National technology transfer centers: an efficient policy instrument to capitalize university research findings?

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Abstract: This paper will examine whether national technology transfer centers (NTTCs) function as an effective policy instrument in promoting the commercialization of university research findings. On the basis of 7 sampled universities, we place our research focus on the role of NTTCs, the performance of NTTCs and the determinants of effectiveness of NTTCs. Academic publications, patents, technology transfer income and revenu generated by spinoffs are used as indicators to assess the effectiveness of NTTCs. Our qualitative and quantitative study provides evidence that NTTCs are not an effective policy tool in accelerating the commercialization of university inventions. Universities without NTTCs can achieve the same or even greater success than universities with NTTCs. We suggest that universities should provide an attractive reward system and automony to NTTCs for stimulating their efforts in marketing patented technology.

Introduction

Following up governmental policies toward accelerating the commercialization of university science & technology (S&T) findings in the 1990s, many Chinese universities wich previously had no university technology transfer offices began to establish UTTOs or similar organizations to manage academic technology transfer activities. In parallel with a UTTO, an IPR office was built to manage university IP issues. Considering that the separate division of labor between UTTO and IPR office hampers the speed of capitalizing university inventions (Zhao, 2005), in 2001 the Ministry of Education and the former State Economic and Trade Commission authorized 6 universities to establish national technology transfer centers (NTTCs) as an experimental institutional innovation for coordinating university S&T resources and accelerating technology transfer. The function of NTTCs embraces the services formerly provided by UTTOs and IPR offices. They are distributed in 6 elite universities: Tsinghua University, Shanghai Jiaotong University, China East Polytechnic University, Huazhong S&T University, Xi'an Jiaotong University and Sichuan University. Our analytical perspectives in this paper are placed to assess whether NTTCs is an efficient policy intrument to capitalize university research findings.

Relevant literature review

Previous research on UTTOs can be classified into three categories:

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

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

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

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

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

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

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

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

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

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

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

Thursby and Kemp (1998) use data envelopment analysis (DEA) combined with regression analysis to examine the productivity of university commercial activities as well as changes in that productivity. They find that universities are today more commercially productive than they were in the recent past and private universities tend to be more efficient in commercialization than public ones, while universities with medical schools are less likely to be efficient. Thursby and Kemp's continuous research on the same issue in 2002 confirms their 1998 findings, but adds new results to the former research, namely that UTTOs efficiency varies not only according to the capabilities of the faculty and staff, but also according to university preferences in the use of their resources. In their model, they use sponsored research agreements, license agreements,

royalty payments, invention disclosures and patent applications as output and federal support, the number of professionals employed in UTTOs, the number of faculty in each university, the weighted average quality rating where the weights are faculty size, whether a university is private and has a medical school as input.

Siegel *et al*. (2003a) explore the quantitative research measure and use the stochastic frontier estimation (SFE) tool to assess relative productivity in UTTOs together with 55 interviews of entrepreneurs, scientists and administrators. They conclude that the productivity of UTTOs depend on organizational practices, namely faculty reward system, TTO staffing/compensation practices, and cultural barriers between universities and firms. They specified that the outputs are the number of licensing agreements and licensing revenues and the inputs are invention disclosures, employees in the TTO, and legal expenditure.

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

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

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

For the third research category of determinants of success of UTTOs, most studies concentrate on the internal organizational structure of UTTOs. Siegel *et al.* (2003a) reveal the palpable differences in the motives, incentives, and organizational cultures of faculty/inventor - UTTO – industry. They believe that reward system for faculty involvement in university-industry technology transfer, compensation and staffing

practices in UTTOs, and actions taken by administrators to extirpate information and cultural barriers between universities and firms determine the successful performance of UTTOs.

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

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

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

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

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

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

revenu generated by spinoffs as indicators are used as indicators to assess the effectiveness of NTTCs.

Research methodology

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

In April 2006, 6 questionnaires were sent respectively to universities with NTTCs (Tsinghua University, Shanghai Jiaotong University, China East Polytechnic University, Huazhong S&T University, Xi'an Jiaotong University and Sichuan University) and 39 questionnaires to other universities without NTTCs. We got two feedbacks from Sichuan University and Huazhong S&T University with NTTCs, 6 feedbacks from other universities without NTTC. In order to collect information about the other 4 universities with NTTCs, we telephoned the officers of NTTCs in China East Polytechnic University, Xi'an Jiaotong University and Shanghai Jiaotong University. Concerning Tsinghua University, we had interviews with a director of NTTC in August 2006. Further, we use Zhejiang University which has no NTTC to compare with the 6 sampled universities with NTTCs. The rationale behind sampling Zhejiang University as a single case is because it represents the critical and revelatory case in testing the necessity to create NTTCs. We contacted the officer of the S&T division in Zhejiang University by telephone contacts and open-minded interviews. Finally, we got the feedback from all sampled universities either by questionnaire or by telephone contacts and open-ended interviews. Our information access to all universities with NTTCs helped us build the complete units of qualitative analysis.

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

The role of NTTCs

Like UTTOs in western universities, NTTCs act as an intermediary between university and industry (Jensen and Thursby, 2001; Jensen *et al.*, 2003) to manage

university intellectual property and technology transfer activities. However, NTTCs and UTTOs function in a different way to attain the objective.

In UK and USA universities, UTTO personnel typically devote substantial effort to encouraging faculty members to disclose inventions (Siegel *et al*., 2003b; Thursby and Kemp, 2002, G. Thursby and Thursby 2002). In the Chinese universities, NTTC staff does not spend much time in persuading researchers to disclose inventions. On one side, professor are motivated to disclose inventions. On the other side, many universities pay much attention to the real application of academic output rather than the identification of IPR arising from university research findings. When NTTCs receive the disclosure of inventions, they assess whether the inventions are worth of filing for patent applications. If the invention is suitable for patenting, the NTTC will enter the patenting procedure with the cooperation of the inventors.

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

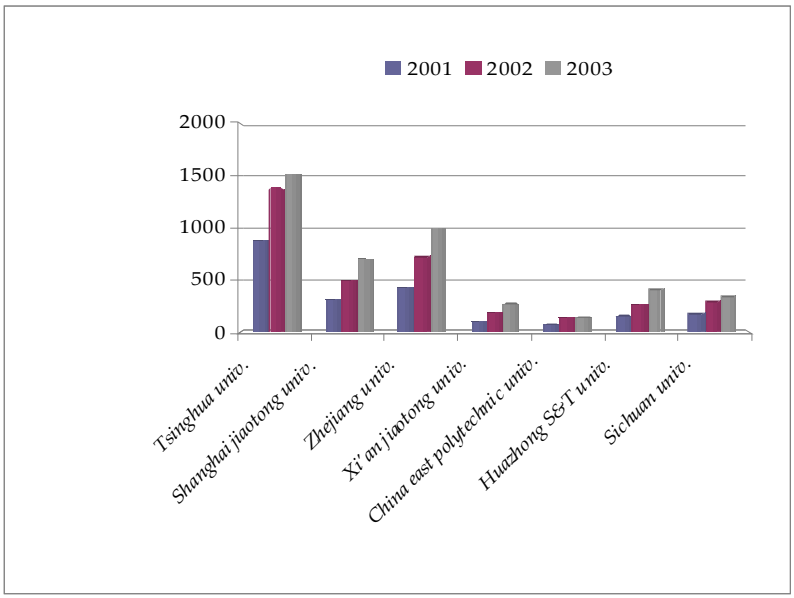
Apart from the exploitation of university research findings, the Tsinghua NTTC prioritizes the introducation and diffusion of foreign technology. The 5 other NTTCs focus more on marketing university inventions, taking the forms of launching cooperative research projects on common technology and creating joint research centers with industry. For example, Shanghai Jiaotong NTTC concentrates on the creation of joint R&D centers with firms and the incubation of innovative academic projects. China East Ploytechnic NTTC prefers to cooperate with LMEs and to develop specific common technology and incubate laboratory inventions. Huazhong S&T NTTC centers its activities on the cooperation with LMEs, the development and diffusion of regional common technology as well as the incubation of selected university research projects. Xi'an Jiaotong NTTC puts emphasis on the development and diffusion of common technology and the incubation of high-tech start-ups. Although the prioritized activities of each NTTC is more or less different, they have the same objective as commercializing university inventions and contributing to the social economic growth.

Assessment of the effectiveness of NTTCs

Since the role of NTTCs is to promote university commercial activities, we use published papers, patenting, licensing revenues and renenues generated by university-run technology firms as indicators to assess the productivity of NTTCs. Published academic papers refer to the papers collected by the Science Citation Index (SCI). We assume that the existence of NTTCs promotes the information exchange between university researchers and firms. The interactions between industry and NTTCs may help researchers get new ideas to produce more qualified academic papers. And the growth of university patentability is supposed to bind with the performance of NTTCs, whose

responsibility is to manage IP activities and exploit research findings. Figure 1.1 below shows that all the sampled universities have increased the published papers collected by SCI.

Figure 1.1: University published papers collected by SCI (2001-2003)



Source: data collected from www.cutech.edu.cn

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

With respect to patenting activities, the sampled universities have made progress (see Table 1.1). The number of both patent applications and issued patents obviously increased, especially after 2002. Between 2002 and 2003, except for Xi'an Jiaotong University and China East Polytechnic University, the number of issued patents doubled in the other sampled universities. Tsinghua University remained the leader with respect to patenting activities from 2001 to 2005, Zhejiang University occupied the 2nd place, and Shanghai Jiaotong University the 3rd one.

Table 1.1: Number of university patent applications and issued patents in SIPO (2001-2005), unit: piece

Name of univ.	2001		2002		2003		2004		2005	
	A.*	G.*	A.	G.	A.	G.	A.	G.	A.	G.
Tsinghua unvi.	380	123	526	136	767	376	762	527	930	527
Shanghai jiaotong univ.	188	34	285	41	730	156	829	332	1093	438

Zhejiang univ.	214	61	353	80	660	211	875	321	1244	534
Xi'an jiaotong univ.	56	29	94	37	189	37	183	131	259	123
China east polytechnic univ.	66	24	64	23	155	44	150	79	198	71
Huazhong S&T univ.	86	23	102	32	236	82	221	136	180	134
Sichuan univ.	52	10	111	13	182	57	203	111	237	124

Source: S&T Development Center of Ministry of Education
A*: represents the number of patent applications.
G.*: represents the number of granted patents.

Do NTTCs contribute to the growth of published papers and university patenting expansion? We use correlation analysis (see Table 1.2) to assess the effectiveness of NTTCs. The age of NTTCs and the number of NTTC staff are regarded as the inputs of NTTCs, and the patent applications and issued patents are viewed as the outputs of NTTCs.

Table 1.2: Correlation coefficients

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

Table 1.2 shows that the number of NTTC staff has a more important correlation with published papers, patentability and R&D expenditure than the age of NTTCs. Additionally, R&D expenditure has a more significant influence on published papers and patentability than the number of NTTCs. And publish papers are highly correlated with university patentability.

Another indicator to assess the productivity of NTTCs is the amount of licensing income (Anderson *et al.,* 2007). Licensing has traditionally been the most efficient mode of university technology transfer in western countries (Chapple *et al.*, 2005; Siegel *et al*., 2003b). However, patent licensing only accounts for a very small part of all technology contracts in Chinese universities. Technology development contracts are the most frequent transaction mode in technology markets, which embed joint research projects between industry and university (Xue, 2006). The data we collected about patent licensing is limited to a very short period of 2001-2002 (see Table 1.3). Thus, we use the income of university-affiliated technology firms as a complementary indicator to analyze the productivity of NTTCs (see Figure 1.2). Because, fostering academic technology-

based firms is identified as the role of NTTCs.

Table 1.3: Comparison of university patent transactions in 2001-2002

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

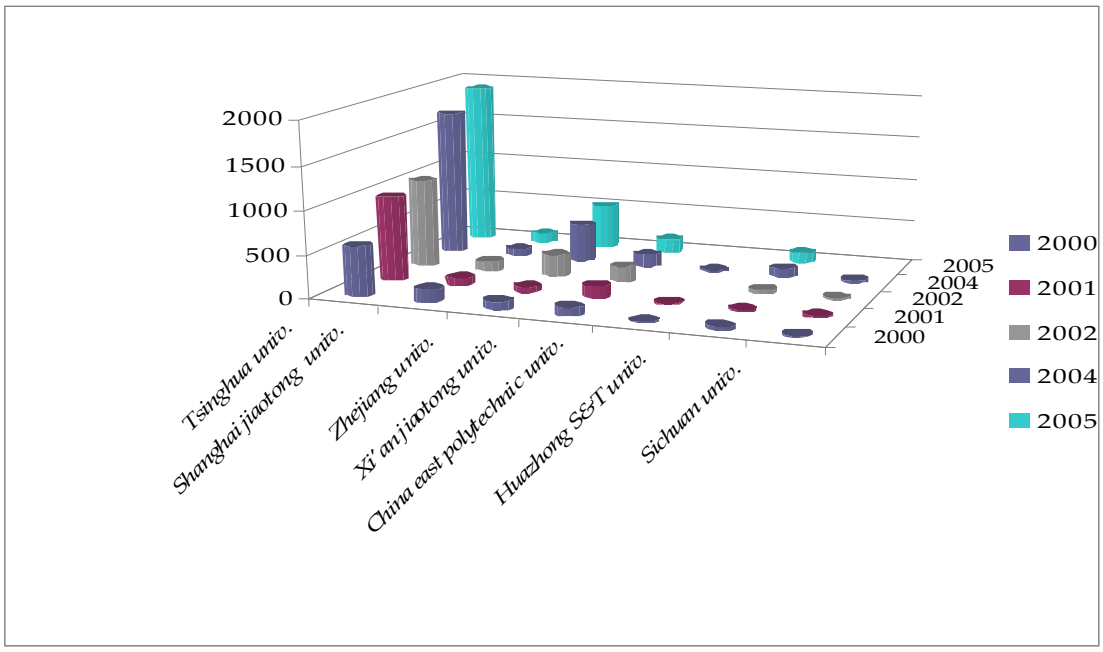
Source: data collected from www.cutt.edu.cn/paiming.
Note: 1 EURO = 10 RMB

Table 1.3 illustrates the progress achieved by NTTCs in Xi'an Jiaotong University and Sichuan University. The number of license agreements and license revenues both increased. Huazhong S&T University shew a little special characteristic. Although its number of license agreements and license income decreased from 2001 to 2002, the revenue per agreement increased from 90 710 € to 111 400 €, much higher than the average license income received by the other sampled universities. It proves that a few license agreements can bring a large sum of revenue. Why could not the existence of NTTCs improve the patent licensing activities in all the sampled universities? The question is addressed by two NTTC officers as follows:

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

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

Figure 1.2: Comparison of the incomes generated by spin-offs of the 6 universities (money unit: million €)



Source: Science and Technology Develop Center of the Ministry of Education.
Note: 1 EURO = 10 RMB
Spin-offs here refer to university-run technology firms.

Figure 1.2 shows that Tsinghua University is the unique one whose spinoffs maintain the growing incomes, whereas other 5 universities fail to sustain the revenues of their spinoffs upward. For example, the spinoffs of Sichuan University got less income in 2002 as compared to 2001, so did the spinoffs of Shanghai Jiaotong University. It seems that NTTCs do not necessarily bring more incomes to university spinoffs. But the revenues generated by university spinoffs were much more than university's licencse incomes.

Although our results arising from the correlation coefficients indicate that NTTCs have a significantly positive effect on the expansion of university patenting and growing published papers, the uncertain income of university spinoffs and license revenues show the inefficiency of NTTCs. From this point of view, we can say that the role of NTTCs to improve university research outcomes and the commercialization of S&T findings is not conclusive.

To further test the effectiveness of NTTCs, we take a close look at Zhejiang University which has no NTTCs. Table 1.1, Table 1.3, Figure 1.1 and Figure 1.2 indicate that Zhejiang University has achieved greater success in publications and marketing university findings than the other 5 universities which have NTTCs.

Behind Tsinghua University, Zhejiang University is ahead of the other 5 universities in terms of published papers, patent licensing revenues and incomes generated by university spinoffs. Zhejiang University has largely explored patenting activities in recent years. In 2005, its number of patent applications and issued patents both surpassed that of Tsinghua University. An officer in charge of technology transfer activities in Zhejiang

University explains the reasons why his university can achieve such remarkable success without NTTC as follows:

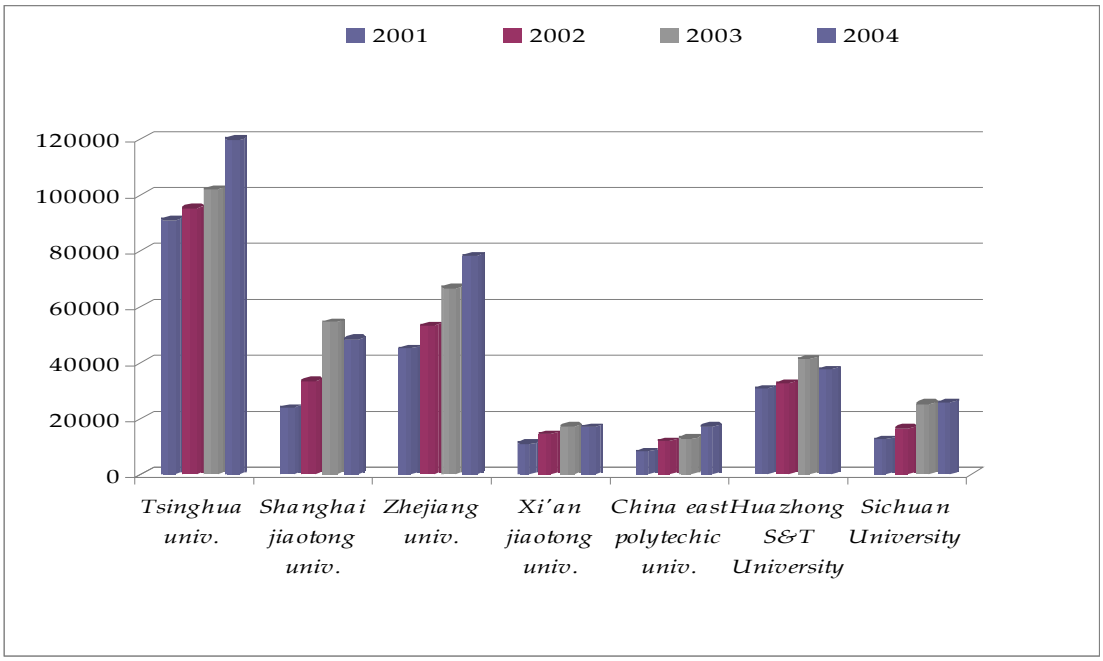
> "Our university has no NTTC but we have a similar office, called S&T development and transfer office, since the beginning of the 1980s. Now the office has staffed 15 persons who manage over 3000 technology contracts. Continuously increasing R&D expenditure, more cooperative research projects with enterprises,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

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

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

The reasons which explain the greater success of Beijing, Fudan and Tianjin universities without NTTCs in commercial activities than some universities with NTTCs are similar to those of Zhejiang University. These universities have organizations similar to NTTCs to manage IP issues and technology transfer activities. And they have succeeded in nurturing innovation, IPR management and entrepreneurship. Moreover, the R&D expenditures of these universities were higher than those of Xi'an Jiaotong University, China East Polytechnic University and Sichuan University from 2001 to 2004 (see Figure 1.3). As we discussed before, R&D expenditure has a significant influence on publications and university patenting activities. More patenting probably creates more opportunities for universities to conduct commercial activities.

Figure 1.3: R&D expenditure in selected Chinese universities (2001-2004), money unit: million €



Source: Bureau of Finance of the Ministry of Education.

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

Determinants of success of NTTCs

Based on the questionnaire, open-minded interviews, telephone contacts and published documents, some determinants of success of NTTCs are consistent with previous research findings: the size of NTTCs and NTTC staff capability (Thursby *et al*., 2001; Thursby and Kemp, 2002; Siegel *et al*., 2003a; Chapple *et al.*, 2005; Anderson *et al*., 2007). Tsinghua NTTC is the biggest one staffed with 40 people, functioning more professionally in comparison with 5 other NTTCs. These advantages help Tsinghua

NTTC perform better than others.

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

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

Conclusion

NTTCs have been operating for 7 years. Our study provides evidence that NTTCs are not an effective policy tool in accelerating the commercialization of university inventions. Universities without NTTCs can achieve the same or even greater success than universities with NTTCs in terms of the commercialization of S&T findings. Zhejiang University provides us a sound proof. But NTTCs play an important role in university patentability and the creation of spin-offs more than in licensing activities. The number of NTTC staff has a significantly positive impact on the rising university patenting. Besides, other factors are found to have influenced the outputs of NTTCs positively: R&D expenditure, rising awareness of IPR management, staffing capabilities, university institutional inventive systems, funding of NTTCs, university-industry linkage and performance mode of NTTCs.

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

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