University Technology Transfer in China: How Effective are National Centers?

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Abstract:

University-industry technology transfer is growing at a rapid rate in China, involving both multi-national and domestic companies. This chapter describes unique characteristics of Chinese National Technology Transfer Centers (NTTCs) and examines whether they can function as an effective policy instrument in promoting the commercialization of university research findings. Our qualitative and

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† Mingfang Li passed away on April 12, 2012. He was an outstanding teacher, scholar, and colleague who presented lectures and papers throughout the world and worked tirelessly to support and encourage the work and success of others. This paper is dedicated to him for bringing together the other two co-authors as well as making major contributions to an earlier version.
quantitative study finds that NTTCs are not by themselves an effective policy tool in accelerating the commercialization of university inventions. We found that universities without NTTCs can achieve the same or even greater success than those with NTTCs. We suggest that Chinese universities should mimic the Western approach by providing an attractive reward system and autonomy to technology management programs that stimulate their efforts in marketing patented technology.

**Introduction to and Background of University Technology Transfer Offices**

University technology transfer is an increasingly important source of regional economic development and revenue for universities. A university technology transfer office (UTTO) plays a central and integral role in the transference of knowledge and technology to companies (Resende et al., 2013). Universities set up dual organizational structures including the creation of a UTTO and the introduction of different career paths for those involved in technology commercialization and for the more traditional academic missions of research and teaching (Markman, Siegel, and Wright, 2008). Different modes of research and technology commercialization (e.g., incubators, research parks, academic spin-offs, open science, etc.) require their own way of organizing (Markman, et al. 2008). Caldera and Debande (2010) investigated the technology transfer activities of 52 Spanish universities over 2001-2005 and found that those with large and experienced UTTOs generate higher volumes of contract research, but the characteristics appear to matter less for university performance in terms of licensing and creation of spin-offs.
An efficient technology transfer strategy requires designing the right incentives and optimally sharing the risk between parties involved in determining the value of the research.

The Cabral-Dahab paradigm (Cabral, 1998) suggests that successful university-industry science parks must possess access to qualified personnel, markets and the capability to provide marketing, managerial expertise, selection of firms and protection of trade secrets, a clear identity, a highly powerful and visible manager, a considerable number of consultancy firms, government backing, and managers capable of finding financial resources. Friedman and Silberman (2003) found the determinants of university technology transfer to be greater rewards for faculty involvement in technology transfer, location of the university in a region with a concentration of high technology firms, a clear university mission in support of technology transfer, and the experience of the university’s technology transfer office.

In this chapter, we describe and examine whether Chinese National Technology Transfer Centers (NTTCs) are an effective policy instrument to promote the commercialization of university research findings. We examine China since it has a long tradition of indigenous innovation and has embraced foreign technology for decades, helping it become the world’s largest trader with more than $4 trillion in imported plus exported goods and the second largest economy. While in earlier stages of Chinese economic reform the country – dubbed as the world’s low-cost factory – relied upon inexpensive manufacturing, further development requires a path that utilizes creativity and innovation to advance its
economy. Thus, indigenous innovation becomes imperative if China is to fulfill the aims of the Ministry of Science and Technology in new discoveries in biotechnology, IT, energy, and other technologies by 2020 and become “the world’s leading science power” by 2050 (“China aims to be one of science powers in world,” 2006).

To achieve these targets, China has embraced university-industry technology transfer, with an increased urgency for scholars, policy makers, and managers to find effective ways to do so. For these reasons, we examined technology transfer efforts at seven Chinese universities, their performance, and the determinants of their effectiveness based on academic publications, patents, technology transfer income, and revenue generated by spinoffs. This section examines broadly the purpose and role of UTTOs, how their performance is assessed, and determinants of their success. The next section utilizes these insights to examine how Chinese NTTCs have performed thus far.

**Purpose and Role of UTTOs**

The role of UTTOs is basically as “a license agent” that coordinates the interactions between university, faculty/inventor, and industry to successfully license university intellectual property. For instance, Jensen and Thursby (2001) stress that University Technology Transfer Offices (UTTOs) aim at striking a balance between university administrator objectives of maximizing license revenues and faculty objectives of pursuing sponsored research. To coordinate these different purposes, they suggest that the inventor should share the royalties and equity with the university in order to proactively
disclose the invention and cooperate in future developments after the license agreement. Jensen, Thursby, and Thursby (2003) further explored this research and concluded that the role of a UTTO is to be a dual agent representing both the university and the inventor.

Markman, Phan, Balkin, and Gianiodis (2005) found that UTTOs underemphasized entrepreneurship in business incubators and new venture formation. Lowe (2006) found that when UTTOs require royalties from inventor-founded firms, inventors are worse off due to limited royalty payments. 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) suggested that UTTOs should practice what they preach about making innovation happen, so in addition to addressing the university’s needs of technology commercialization they should also treat nurturing of innovation and entrepreneurship as their core mission. Stadler, Castrillo, and Veugelers (2007) demonstrated 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 their projects, it raises the buyer’s beliefs on expected quality and results in fewer but more valuable innovations being sold at higher prices.

Performance Assessment of UTTOs

Quantitative analyses to evaluate the performance of UTTOs are based on a production function framework which uses the inputs and outputs to measure their efficiency, while qualitative studies are
based on university surveys. For instance, Trune and Goslin (1998) examined the effectiveness of UTTOs from a financial profit/loss analysis perspective. Their results show that about half of UTTOs are profitable and local communities benefit from their contribution to economic development.

Thursby and Kemp (1998) found that universities are more commercially productive than they were in the recent past. Private universities tend to be more efficient in commercialization than public ones while universities with medical schools are less likely to be efficient because medical schools receive substantial funding from the federal government and they conduct several clinical trials which reduce their commercialization efficiency. However, faculty-inventors in the biotechnology sciences tend to be more oriented toward commercialization than those in the physical sciences due to its more applied nature and a seller’s market for biological science.

Thursby and Kemp (2002) used sponsored research agreements, license agreements, royalty payments, invention disclosures, and patent applications as output; input consisted of 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, and whether a university is private and has a medical school. Siegel, Waldman, and Link (2003a) specified outputs as the number of licensing agreements and licensing revenues, and inputs as invention disclosures, employees in the UTTO, and legal expenditure. They concluded that the productivity of UTTOs depended on such organizational practices
as the faculty reward system, TTO staffing/compensation practices, and cultural barriers between universities and firms.

Chapple et al. (2005) found that having a medical school has a negative effect on UTTO efficiency and suggested reconfiguring UTTOs and upgrading its staff’s competences to improve their efficiency. Similarly, Anderson, Daim, and Lavoir (2007) had the same conclusions 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 adding other factors to analyze the productivity of UTTOs, such as the number of people working in the UTTOs, the impact of different IP policies, and faculty incentive systems.

**Determinants of Success of UTTOs**

Most studies reveal that the success of UTTOs may be attributed to their organizational structure, motives, incentives, organizational culture, and university support. For instance, Siegel et al. (2003a) reveal the palpable differences in the motives, incentives, and organizational cultures of the faculty/inventor-UTTO-industry triad. They believe that the successful performance of UTTOs is based on the 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. Friedman and Silberman (2003) support Siegel et al.’s (2003a) results but broaden them to other factors that have significant positive effects on UTTO output.
(measured by licenses executed) such as the age of UTTOs, university location, and mission to support technological transfer.

Link and Siegel (2005) showed 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 proposed that university administrators who wish to foster university-industry technology transfer should be mindful of the importance of financial incentives. Chapple et al. (2005) found older UTTOs at UK universities functioned less efficiently due to an absence of learning effects, while larger UTTOs suffered from the problem of being generalists rather than specialists. They stress the need to recruit and train technology licensing officers with the appropriate skills and capabilities.

Other studies, however, offer different insights. For instance, Thursby, Kemp, Jensen, and Thursby (2001) illustrated that larger UTTOs (measured by the number of staff) were successful, and Markman, Gianiodis, Phan, and Balkin (2005) showed 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) found that the age of a UTTO and the quality of its engineering faculty have significantly positive influences on licensing activities. These studies highlight the importance of the organizational structure and an attractive incentive system on the successful performance of UTTOs.
Chinese National Technology Transfer Centers

The impetus of Chinese NTTC formation is similar to that of Western UTTOs: to promote technology transfer from university to industry. However, the roles, performance, and effectiveness of NTTCs exhibit unique Chinese characteristics. Table 1 provides a summary of the comparison of the two technology transfer approaches along purpose and role, performance assessment, and success determinants. We adopt as guidance the extant research findings (Chapple et al., 2005; Friedman & Silberman, 2003; Jensen et al., 2003; Siegel et al., 2003a; Thursby & Kemp, 2002) to assess whether Chinese NTTCs function as an effective tool in accelerating the commercialization of university research findings. Our analytical perspectives will focus on the role, performance, and success determinants of NTTCs. We use these identical criteria to assess whether Chinese NTTCs function as an effective policy tool in accelerating the commercialization of university research findings. Academic publications, patents, technology transfer income, and revenue generated by spinoffs are used as indicators to assess the effectiveness of NTTCs.

The research methodology used in this section is based on case studies. We focus on six universities which were the first batch to be allowed to set up a NTTC in China: East China University of Science and Technology, Huazhong Science and Technology University, Shanghai Jiaotong University, Sichuan University, Tsinghua University, and Xi’an Jiaotong University. The analysis of these six universities
provides a general picture of NTTC as an effective public policy tool in promoting the commercialization of university inventions in China. In addition, we use Zhejiang University which does not have a NTTC to compare research, patenting, and commercial activities.

The rationale behind choosing Zhejiang University as a single case is that it ranks as one of the top five Chinese universities (comparable with Tsinghua University and Shanghai Jiaotong University) and is well-known for its technology management programs. While we recognize that the exception might not prove the rule, we use it as an exemplar that demonstrates what is possible under the correct circumstances even in the absence of an NTTC. While other universities might not be able to replicate all of the factors that explain an unusually high level of technology transfer activity at Zhejiang University, we believe it is nonetheless useful to use it as a baseline of what is possible. For those unfamiliar with Zhejiang University, it is located in the city of Hangzhou, an economically dynamic coastal region approximately 125 miles southwest of Shanghai. Over 29,000 SMEs of more than 5 million RMB in sales and 2,288 high-tech firms reside in Zhejiang Province (the number of firms cited is from Xu, 2010). A developed business environment, strong local government-sponsored R&D consortia, and dynamic private firms combine for the fruitful cooperation between Zhejiang University and local industry.

Among the oldest Chinese universities (founded in 1897 by Hangzhou’s pro-Western mayor) and largest (with 46,000 students in 37 colleges and schools spread across 5 campuses), its nearly 7 million volume library collection is one of China’s largest and its 3,300 standing faculty boast the highest rate of
research papers published per faculty member of any of the top Chinese universities. Its leading position in China in publications and patents contributes to Zhejiang University’s reputation for its diligent study and research, especially in science and technological innovation. For instance, Essential Science Indicator (ESI) ranks Zhejiang University among the top 1% in 15 disciplines, with 4 listed in the top 100 of the world’s academic institutions (“Introduction to Zhejiang University”). It aspires to become an influential source of innovation with its very strong reputation among both academics and graduate employers. Because of these, The Times Higher Education considers it as one of the top universities in the world (“World University Rankings”).

We pursued our hybrid (both qualitative and quantitative) research project following advocated methodologies (e.g., Yin, 1994) to enhance our conclusion validity. We examined multiple sources of information to triangulate, including annual official surveys of university patents and spin-off revenues. Furthermore, we examined published documents and conducted our own surveys as well as personal and telephone interviews of managers working in NTTCs and Science and Technology Divisions of various universities in China.

**Purpose and Role of NTTCs**

Like UTTOs in Western universities, NTTCs act as an intermediary between university and industry to manage university intellectual property and technology transfer activities (Jensen & Thursby, 2001; Jensen *et al.*, 2003). However, NTTCs and UTTOs function differently to attain their respective
objectives. In UK and U.S. universities, UTTO personnel typically devote a substantial amount of efforts to encouraging faculty members to disclose inventions (Siegel, Waldman, Atwater, & Link, 2003b; Thursby & Kemp, 2002; Thursby & Thursby, 2002). In Chinese universities, NTTC staff do not spend much time in persuading researchers to disclose inventions. On the one hand, professors are motivated to disclose inventions because in some universities, patents have been used as one key criterion of research workload. On the other hand, many universities concentrate on the practical application of academic output rather than identifying intellectual property rights that arise from university research findings. When NTTCs receive the disclosure of inventions, they assess whether they are worth filing for patent applications and enter the patenting procedure with the cooperation of the inventors only if the invention is deemed suitable for patenting.

Additionally, UTTOs in Western universities diffuse inventions mainly 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 is in part due to the stronger absorptive capacity of Western firms compared to Chinese firms. Large and medium-sized enterprises (LMEs) are the main providers of R&D expenditure in China, sharing 66% of total business expenditure for R&D in 2000 and increased to 75% in 2005; however, only 24.1% of total LMEs in China conducted in-house innovation activities (National Bureau of
Statistics of China\(^\dagger\). The increased R&D expenditure may have been used to outsource foreign or domestic technology or both. Large firms tend to sign joint research contracts with academic institutions whereas small firms tend to ask for consulting service from universities.

Apart from capitalizing on its own university research findings, the Tsinghua NTTC prioritizes the introduction and diffusion of foreign technology. The five other NTTCs focus more on marketing university inventions, usually by launching cooperative research projects on common technology and creating joint research centers with industry. For example, Shanghai Jiaotong NTTC concentrates on creating joint R&D centers with firms and the incubation of innovative academic projects. East China University of Science and Technology NTTC prefers to cooperate with LMEs and develop specific common technology and incubate laboratory inventions. Huazhong Science and Technology NTTC focuses 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 emphasizes the development and diffusion of common technology and the incubation of high-technology start-ups. Although the prioritized activities of each NTTC are more or less different, they have the same objective to commercialize university inventions.

Performance Assessment of NTTCs

As the role of NTTCs is to promote university commercial activities, we use published papers, patenting, licensing revenues, and revenues generated by university-run technology firms as indicators to assess the effectiveness of NTTCs. We avoid using the terminologies of productivity and efficiency because our paper focuses on the analysis of how NTTCs affect researchers, staff, and the commercialization of academic output. The effectiveness of NTTC meets our requirements. Productivity refers to a ratio of output to input and efficiency is equivalent to productivity. Adopting Thursby and Kemp’s (1998) explanation, an efficient NTTC could produce greater output compared to another NTTC with similar levels of inputs. Alternatively, it is one that, when compared to other NTTCs, could produce a similar level of output with fewer inputs. Since our analytical focus compares NTTC outputs rather than that productivity, we prefer the usage of effectiveness instead of productivity/efficiency. In our assessment framework, 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 shows that all the sampled universities have increased the published papers collected by SCI.
With respect to patenting activities, the sampled universities have made significant progress (see Table 2). The number of both patent applications and issued patents obviously increased, especially after 2002. Between 2002 and 2003, except for East China University of Science and Technology and Xi’an Jiaotong University, the number of issued patents doubled in the other NTTC universities. Tsinghua University remained the leader with respect to patenting activities from 2001 to 2005, Zhejiang University occupied the second place, and Shanghai Jiaotong University was third.

We use correlation analysis (see Table 3) to assess the effectiveness of NTTCs in contributing to the growth of published papers and university patenting expansion. In spite of the sample of only six NTTCs, many of these variables show significant correlations. Nonetheless, we are cautious in making sweeping generalizations. The age of NTTCs, number of NTTC staff, and R&D expenditures are regarded as the inputs of NTTCs, and the number of published papers, patent applications, and issued patents are viewed as the outputs of NTTCs. Only the age of NTTCs is not significantly correlated at the 0.05 level (2-tailed test) with any of the other variables; all other variables are significantly correlated at the 0.05 level (2-tailed test). The highest correlation is between published papers and patents issued, followed by R&D expenditures and published papers and R&D expenditures and patents issued. Clearly, there is a
strong relationship between R&D → published papers → patents issued although we cannot conclude that causality exists.

Another indicator to assess the productivity of NTTCs is the amount of licensing income (Anderson et al., 2007). Whereas patent licensing has traditionally been the most efficient mode of university technology transfer in Western countries (Chapple et al., 2005; Siegel et al., 2003b), it accounts for only 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 4). Thus, we use the income of university-affiliated technology firms as a complementary indicator to analyze the productivity of NTTCs (see Figure 2) because fostering academic technology-based firms is identified as the role of NTTCs.

Table 4 illustrates the progress achieved by NTTCs in Xi’an Jiaotong University and Sichuan University, with the number of license agreements and license revenues both having increased. Huazhong Science and Technology University shows 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 € which was much higher than the average license income received by the
other sampled universities. It proves that a few license agreements can bring a relatively large sum of revenue. Two different NTTC officers addressed why the existence of NTTCs could not improve the patent licensing activities in all the sampled universities:

“University technology-transfer activities usually focus on a minority of science and technology 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 science and technology 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.”

These comments reveal two interesting insights. First, we believe NTTC activity scope, whether derived from university mandates or emerged from experimentation, may be closely related to NTTC effectiveness. Second, NTTCs are part of a larger organization – the university – and the administration might limit NTTC decision making autonomy, leading to limited patent licensing activities. Thus, initiatives by NTTCs and the interactions between NTTC and the host institution may to a larger extent determine NTTC effectiveness.

Figure 2 shows that Beijing University, Fudan University, and Zhejiang University – in spite of not having a NTTC – generated more economic incomes than those with NTTCs, except for Tsinghua University. That is a unique case whose spinoffs maintain growing incomes, whereas all the other universities with NTTCs failed to sustain growing revenues of their spinoffs. For example, the spinoffs of Sichuan University received less income in 2002 as compared to 2001, as did the spinoffs of Shanghai Jiaotong
University. It seems that while NTTCs do not necessarily bring more income to university spinoffs, the revenues generated by university spinoffs were nonetheless much more than university license 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 unpredictability of NTTCs. From this point of view, we believe the role of NTTCs needs to further evolve in order for them to improve university research outcomes and subsequent commercialization.

To further test the effectiveness of NTTCs, we take a close look at Zhejiang University. Tables 2 and 4 and Figures 1 and 2 indicate that while behind Tsinghua University, Zhejiang University is ahead of the other five 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, and in 2005 its number of patent applications and issued patents both surpassed those of Tsinghua University. An officer in charge of technology transfer activities in Zhejiang University explained the following reason why his university can achieve such remarkable success without a NTTC:
Our university has no NTTC but we have had a similar office, called Science and Technology Development and Transfer Office, since the beginning of the 1980s. Now the office has a staff of 15 persons who manage over 3,000 technology contracts. Several key activities have contributed to our strong capability to commercialize science and technology findings. They include continuously increasing R&D expenditure, more cooperative research projects with enterprises, cumulative practices in exploiting science and technology findings, and strengthening IPR management.

Zhejiang University’s incentive policy on Intellectual Property Rights (IPR) is an especially important factor. The university organizes training courses on IPR to improve researchers’ knowledge of IPR and provides inventors with subsidies to cover the patenting cost, both of which stimulate the enthusiasm of inventors for patenting activities. In addition, Zhejiang University maintains close contacts with local governments as well as domestic and foreign firms, especially local key firms. For instance, university-government science and technology cooperation projects cover over twenty cities and counties. An innovation infrastructure platform has been created, consisting of centers for technology transfer, product innovation, and technology development. Many researchers are employed as technical directors or advisors by firms, and thousands of masters degree students engage in technical consulting services. To sum up, these measures which encourage researchers to generate and diffuse innovation also promote the success of Zhejiang University in commercializing science and technology findings.

To further substantiate our conclusion, Zhejiang University is not a unique case. Other universities, such as Beijing University, Fudan University, and Tianjin University, have shown 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 ranked first in revenues generated by technology-based spinoffs among all Chinese universities. Fudan University ranked fourth and Tianjin University fifth in terms of patent applications during the 2001-2004 period, ahead of East China University of Science and Technology, Huazhong Science and Technology University, Sichuan University, and Xi’an Jiaotong University.

The explanations for the greater success of Beijing University, Fudan University, and Tianjin University without NTTCs in commercial activities than some universities with NTTCs are similar to those of Zhejiang University. These universities have organizations similar to NTTCs that 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 from 2001 to 2004 than those of East China University of Science and Technology, Sichuan University, and Xi’an Jiaotong University (see Figure 3). As previously shown, R&D expenditure has a significant influence on publications and university patenting activities, and this greater patenting probably creates more opportunities for universities to conduct commercial activities.

In addition, the yearly-disclosed unofficial ranking of universities in China influences public attitude toward their image. Many academic performance indicators are used as ranking criteria, including 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 because they might 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. Beijing University, Fudan University, Tianjin University, and Zhejiang University are historically and currently prestigious higher education institutions in China. Massive R&D expenditures, abundant human resources for research, 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. While there certainly are other prestigious universities that do not have a NTTC (e.g., Nanjing University), we cannot find any that outperform these.

**Determinants of Success of NTTCs**

Several determinants of success of NTTCs used in this section are consistent with previous research findings. First, NTTC size and staff capability matter (Anderson et al., 2007; Chapple et al., 2005; Siegel et al., 2003a; Thursby & Kemp, 2002; Thursby et al., 2001). Tsinghua NTTC is the largest one, staffed with 40 people and functioning more professionally compared to the other five NTTCs. These advantages help Tsinghua NTTC perform better than the others.
Second, university R&D expenditure, rising awareness of IPR management, funding of NTTC, university-industry linkage, and performance mode (whether NTTCs have a company) all impact the effectiveness of NTTCs. R&D expenditure and the awareness of IPR management have a positive and significant influence on university patenting expansion, and funding NTTCs, university-industry linkage, and performance mode determine the productivity of NTTCs in the commercialization of research achievements.

The above determinants converge to show that establishing NTTCs is only one of several factors that facilitate rising university patenting and commercial activities. Since 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 as long as they meet these requirements. Zhejiang University is an excellent 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 alone do not seem to be an efficient political tool in promoting university technology transfer. Our research suggests that greater NTTC flexibility will allow them to fulfill their mission in promoting university technology transfer. Learning from Zhejiang University and other supporting examples, Chinese NTTCs will have to improvise to become more effective.
Conclusions

NTTCs have been operating in China since 2001. This qualitative and quantitative study provides evidence that they have not been an effective policy tool in accelerating the commercialization of university inventions. We found that universities without NTTCs, such as Zhejiang University, were at least as successful as those with NTTCs in terms of commercializing science and technology findings. Still, NTTCs are more important in university patentability and creating spin-offs than they are in licensing activities. While the number of NTTC staff has a significantly positive impact on rising university patenting, other factors have also contributed to NTTC output: R&D expenditure, rising awareness of IPR management, staffing capabilities, university institutional incentive systems, funding of NTTCs, university-industry linkage, and performance mode of NTTCs.

For performance of NTTCs to improve, we suggest that universities provide an attractive reward system to NTTC staff to stimulate 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 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 a national innovation system, including creating technology markets, offering technology business incubators, and providing science parks and Innofunds to develop mechanisms for technology marketability.
References


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National Bureau of Statistics of China documents accessed at
http://data.stats.gov.cn/workspace/index?m=hgnd and


### Table 1

A Comparison of Technology Transfer Approaches

<table>
<thead>
<tr>
<th>Purpose and Role</th>
<th>University Technology Transfer Offices</th>
<th>National Technology Transfer Centers</th>
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<tr>
<td></td>
<td>• Coordinate interactions between university, faculty/inventor, and industry and successfully license university intellectual property</td>
<td>• Capitalize on inventions through technology development contracts and creating university technology-based-firms</td>
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<td></td>
<td>• Encourage faculty to disclose inventions</td>
<td>• Do not spend much time persuading researchers to disclose inventions, although faculty are motivated to disclose inventions</td>
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<td></td>
<td>• Foster business incubation and new venture formation</td>
<td>• Market university inventions, usually by launching cooperative research projects on common technology and creating joint research centers with industry</td>
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<tr>
<td></td>
<td>• Diffuse inventions through successfully license university intellectual property</td>
<td>• Practical application of academic output rather than intellectual property rights</td>
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<td></td>
<td>• Balance university administrator objectives of maximizing license revenues with faculty objectives of pursuing sponsored research</td>
<td>• Leverage the university objectives of transferring technology with faculty objectives of further sponsored research</td>
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<tr>
<td></td>
<td>• Represent both the university and the inventor, with success based on meeting faculty and university objectives</td>
<td>• Intermediary between university and industry to manage university intellectual property and technology transfer activities</td>
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<td>• Stimulate a culture of innovation and entrepreneurship on university campuses</td>
<td>• Commercialize university inventions and contribute to economic growth</td>
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<td>• Pool inventions across research units within universities and build a reputation for honesty</td>
<td>• Assess whether inventions are worth filing for patent applications and enter the patenting procedure with the cooperation of the inventors only if the invention is deemed suitable for patenting</td>
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<tr>
<td></td>
<td>• Work with firms possessing strong absorptive capacity</td>
<td>• Work with firms possessing limited absorptive capacity</td>
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### University Technology Transfer Offices

- Production function framework which uses inputs (federal support, number of employees and faculty, whether private and has a medical school, invention disclosures, legal expenditure) and outputs (financial profit/loss, sponsored research and research productivity, license agreements and royalty payments, invention disclosures and patents, start-ups and employment)
- About half are profitable and local communities benefit from their contribution to economic development
- Private universities tend to be more efficient in commercialization than public ones while universities with medical schools are less likely to be efficient
- Productivity depends on faculty reward system, staffing and compensation, and cultural barriers between universities and firms; other factors might include number of personnel and impact of different IP policies
- Licensing has traditionally been most efficient mode of university technology transfer

### National Technology Transfer Centers

- Production function framework which uses inputs (age of NTTC, number of staff, R&D expenditure, published papers and outputs (patents)
- Activity scope, initiatives by NTTCs, and their interactions with host institution determine effectiveness
- Patent applications and issued patents have increased, along with published papers
- Patent licensing revenues account for very small part of all technology contracts in Chinese universities, but a few license agreements can bring large revenues
- Revenues generated by university spinoffs do not necessarily bring more income to university spinoffs but were much greater than university’s license incomes

### Success Determinants

- University goal, priorities, and use of resources
- Motives and organizational cultures of the faculty/inventor-UTTO-industry triad and cultural barriers between universities and firms
- Faculty compensation practices and incentive structure (i.e., percentage of royalty payments to faculty members)
- Age and size, university location, and mission to support technological transfer (e.g., older and larger UTTOs are less efficient but can speed up licensing to new ventures)
- Number of personnel and capabilities of the faculty and staff, especially the quality of engineering faculty
- IP policies and structure of agreements

- Funding and university R&D expenditures
- Several major universities without NTTCs have been successful with their large R&D expenditures, abundant human resources for research, and an attractive incentive system
- Performance mode (whether NTTCs have a company) and university-industry linkage and ability to exploit research findings
- Cannot conclude that NTTCs have improved research and commercialization, and are probably not efficient in promoting university technology transfer
- Size and staff capability matter
- Age does not seem to matter
- IP policies and management that nurture innovation and entrepreneurship
### Table 2:
Number of University Patent Applications and Issued Patents (2001-2005)

<table>
<thead>
<tr>
<th>University/Location</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>East China Univ. of Sc and Tech./</td>
<td>66</td>
<td>24</td>
<td>64</td>
<td>23</td>
<td>155</td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(36.4%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huazhong S&amp;T Univ./Wuhan</td>
<td>86</td>
<td>23</td>
<td>102</td>
<td>32</td>
<td>236</td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(26.7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shanghai Jiaotong Univ./Shanghai</td>
<td>188</td>
<td>34</td>
<td>285</td>
<td>41</td>
<td>730</td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(18.1%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sichuan Univ./Chengdu</td>
<td>52</td>
<td>10</td>
<td>111</td>
<td>13</td>
<td>182</td>
</tr>
<tr>
<td>(19.2%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(11.7%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tsinghua Univ./Beijing</td>
<td>380</td>
<td>123</td>
<td>526</td>
<td>136</td>
<td>767</td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(32.4%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(25.9%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xi’an Jiaotong Univ./Xi’an</td>
<td>56</td>
<td>29</td>
<td>94</td>
<td>37</td>
<td>189</td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(51.8%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(39.4%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zhejiang Univ./Hangzhou</td>
<td>214</td>
<td>61</td>
<td>353</td>
<td>80</td>
<td>660</td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(28.5%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(22.7%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: S&T Development Center of Ministry of Education

A*: represents the number of patent applications.

G*: represents the number of patents granted.

(Percent granted to applications in parenthesis.)

Note: Data in 2001 represent the number of university papers published in Science Citation Index collected from international 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. Hong Kong, Macao, and Taiwan are not included in the calculations.
Table 3
Correlation Coefficients

<table>
<thead>
<tr>
<th>Inputs</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age of NTTC</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Number of NTTC staff</td>
<td>0.587</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. R&amp;D expenditure</td>
<td>0.594</td>
<td>0.929**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Published papers</td>
<td>0.506</td>
<td>0.945**</td>
<td>0.983**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. # patent applications</td>
<td>0.352</td>
<td>0.870*</td>
<td>0.908*</td>
<td>0.938**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6. # patents issued</td>
<td>0.589</td>
<td>0.977**</td>
<td>0.981**</td>
<td>0.990**</td>
<td>0.926**</td>
<td>1</td>
</tr>
</tbody>
</table>

** Significant at 0.01 level (2-tailed test).
* Significant at 0.05 level (2-tailed test).

Table 4
Comparison of University Patent Transactions* in 2001 vs. 2002

<table>
<thead>
<tr>
<th>University</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of licensing agreements</td>
<td>License revenues (mil €)</td>
</tr>
<tr>
<td>East China Univ. of Sc and Tech.</td>
<td>18</td>
<td>0.90</td>
</tr>
<tr>
<td>Huazhong S&amp;T Univ.</td>
<td>7</td>
<td>0.64</td>
</tr>
<tr>
<td>Shanghai Jiaotong Univ.</td>
<td>9</td>
<td>1.25</td>
</tr>
<tr>
<td>Sichuan Univ.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tsinghua Univ.</td>
<td>137</td>
<td>7.18</td>
</tr>
<tr>
<td>Xi’an Jiaotong Univ.</td>
<td>8</td>
<td>0.19</td>
</tr>
<tr>
<td>Zhejiang Univ.</td>
<td>45</td>
<td>2.01</td>
</tr>
</tbody>
</table>

Source: Data collected from www.cutt.edu.cn/paiming.
* The patents are for invention, design model, and utility.

Note: 1 EURO = 10 RMB
Figure 1
University Published Papers of Nine Selected Chinese Universities Collected by SCI (2001-2005)

Source: Data collected from www.cutech.edu.cn
Figure 2
Incomes Generated by Spin-Offs* of Nine Selected Chinese Universities (1999-2005)
(money unit: million €)

Source: Science and Technology Development Center of the Ministry of Education.

Note: 1 EURO = 10 RMB

*Spin-offs here refer to university-run technology firms.
Figure 3
(money unit: million €)

Source: Bureau of Finance of the Ministry of Education.