technology” policy to be pointed out was in “Decisions on Acceleration of Science and Technological Progress” that issued by State Council and Party Central Committee in 1995.

3. Role of Technology Market in China's Innovation System

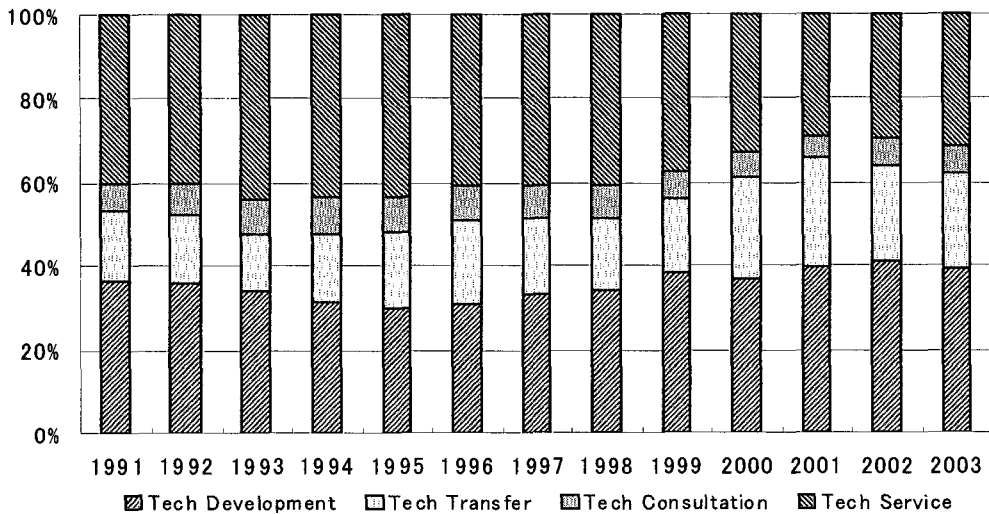
In order to access these policy initiatives for industry science linkages, analysis of technology market is provided in this section. Figure 1 compared the size of technology market and R&D. First, the size of technology market grows more than 10 times from 1991 to 2003, and this speed is faster than that of in-house R&D. Second, the size of technology market as compared to in-house R&D is also very large. In 2003, the amount of technology market transaction reached 100 billion RMB, and this size is more than two third of that of R&D.



Sources: China Statistical Yearbook on Science and Technology and Annual Report on Statistics of China's Technology Market.

Figure 1: Technology Market and R&D

The activities covered by technology market include technology development, technology transfer, technology consultation and technology services. Figure 2 shows the share of each type of activities in transaction amount. The share of technology development and technology transfer increases while the other two activities lost its share. In 2003, the total share of first two types of activities, which has more advanced technology contents than the other two, reached more than 60%. The total amount of transaction of technology development and transfer is 6.92 billion RMB, as compared to total amount of R&D, 15.40 billion RMB in 2003. This large relative size of traded technology to in-house R&D (45%) shows the importance of technology market in China's innovation system.



Sources: China Statistical Yearbook on Science and Technology and Annual Report on Statistics of China's Technology Market.

Figure 2: Share of Trading Volume by Transaction Types

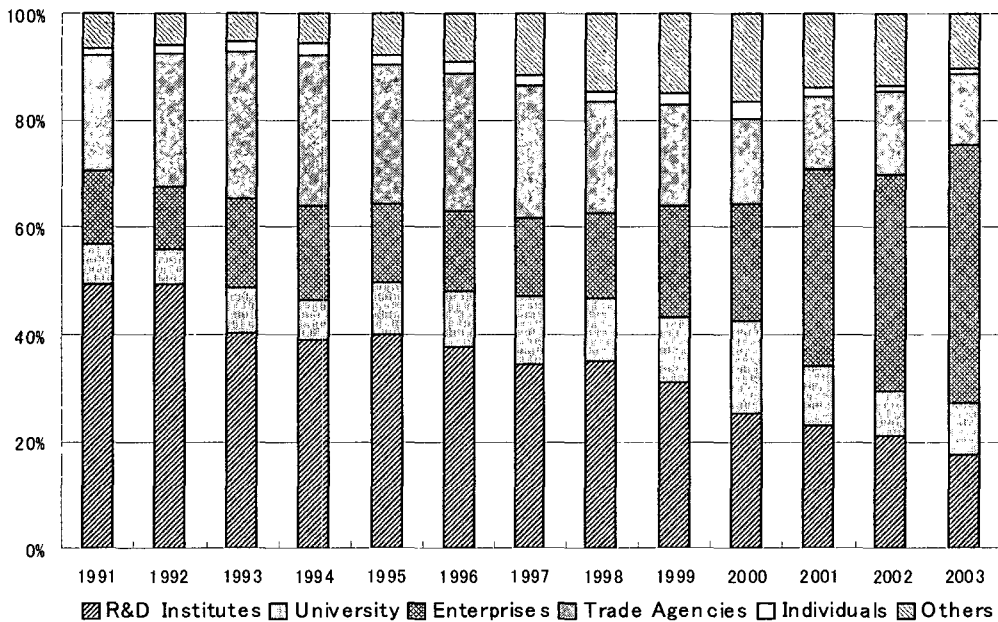
In China, a technology market refers to the physical entity to facilitate technology transactions between sellers and buyers. In 1984, the first technology market, or technology transaction center was created in Wuhan, which consisted of about 60 technology transfer offices in PRIs, universities and firms in this area. Subsequently, technology transaction and management centers have been established in many regions. In June 1987, Chinese Parliament passed "Technology Contract Law"²⁾, which clarified the definition of technology market activities, i.e., technology development, technology transfer, technology consultation, and technology service. In this starting up period, China's technology markets were growing rapidly but amid considerable confusion. To promote technology market development, government offered tax incentive for technologies traded in technology market. However this policy caused some confusion in actual implementation, since the definition of activities covered by tax incentive was still unclear.

In 1992, the National Science and Technology Committee (renamed to the Ministry of Science and Technology in 1998) established China Technology Market Association as a central organization, which facilitates uniform implementation of technology market policies all over China. In addition, regional technology market management & promotion organizations were established and the

2) Related law files include "Technology Contract Law Implement Regulations" that announced in 1989 and "technology contract arbitrage interim regulations" in 1990.

regional governments made more than 30 ordinances on technology market management to settle down confusions and mistreats at implementation level. These regulations on technology markets as well as improvements of property right scheme on intangible technology are major factors behind increasing size of technology market transactions in Figure 1. According to “Annual Report of Technology Market, 1998”, the technology market management and promotion associations are built in all of the 31 provinces and 5 special planning cities. In addition, in 75% of the cities and 60% of the counties or towns, technology transaction contract registration offices are under operation in technology transaction activities.

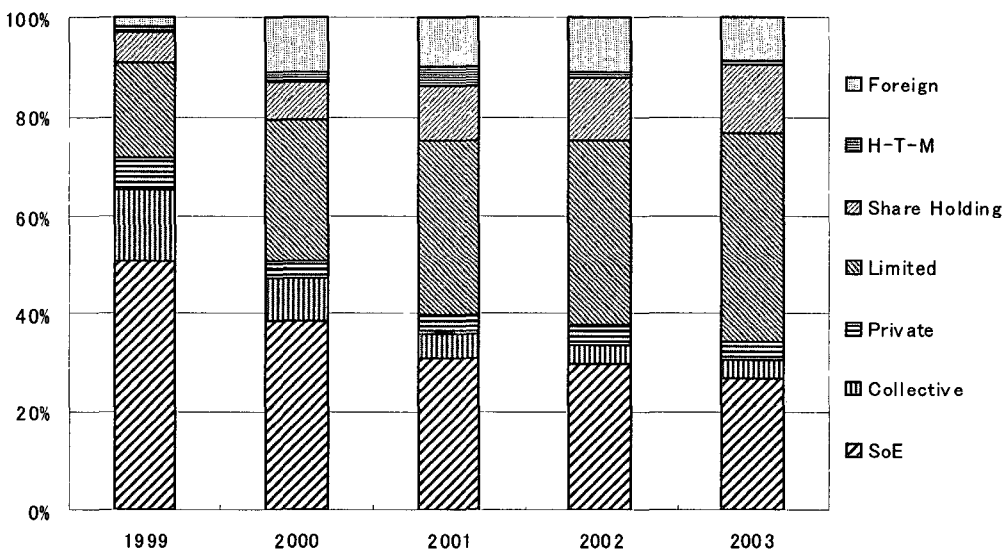
Figure 3 shows the structure of technology market by seller type. As a technology provider, PRIs used to play an important role in 1991, but its share went down to 20% in 2003, due to the restructuring of PRIs described in the previous section. On the other hand, the share of enterprise increased. In process of innovation system reform, an enterprise becomes a major player, but technology intensive firms are spin outs of PRIs and universities in many cases. In this sense, R&D at science sector is still contributing significantly to innovation performance in China.



Sources: China Statistical Yearbook on Science and Technology and Annual Report on Statistics of China’s Technology Market.

Figure 3: Share of Technology Contract Volume by Type of Sellers

Figure 4 shows the share of technology transaction by buyer type. The share of state owned enterprises (SOEs) decreased from 1999. In contrast, the share of limited ownership companies is increasing. SOEs reform has been accelerated since the late 1990's (Jefferson and Rawski, 1994; Jefferson et. al, 2000), and substantial numbers of them were transformed into limited ownership companies or stock holding companies (Motohashi, 2005a). The shift of share from SOEs to limited ownership companies in Figure 4 reflects such ownership structure changes. From 2000, the foreign capital companies have joined into China's technology market to take part in technology transfer activities.



Sources: China Statistical Yearbook on Science and Technology and Annual Report on Statistics of China's Technology Market.

Figure 4: Share of Technology Contract Volume by Type of Buyers Firms

Men and Motohashi (2005) investigated the role of technology market in China's economic development by using regional level data from 1991 to 2003. In this study, determinants of technology market are analyzed, as well as the impact of technology market on productivity at regional level is tested by estimating production function. Major findings are as follows.

Both demand side and supply side factors explain the size of technology market. Demand factors include the GDP size as well as the share of manufacturing outputs. Supply factors include S&T spending of universities and PRIs.

Positive and statistically significant impacts of technology market on productivity growth at

regional level are found. However the size of impact decreases over time, suggesting that relative importance of in-house S&T increases.

4. Growing S&T Outsourcing of Firms

Science and industry linkage can be captured by the size of S&T outsourcing of firms to science sector as well. NBS's Survey on Science and Technology Activities provides the data of S&T outsourcing for all large- and medium-sized enterprises (LMEs) from 1996. The results of this survey are used as official S&T statistics in China, and the aggregated statistics are published annually as the Chinese S&T Statistical Yearbook. There are two types of questionnaires used, one for manufacturing firms and the other for non-manufacturing firms. In this study the annual data for manufacturing firms, which has more detailed survey items as compared to the data for non-manufacturing firms, are used.³⁾

In the S&T Survey, the data for intramural S&T activities and outsourcing expenses are collected separately. While only total amounts for outsourced S&T are available for 1996 and 1997, the survey for outsourced S&T to universities and public research institutes was conducted starting in 1998. From the 2000 survey, the type of outsourcing activities is further broken down by type of counterpart, i.e., outsourcing to universities, public research institutes, international counterparts, and/or domestic firms.

Figure 5 show the share of firms with S&T outsourcing to all S&T firms. Outsourcing counterpart can be science sector (universities and PRIs) or private sector such as other firms. In this graph, the shares of any type of S&T outsourcing and S&T outsourcing to science sector are provided. First, the share of outsourcing firms is increasing, which shows the growing S&T linkages at Chinese manufacturing firms. In addition, it is shown that science industry linkage as is captured by S&T outsourcing to science sector becomes popular, too. In 2002, about 23% of S&T firms are conducting S&T outsourcing to universities or PRIs.

3) Details of S&T survey as well as the datasets used in this section are provided in Motohashi and Xiao (2004) and Jefferson et. al (2003).

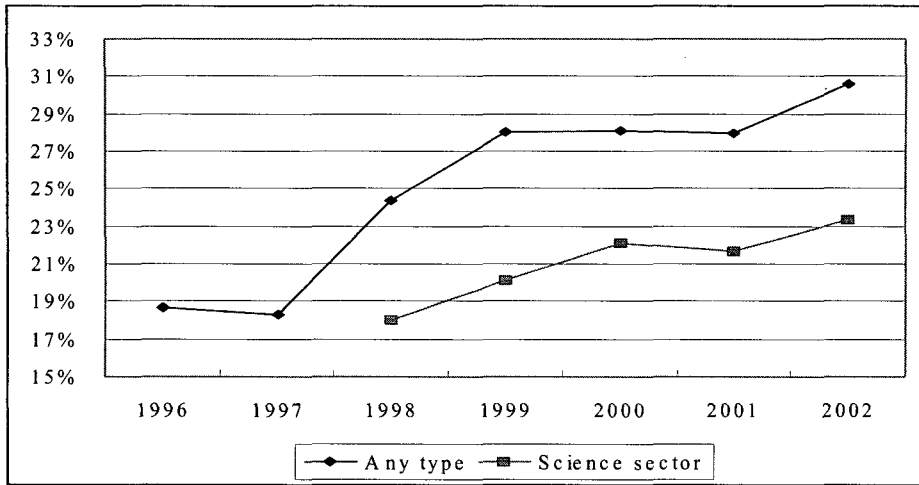


Figure 5: Share of Firms with S&T Outsourcing

Figure 6 shows the difference of this diffusion rate by type of counterpart. Universities and PRIs are popular counterparts for outsourcing. One of the factors behind this trend is ongoing science system reform intended to encourage science industry linkages as was described in chapter 2. Compared to domestic interactions, international technology collaboration as is captured by S&T outsourcing to international organizations is still at a low level. It should be noted also that the share of S&T outsourcing firms are increasing for all types of counterparts.

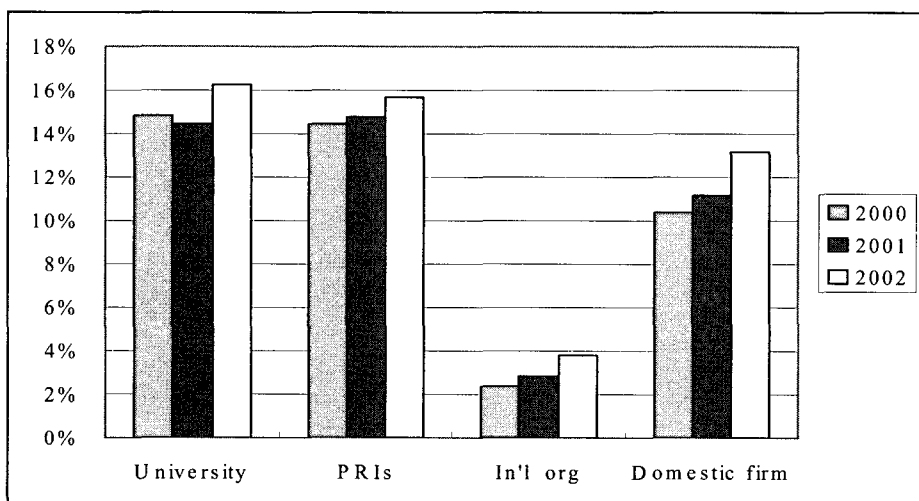


Figure 6: S&T Outsourcing by Type of Counterpart

Figure 7 shows the S&T outsourcing by type of firm ownership. A relatively high percentage of both stockholding firms and SOEs engaged in S&T outsourcing is found. In contrast, the percentage of foreign-owned enterprises doing so was relatively low. Some foreign-owned enterprises were established as production bases. In such enterprises, S&T activities are not relevant because technological contents are provided by the parent companies. It is found that foreign owned companies collaborates more with international organizations, which presumably are their parents or affiliated companies outside China.

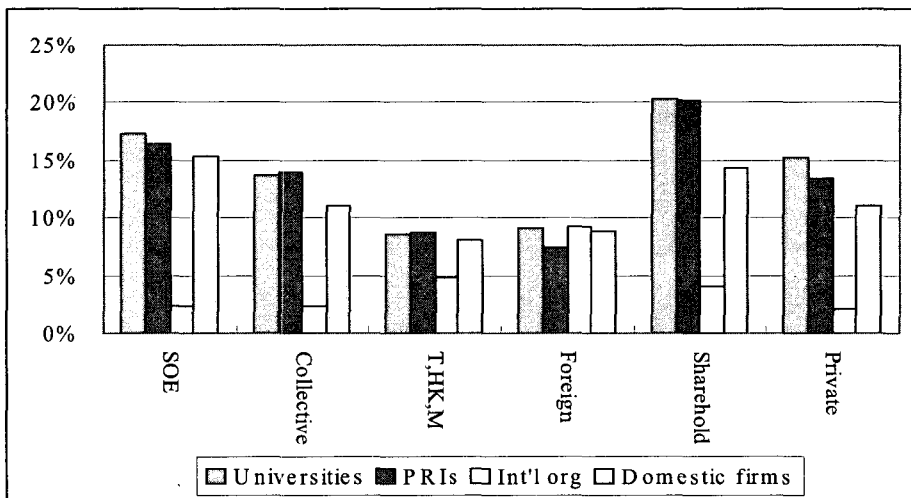


Figure 7: S&T Outsourcing by Type of Firm Ownership

Figure 8 shows the share of firms with S&T outsourcing to science sector by industry. First, a great variance in S&T outsourcing activities can be found across industries. More than 30% of firms are collaborating with universities and PRIs in petrochemicals and drugs. The primary motivation for working with these institutions is the need for scientific knowledge in innovation processes. It has been found that innovations in the chemical industry, including in drugs and petrochemicals, in developed countries are driven by scientific knowledge (Arora et. al, 2001), and this is the case for Chinese enterprises as well.

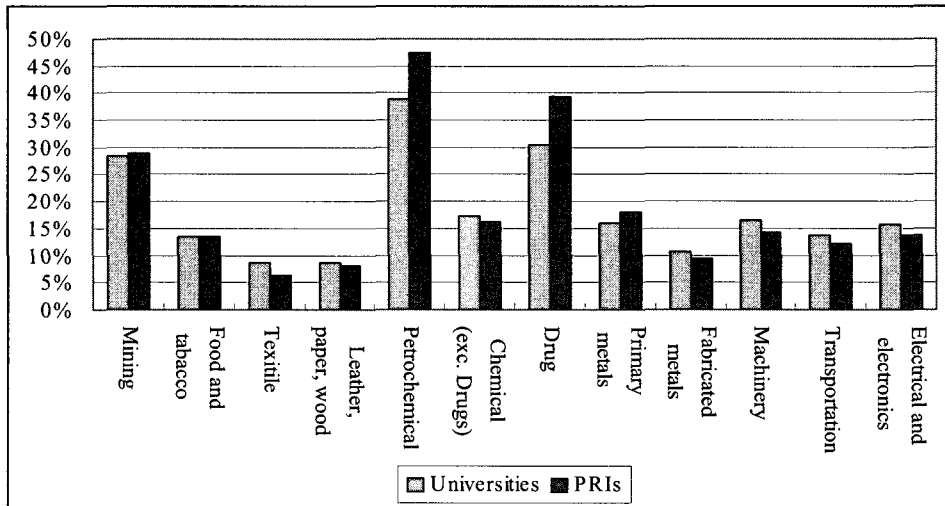


Figure 8: S&T Outsourcing to Science Sector by Industry

In general, innovation policies directed toward creating a network-based system with active interaction between innovation players appear to be working. S&T outsourcing activities at Chinese firms are becoming popular across firm ownership types. In the Chinese innovation system, PRIs, including the Chinese Academy of Science, play a relatively important role as compared to other countries. In the process of reforming public research institutes, a substantial number of spin-off companies from PRIs have been created. This is the case for universities as well. These firms will be included in the S&T Survey, and should make a significant contribution to the increasing trend of S&T outsourcing activities.

Finally, Motohashi and Xiao (2005) analyzed the determinants of each type of S&T outsourcing by using the same dataset in this section. One of major findings of this paper is that firms with S&T outsourcing to science sector have focused more on basic and applied in-house research rather than development activities. Even though various policy actions have been taken in order to change the innovation system into network-type system, Chinese manufacturing firms still possess only a low level of technological capability, if they are compared with firms in developed countries. In this sense, collaboration with PRIs and universities, which possess a relatively higher level of technology, is an effective way to achieve competitive innovation capabilities. Although the overall level of basic R&D investment is very low in China, some firms with a long-term perspective on R&D are expected to seek a long-term competitive advantage by working with PRIs and universities.

5. Patent Data Analysis: Co-invention of Science and Industry Sector

In this section, patent database is used for analyzing science industry linkage. China's patent system has started in 1985, and there are three types of patent in Chinese system, i.e., invention patent, utility models and design. Invention patent requires the highest technological contents, which can be compared with patent rights in developed countries. Therefore, in this section, invention patent data from 1985 to 2003 are used. Original data come from SIPO (State Intellectual Property Office), and the analytical database has been developed after some data cleaning works. There are about 330,000 invention patents in our dataset, and about half of them are patent applied by foreign entities. In this section, the data for patents by domestic applicants (about 130,000 patents) are used.

Figure 9 shows a trend of patent applications. A sharp increase in patent applications can be seen from 2000. This reflects growing technological capabilities in Chinese applicants. At the same time, it is expected that a protection of invention by patent right be enforced better than before due to China's accession to WTO in 2001, so that the propensity to patent application will also increase. The number of patent application decreases from 2001, but this is caused by truncation of the dataset, instead of decrease in patent application.⁴⁾

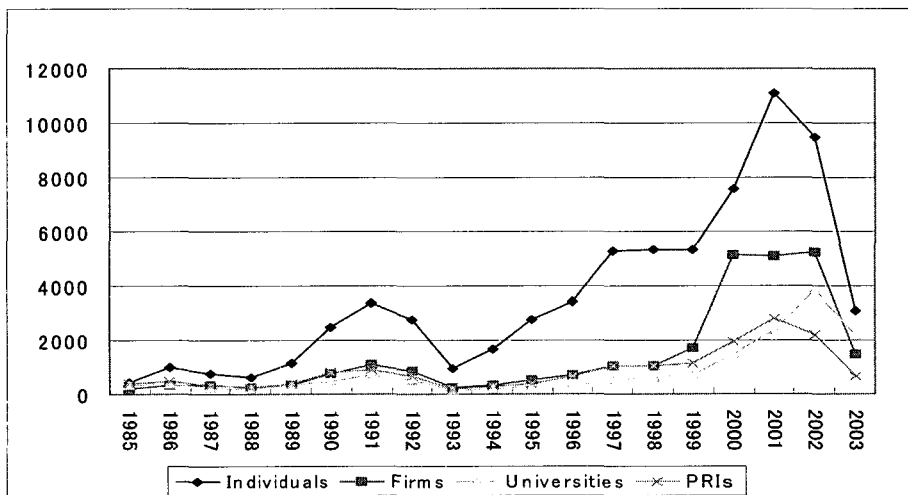


Figure 9: Number of Domestic Patent Applications by Type of Applicants

4) This dataset covers all invention patent published until 2003. Publication of applied patent takes place within 18 months after application, there are significant number of patents applied in 2002 and 2003 are not published yet, and are missed from this dataset.

Figure 10 shows the share of patent application by applicant type. In China, the share of patent application by individuals is large. Almost half of applications are made by individual, and this ratio is substantially lower in other countries.⁵⁾ However, the share of individual patent application decrease, while the share of firms and universities are increasing. The share of PRIs decreases due to the restructuring and privatization as is described in previous sections. In addition, substantial numbers of individual patent applications in an old era are those which were invented by employees of firms and universities. However, as a employer and employee contract has been more clearly articulated recently, the number of such individual patent applications decreases.

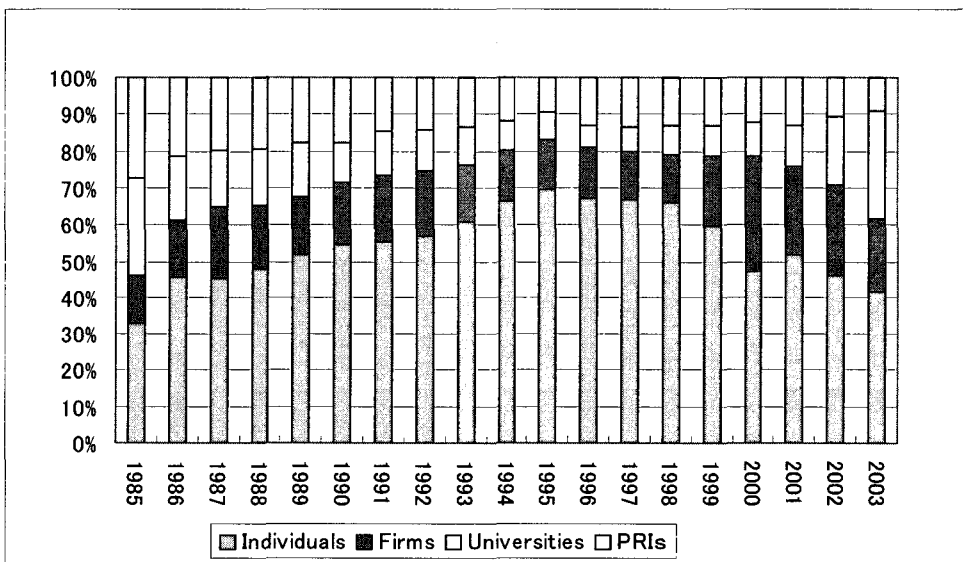


Figure 10: Share of Domestic Patent Applications by Type of Applicants

In this datasets, there are some patents with multiple applications. Here, co-invention activities of industry and science sector (universities and PRIs) are analyzed by using the patents jointly applied by both sectors. As compared to previous two sections focusing on technology diffusion from science to industry, a co-invention indicator in this section reflects direct interactions of researchers in science and industry sectors. Figure 11 presents the share of science industry

5) The shares of individual patent for Japan and United are 1.8% and 1.1%, respectively. US data comes from NBER patent database (Hall et. al, 2001), and 1.1% is the share of individual patent at registration base, because patent application information is not available in US patent system. Japanese data comes from JPO patent data, and 1.8% is the share by the number of patent application.

co-invention patents to total domestically applied patents. The share of firm and university patent jumped up in 2000 and stays at higher level as compared to previous periods. In contrast, the share of firm and PRI increased in the late 1990's, but it has dropped sharply since 1999.

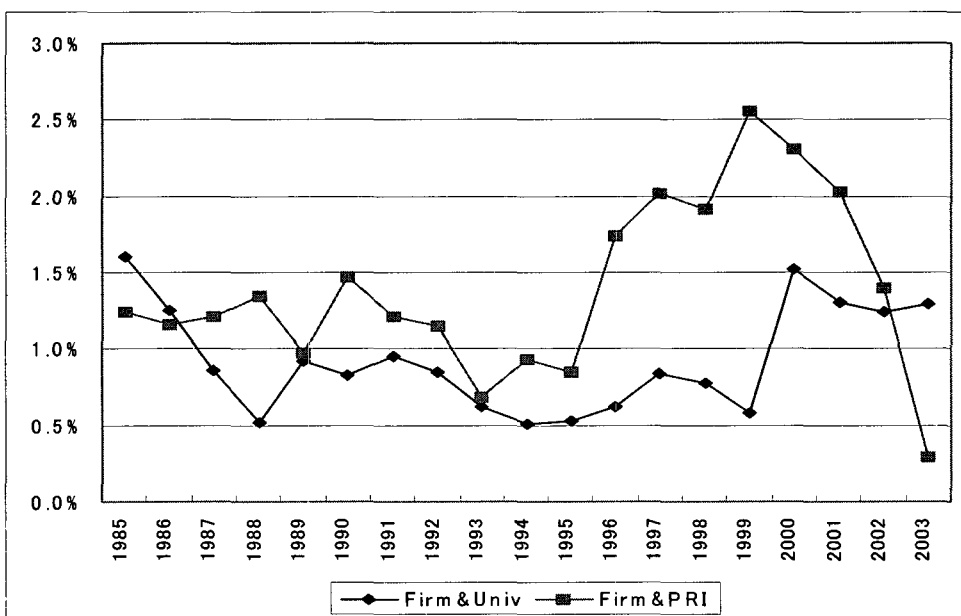


Figure 11: Share of Co-invention Patents of Industry and Science Sectors

In order to look into more detail, Figure 12 and Figure 13 show the same indicator by technology field of patent for university and PRI, respectively. As for firm and university patents, the growing share of co-invention patent comes from all technology fields, but it is found that a jump in 2000's can be explained by electronics and ICT patents. In this sense, research activities at universities become more important to innovation activities at Chinese IT companies, which are gaining technological capabilities rapidly. As for firm and PRI patents, it is found that aggregated trend is driven by chemical patents. Most of co-inventions at chemical patents are those by Chinese Academy of Science and big state owned petrochemical enterprises. However, the number of such patents decreases sharply, which reflects privatization of research institutes belonging to Chinese Academy of Science.

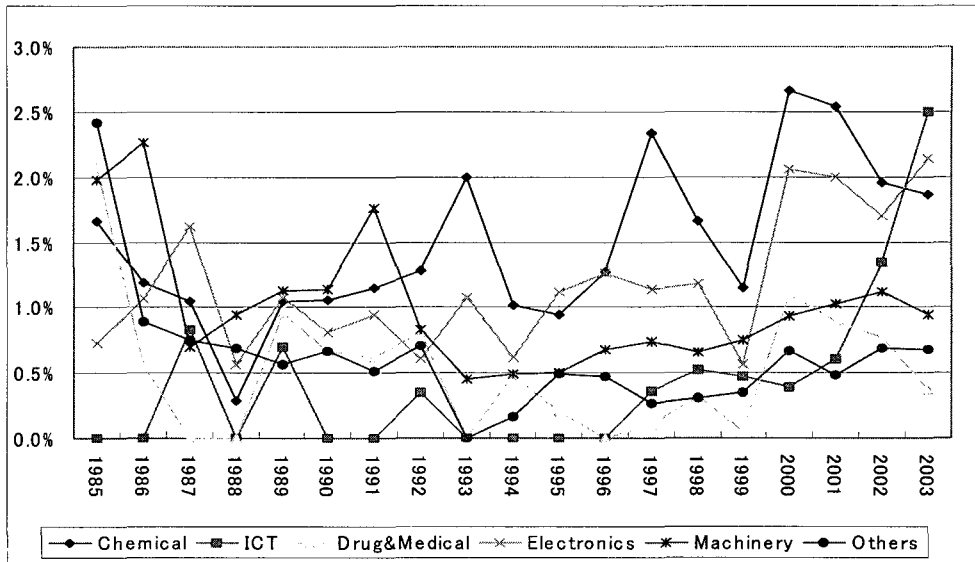


Figure 12: Share of Co-invention Patents with Universities by Technology

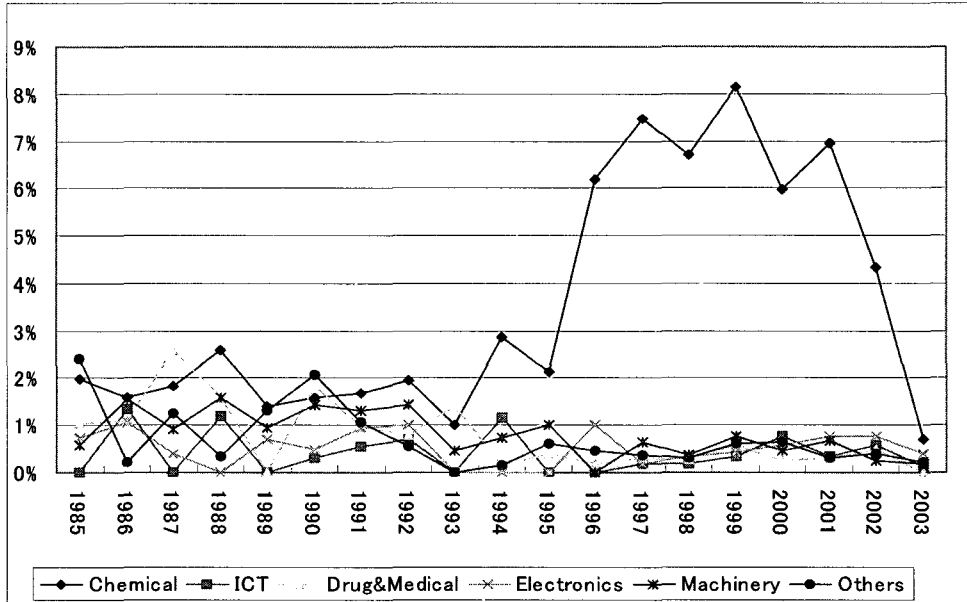


Figure 13: Share of Co-invention Patents with PRIs by Technology

6. Conclusion

In this paper, innovation policies for systems reform in China since the middle 80's are surveyed and its impacts on science industry linkage activities are investigated by looking into (1) technology market, (2) S&T outsourcing activities of firms and (3) co-invention patents by applicants in firms, universities and PRIs. All of these findings suggest that the role of science sector in China's economic development process has become larger, and double skin problem in China's innovation system has been gradually solved by a number of policy actions to facilitate science industry linkages.

However, institutional reforms toward market based innovation system are still in progress. For example, substantial regulations and state interventions still remain in operation of technology market, although its size is growing rapidly. There is evidence suggesting productivity impact of technology market in regional economy decreases over time (Men and Motohashi, 2005). In order to achieve efficient market transaction of technology in the market, further regulatory reforms are needed in a way to operate technology market. Strengthening IPR system is also important to facilitate technology market transactions. After China's accession to WTO in 2001, several actions to improve IPR system and enforcement mechanism have been taken. It is important to keep this effort for China to further develop in knowledge based economy.

In terms of science industry linkages by S&T outsourcing, the share of firms collaborating with science sector increases, but the level of such activities is still lower than that in developed countries. For example, more than half of all Japanese R&D firms are conducting joint research projects with universities (Motohashi, 2005b). The relative technological capability of firms as compared to PRIs and universities is still significantly lower in China than in Japan, and except for top tier companies, most of Chinese firms have not enough absorptive capacity to collaborate with the science sector. In addition to promoting a policy of science and industry linkages, it is important to consider improving the technology level of domestic companies for them to achieve effective collaboration with universities and PRIs.

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