Transfer of Technology and Innovation from Universities to Firms: The Case of China

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Universities increasingly function as a source of knowledge, innovation, and technological progress, particularly with the rise of the knowledge economy. This is in the context of the multi-faceted roles of universities: training the next generation of leaders, managers, and professional and technical personnel; engagement in the creation of codified knowledge in different forms – publications, patents, and prototypes; and contribution to local and national economies through research commercialization, problem solving, and providing public space (Cambridge-MIT Institute 2005, Poyago-Theotoky and others 2002). In many OECD countries, universities are key players in cutting-edge innovation and industrial commercialization. But this is yet to be the case for developing countries: even with considerable energy and investment to promote research in universities, their impact as critical agents of technological progress remains limited.

During economic reform, China's strategies for enhancing indigenous research and innovation capabilities have in part involved the promotion of university-based research and commercialization, accompanied by measures to encourage horizontal, market-based ties between high education and the business sector (firms). The initial results were promising: a number of enterprises affiliated with universities were among the earliest non-governmental high-tech producers in the 1980s and 1990s. Encouraged by such success, the Chinese leadership hoped to leverage what could be gained from academic research to acquire technological capability in more of its industrial sectors. Consequently, universities have acquired a new mission in addition to teaching and research – the third mission – as key agents for transfer of technology and innovation.

To make universities as innovative bases, China has had to strengthen academic research capacity, which was seriously neglected in pre-reform and early reform eras when the role of higher education was confined to teaching primarily. Since the mid-1990s, however, universities have gained clear recognition as an integral part of China's national innovation system, with two major national programs specifically designed to elevate the importance of academic research. One was "Project 211," providing significant funding to a group of 211 institutions with joint sponsorship by the State Planning Commission, Ministry of Finance, Ministry of Education (MOE), and provincial governments. On the heel of the "Project 211," MOE launched another nationwide program "985" aimed to turn China's top universities into world-class research universities. Competition for "985" designation was fierce as selected institutions would receive substantial funding to expand their research capacities and disciplinary scope, with matching funds from provincial governments. Accompanying these is the establishment of a new legal framework at the national level to enable ties between research and production, which made relatively generous allowance for rewarding the discoverers of new, commercially useful knowledge and made it easier for research personnel to move back and forth between research and business (Suttmeier and Cao 1999).

However, universities have yet to become key drivers of innovation in China. Compared to both select OECD countries and emerging economies, the share of higher education in total national

R&D expenditure remains low in China, at about 6.8 percent in 2016 (see Table 1). The business sector (firms) now has the lion's share at about 77 percent, compared to less than 40 percent in mid-1990s (Hsiung 2002). In addition, with expanded corporate R&D, higher education's share in both national R&D expenditure and personnel is in fact trending downwards in recent years (see Figure 1), even though the growth in the absolute volume of R&D personnel in universities has been steady since 2000, and on par with the overall expansion of the R&D workforce (Wu 2017).

Table 1. R&D and higher education expenditure in China and select countries

	China	*Brazil*	*Mexico*	*Russia*	*S. Korea*	*Japan*	*U.S.*
Gross domestic expenditure on R&D (GERD), 2016							
GERD PPP (US$, billions)	410	37	10	37	76	149	464
As % of GDP PPP	2.1	1.2	0.5	1.1	4.2	3.1	2.7
R&D expenditure by performing sector, 2016 (%)							
Business	77.5	-	30.6	58.7	77.7	78.8	71.2
Higher education	6.8	-	26.8	9.1	9.1	12.3	13.2
Government	15.7	-	36.5	32	11.5	7.5	11.5
Private nonprofit	0	-	6.23	0.21	1.6	1.38	4.07
*Expenditure in higher education, 2015**							
Annual expenditure per student (US$, PPP)	4,550	14,261	8,170	8,369	10,109	19,289	30,003
As % of GDP per capita	76.0	92.1	45.0	32.8	26.4	44.0	50.4

1. GRED: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

2. GRED for India and Brazil: https://www.iriweb.org/sites/default/files/2016GlobalR%26DFundingForecast_2.pdf

3. GDP PPP: https://data.worldbank.org/indicator/ny.gdp.mktp.pp.cd

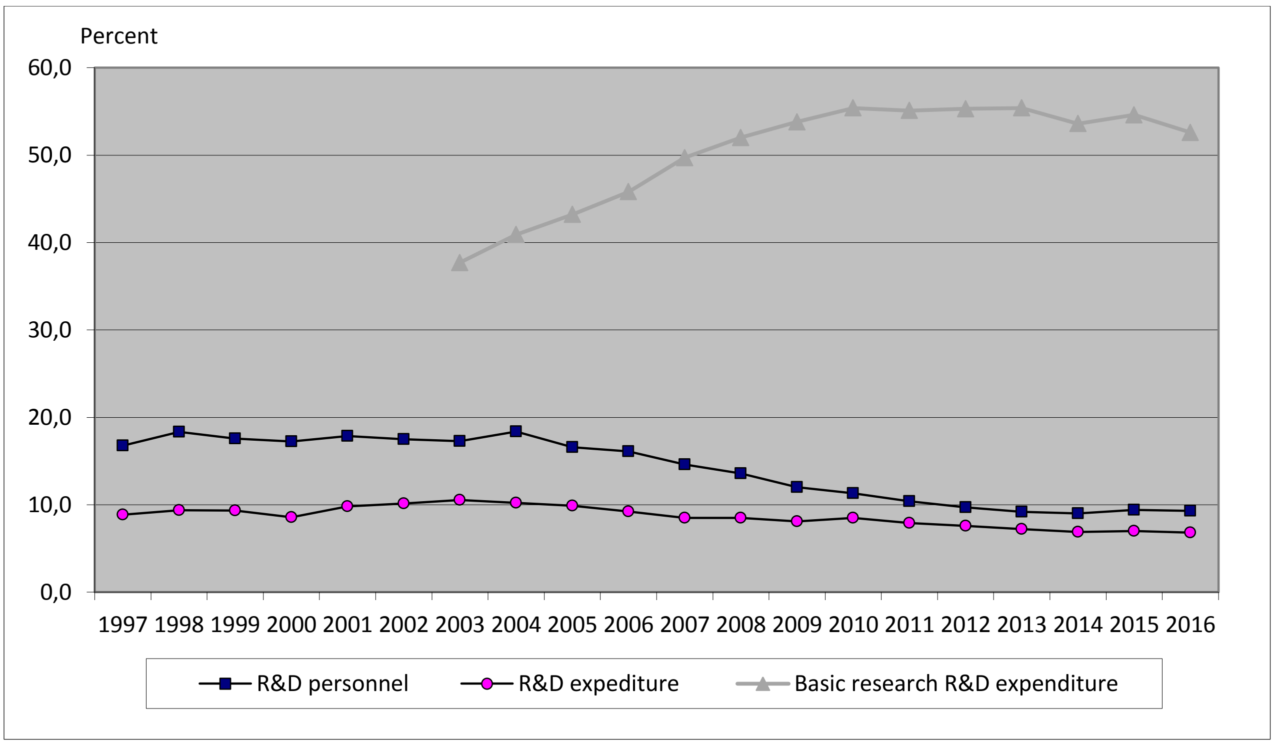
4. R&D expenditure by performing sector: https://www.oecd-ilibrary.org/science-and-technology/main-science-and-technology-indicators/volume-2018/issue-1_msti-v2018-1-en

5. Expenditure in higher education: https://www.oecd-ilibrary.org/education/education-at-a-glance-2018_eag-2018-en

* Data on China are for 2012.

Universities, nonetheless, are the most important performer in basic research, now counting for the majority of such expenditure nationally (see Figure 1). The amount of basic research spending in higher education has been growing steadily since 1995, and its share in all university R&D expenditure has picked up momentum (see Table 2). In comparison, applied research and product/process development are experiencing shrinking shares. Even more encouragingly, the university sector's share in granted domestic patents is speeding up again in recent years (Figure 2). By official definitions, patents in China are divided into three groups: inventions, new utility models, and new exterior designs. Inventions, and to a lesser degree new utility models, are the most fundamental and beneficial paths for technology development in the long run. The university sector is particularly prominent in generating invention patents, counting for 20-25 percent of the country's total in the last decade (see Figure 2). Around 2002-2003, a major shift occurred in the absolute number of patents – inventions overtook utility models in academic patenting. Close to 50 percent of all patents granted to higher education was related to inventions in 2016 (MOE 2017).

Figure 1. University sector's share in China's R&D activities, 1997-2016



Source: MOST (various years).

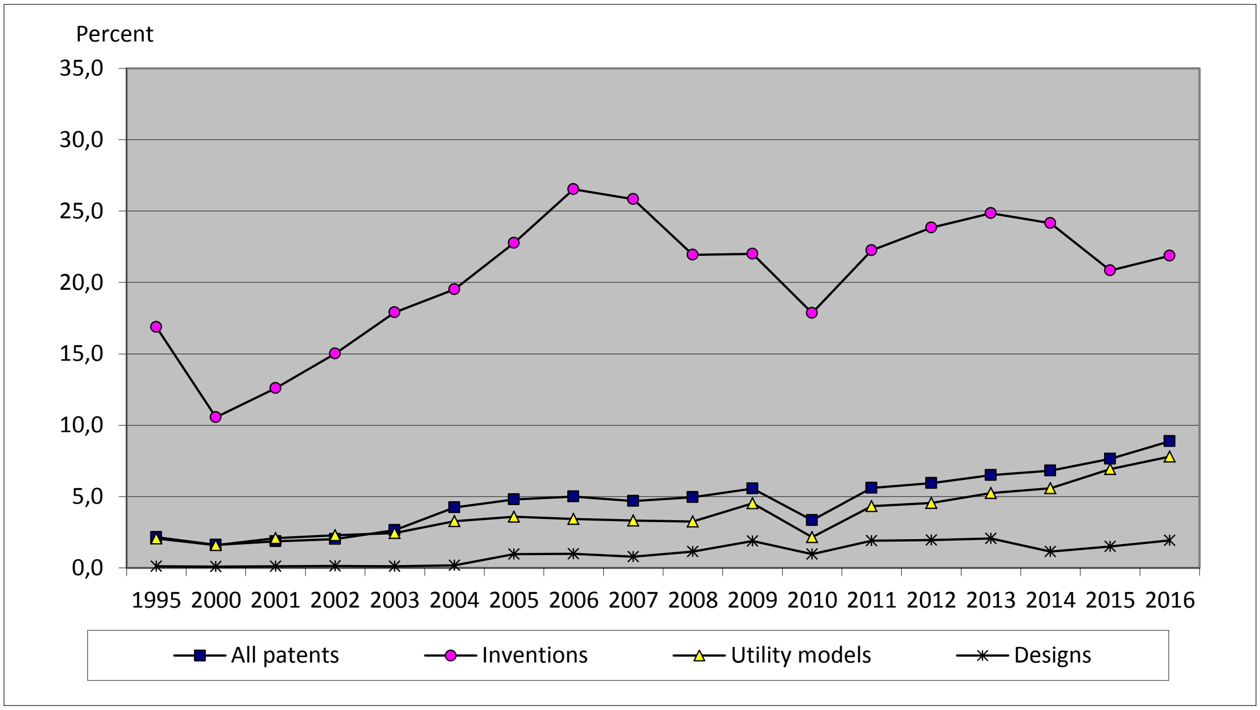
Table 2. Academic research revenues and expenditures, 1995-2016

	1995		2001		2007		2013		2016	
	Amount	Percent	Amount	Percent	Amount	Percent	Amount	Percent	Amount	Percent
S&T revenues (RMB millions)										
Total	4,774	100.0	17,473	100.0	54,536	100.0	122,269	100.0	153,701	100.0
From government sources	2,081	43.6	8,824	50.5	29,606	54.3	72,794	59.5	98,016	63.8
From industry sector	2,266	47.5	7,086	40.6	20,955	38.4	42,041	34.4	43,872	28.5
From other institutions	427	8.9	1,563	8.9	3,975	7.3	7,434	6.1	11,813	7.7
R&D expenditures (RMB millions)										
Total	2,647	100.0	7,241	100.0	24,020	100.0	65,001	100.0	75,258	100.0
Basic research	368	13.9	1,137	15.7	6,586	27.4	22,424	34.5	29,368	39.0
Applied research	1,501	56.7	4,301	59.4	13,019	54.2	32,928	50.7	36,625	48.7
development	778	29.4	1,803	24.9	4,415	18.4	9,649	14.8	9,265	12.3

Source: MOE (various years).

There are strong incentives for university to engage in technology transfer to industry. A non-insignificant fact is that research funding from industry accounts for about a third of the total university S&T revenues (see Table 2). A direct push for commercializing academic research and innovation came in 2001, when the State Economic and Trade Commission and MOE jointly set up the first group of state technology transfer centers in six universities. Perhaps even more important was a clear directive from the MOE in 2002 that encouraged the development of university-affiliated enterprises, after some heated debate on whether commercialization and links with industry should be a central mission of universities (Wu 2007). Further policy discourse led to the current position that the three major missions of universities would be teaching, research, and commercialization. Now the number of patents and income from technology transfer has become important criteria when the MOE evaluates universities and their leadership (Tang 2006). To promote university-industry linkages, various national and local policies have been implemented, such as providing financial and legal services for faculty and student startups, strengthening patent laws, encouraging the establishment of university-based science parks, and building high-tech development zones near major universities (Wu 2017)

Figure 2. University sector's share in granted domestic patents, 1995-2016



Source: MOE (various years).

Entering into technology transfer contracts with firms is the most significant mechanism of innovation diffusion for Chinese universities. In the period of 2000-2016, income from such contracts amounted to an average of about 12 percent of R&D revenues in higher education (see Table 3). A number of factors are likely underlining this trend. During the early years of economic reform, the business sector had been a weaker actor in China, particularly in comparison to public research institutes. Industry-specific research institutes within different ministries were responsible for solving specific applied problems as well as introducing new technology into enterprises. The lack of in-house R&D capability in most firms means that they could not rely on themselves for solving more complex technical problems in production (Xue 2004). This is borne out by the increasing share of technology transfer contracts signed between universities and private firms (see Table 3). But what is striking is the fact that none of the major forms of university technology transfer enjoyed much growth in volume since the mid-2000's, during which time China's high-tech sectors enjoyed double-digit growth (Wu and Zhou 2012). In fact, the share of technology contract values has been declining in recent years, become less significant as a revenue stream for universities (see Table 3).

Table 3. Academic technology transfer, 2000-2016

	2000	*2003*	*2006*	*2009*	*2012*	*2016*
Technology transfer contracts						
Number	4,946	7,809	6,878	8,770	10,275	9,592
Value (million RMB)	1,788	2,374	1,964	3,120	3,876	5,025
As % of university R&D revenues	22.0	15.4	7.6	6.6	5.0	5.3
Patent licensing						
Number of patents licensed and sold	299	611	701	1,571	2,357	4,803
As % of granted patents	19.3	15.5	6.3	5.6	3.4	3.3
Value of patent licensing and sales (million RMB)	185	360	287	762	821	2,270
As % of university R&D revenues	2.3	2.3	1.1	1.6	1.1	2.4
Share of technology transfer contract value (percent)						
State enterprises	53.6	33.7	49.0	34.2	34.4	32.6
Private enterprises	18.8	34.7	33.7	47.7	49.9	47.9
Foreing-invested enterprises	10.0	3.1	4.5	5.4	4.6	10.4
Others	17.6	28.5	12.8	12.7	11.2	9.1

Source: MOE (various years).

Patent licensing, commonly used in the West for universities to diffuse innovation, has yet to become a major mechanism in China. Between 2000 and 2016, patent licensing and sales generated only a very small portion of university R&D revenues (around 2 percent, see Table 3) Nationally, an average of about 11 percent of granted patents were licensed out by universities, but this share showed a pattern of decline recently (Wu 2017). This record also is a long distance from the average level of academic patent licensing in industrialized countries, at about 80 percent (Wu and Zhou 2012). The under-performance of patent licensing and sales may stem from the mismatch between academic research and firm demands, as well as institutional barriers. Chinese universities, however, frequently work with domestic enterprises to adapt foreign technology for the domestic market.

Besides the conventional forms of transfer of technology and innovation discussed above, university-affiliated enterprises received much attention early on. In particular, China had some success in creating large university-affiliated computer companies in the 1980s and 1990s. During that time, waves of spin-off were created by major universities and public research institutes, in part to commercialize their R&D results and in part to supplement budget shortfalls caused by shrinking central government spending on research. Some of China's leading high-tech companies emerged during this time, such as Lenovo (affiliated with Chinese Academy of Science), Founder (affiliated with Peking University), Ziguang (affiliated with Tsinghua University), Tongfang (affiliated with Tsinghua University), and many others. Those in Beijing formed the backbone of China's first science park – Zhongguancun (Zhou 2008). The commercial success of these companies in the 1990s generated considerable optimism for major roles universities could play in China's high-tech development. Yet, the momentum seemed to have dissipated in the new millennium. Overall, university enterprises are declining in numbers and contributing less to academic R&D revenues (Wu and Zhou 2012). This may be signaling a gradual shift in university technology transfer from affiliated spinoffs into more flexible institutional arrangements, such as joint R&D, contract research, sharing research labs, licensing, and technology sales.

Overall, despite the heightened attention, investment and involvement by the state, university-industry linkages remain at a nascent stage with limited effects on technological progress. The key role of universities so far centers not so much on cutting-edge innovation but on adaptation and redevelopment of existing foreign technology/products. While these functions are very important for China, it seems the promises of universities as a center of knowledge creation and commercialization has not been fulfilled so far (Wu and Zhou 2012). In short, while China is moving rapidly in other areas of technology acquisition or development in a globalized world, the third mission of universities seems stalled. More stark is the backdrop of its corporate sector getting closer to the technological frontier, driving innovations in such emerging areas as renewable energy, next generation telecommunication technologies, big data and supercomputers, artificial intelligence and robotics, and e-commerce.

The diversification of technological sources and the relentless market competition for firms to cultivate their internal technological capacity, coupled with the slow pace of institutional reforms in the higher education sector, are some of the key reasons that universities are likely to be out of sync with industrial growth. There are persistent and even growing structural mismatches between academia and industry, and institutional barriers in technology transfer (Wu and Zhou 2012). The availability of creative and productive personnel, and not the availability of funding, is another major constraint in promoting quality research in universities (Gallagher and others 2009). The recent founding of Westlake University, a private research-oriented school aiming to use its autonomy to challenge leading Western science and technology institutions, signals the willingness of the central government to try a new form of academic governance.

In hindsight, China's experience in the higher education sector has been predicated upon a state-centered process in which the central ministries determine investment priorities for elite institutions and critical policies for academic innovation and commercialization. As such, universities are far from autonomous, particularly in the areas of academic programs, allocation of funds, and organizational structure. In fact, universities have yet to enjoy the same degree of autonomy as state-owned enterprises, not to mention private firms. It is important to recognize the historical legacies that Chinese universities need to overcome, both internally and externally, particularly given the short history of university-based research and commercialization.

Perhaps a more salient feature of the Chinese experience is the increasing entrepreneurial bent of its elite universities. University administrators have become more willing to engage in commercial pursuits and set up enterprises. Given that universities' share in granted domestic patents is increasing steadily, it is conceivable that patent licensing will become a more important mechanism to diffuse academic research. Nonetheless, one needs to recognize that even in the most advantageous countries or regions, there remain enormous difficulties of commercializing academic innovations. Major technological breakthroughs are the product of cumulative interactions and advances involving the flow of ideas and people back and forth between academia and industry.

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Professor Wu has had a number of academic leadership roles outside of the university setting. She is the Vice President and President-Elect of the Association of Collegiate Schools of Planning (ACSP), a consortium of university-based programs offering credentials in urban and regional planning, with more than 100 full-member schools in North America. Between 2008 and 2012, she was an editor of the Journal of Planning Education and Research, ACSP's flagship journal. She has been a member of the International Advisory Board for the Urban China Research Network, as well as serving on the editorial board of four journals. In addition, she has provided consultation to the Ford Foundation, Lincoln Institute of Land Policy, and World Bank.