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Exploring the Role of University-Run Enterprises in Technology Transfer from Chinese Universities

Xibao Li[1] and Justin Tan[2]
[1]*Tsinghua University, China, and* [2]*York University, Canada*

ABSTRACT Universities in China have increased their entrepreneurship significantly, yet a good understanding of the specific characteristics of university-based technology transfers remains missing. This study focuses on a special type of university spinoffs in China, University-Run Enterprises (UREs), and examines how URE eminence contributes to a university's technology transfer performance, using panel data covering 195 universities over the five years from 2002 to 2006. The findings reveal that URE eminence not only signifies a university's strong entrepreneurial culture, but also signals commercial values and quality of the university research. It moderates the contribution of university scientists from the supply side and that of sourcing firms from the demand side.

KEYWORDS academic entrepreneurship, spinoffs, technology transfer, university-industry linkage, university-run enterprises

ACCEPTED BY Senior Editor Can Huang

INTRODUCTION

Universities increasingly include economic development mandates in their mission statements and take active, entrepreneurial approaches toward commercializing their research (Etzkowitz, 2003; Shane, 2002). In the United States, many universities license patents or take equity in spin-off companies to benefit from their faculty's research efforts (Feldman, Feller, Bercovitz, & Burton, 2002). Such technology transfer efforts have received substantial research attention (Debackere & Veugelers, 2005; O'Kane, Mangematin, Geoghegan, & Fitzgerald, 2015; Thursby & Thursby, 2002; Wright, Clarysse, Lockett, & Knockaert, 2008). A large volume of this research has placed an emphasis on the organizational designs of universities and tried to identify which internal elements (e.g., status, incentive systems, faculty experience) might inhibit or promote the commercialization of university-owned technologies (Friedman & Silberman, 2003; Markman, Gianiodis, Phan, & Balkin, 2004; Owen-Smith & Powell, 2001; Thursby & Thursby, 2004). This research,

Corresponding author: Xibao Li (lixibao@sem.tsinghua.edu.cn)

drawn from US experience, contributes notably to the understanding of university entrepreneurship. However, university entrepreneurship is context dependent and deeply embedded in local innovation networks (Rothaermel, Agung, & Jiang, 2007). Because the organizational designs of universities differ so much and universities' systems are not internationally comparable, universities in less well-developed economies are unlikely to exhibit the same patterns or dynamics of entrepreneurship as those in developed countries (Rothaermel et al., 2007).

Compared to counterparts in the US and European countries, university entrepreneurship in China is rather unique. Several distinctive features mark Chinese university technology transfer. First, academic knowledge is transferred mainly in the form of sponsored technology contracts or agreements between university scientists and sponsoring firms (Xue, 2006).[1] As a result, most universities receive a disproportionate share of their research funding from industry. In 2005, more than 40% of Chinese universities' research funding came from industry (Ministry of Education of China, 2006), compared with less than 5% in U.S. universities (National Science Board, 2008).[2] Secondly, Chinese universities rarely use patent licensing to reap revenues from their academic research.[3] Given the dominance of technology contracts, the role of technology transfer offices (TTOs) in Chinese universities is focused on managing these agreements. At the same time, university scientists are more directly and deeply involved in the process of technology transfer. Finally, and more importantly, the existence and operation of businesses under university administration is one of the most remarkable features of Chinese university systems (Wu, 2010). Unlike western university spin-offs (Steffensen, Rogers, & Speakman, 1999), Chinese UREs usually are wholly owned and managed by the university. Their top management teams are composed of faculty members, headed by the university's president.[4] Such UREs are a special form of spinoffs found almost exclusively in China (Chen, Patton, & Kenney, 2016). They serve as an important institutional and organizational resource for Chinese universities and provide an appropriate solution for university technology commercialization in the early stage of China's development (Kroll & Liefner, 2008).

But that is not to say that other channels for technology transfer are unknown. In China, two separate institutional set-ups for commercializing university technology operate side by side. UREs apply university-developed technology directly in their business operations, while TTOs facilitate linkages between university scientists and firms sourcing technology. In this setting, how would the UREs facilitate or moderate technology transfer through TTOs? Prior studies have shed almost no light on this issue.[5] In a comprehensive review of literature published in both Chinese and English journals, Chen et al. (2016: 910) concluded that, despite a lot of works on technology transfer from Chinese universities, it is still unclear what roles UREs have played in encouraging the transfer of university-owned technology.

In order to address this question, we set out to investigate empirically how the existence and development of UREs moderates the performance of university TTOs. Drawing on Etzkowitz's (2003) view of academic entrepreneurship as

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being both endogenous and exogenous, we formulate the performance of technology transfer (in particular, the number of technology contracts signed by scientists and firms) in a university as being determined by both supply and demand factors. That is, university technology transfer is related not only to the university's internal research capacities (the supply side), but also to external commercial or societal needs (the demand side). We posit that, although not directly involved in facilitating the commercialization of university scientists' research as TTOs do, UREs represent an important form of institutional resource that acts as role models in promoting entrepreneurship among a university's academics. Successful UREs signal to a university's scientists that the university support entrepreneurship and promotes engagement in the commercialization of research. They also demonstrate to outside firms that the host university is generating productive research results, thus attracting demand from the outside. UREs in this sense serve as a facilitator in China and play an important role in fostering the transfer of a university's technology.

This study was designed to advance scholarly understanding of the dual roles that UREs play in Chinese university systems. The results also contribute to the findings about organizational designs in university entrepreneurship (Debackere & Veugelers, 2005; Siegel, Waldman, & Link, 2003).

RESEARCH CONTEXT

The Evolution of UREs

The development of Chinese university entrepreneurship generally follows a Stanford-type strategy, with academic-based industrial development and industrially based academic development (Etzkowitz, 2003). Indeed, university entrepreneurship is not a new phenomenon in China, and most Chinese universities have a strong commercial orientation.[6] A comprehensive discussion of Chinese university entrepreneurship is beyond the scope of this article, but it is nevertheless useful to give a brief description of how UREs evolved in China and how they relate to the general technology transfer systems in Chinese universities.

Under central planning regime, universities, like most state-owned organizations in China, were self-contained communities, multifunctional and to some extent self-sufficient (Lv & Perry, 1997). It was only after China reformed its science and technology system in the early 1980s that they (and other research institutes) could appropriate benefits from their research. The lack of R&D by Chinese firms provided universities with an incentive to step directly into business pursuits (Eun, Lee, & Wu, 2006). In the days of central planning there as a clear division of science & technology (S&T) activities. The Chinese Academy of Science was in charge of basic research; industry-specific research institutes solved problems and introduced technology to manufacturers; and universities were responsible for training and education with limited research involvement

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(Liu & White, 2001). Firms were simply manufacturing workshops, with few absorptive capacities for assimilating university knowledge (Cohen & Levinthal, 1990). After market-oriented reforms started though, universities began conducting applied research such that they gradually gained a strong comparative advantage in terms of running their own businesses.[7]

As government agencies cut funding for research to encourage universities and research institutes to establish a market-oriented technology transfer mechanism, those organizations sought instruments that would enable them to reap benefits from their R&D (Xue & Forbes, 2006). Faced with a strong incentive to commercialize their technologies, weak technology competition from Chinese firms, a lack of intermediary institutions, and a changing legal and regulatory environment, many universities set up self-financed, market-driven ventures to transfer scientific research to the market (Eun et al., 2006; Gu, 1999). However, private ownership by faculty members was not allowed. So, all these ventures were initially established, funded, and managed by university administrations. None were really separated (or spun off) from the universities.[8]

Although UREs provided universities with an easy, fast way to alleviate financial pressures, they also created substantial financial and ownership risks (Xue, 2006). In particular, when a successful URE grew large, university leadership was in many cases no longer competent to manage it.[9] As the Chinese government began to increase investments in higher education in the late 1990s, financial pressures on universities were also reduced somewhat. Furthermore, critics argue that devoting too many university resources to UREs comprised the quality of education and research. Against such a backdrop, the government began by the late 1990s to encourage universities to extract themselves from URE operations and support spinoffs which were in part privately financed (Kroll & Liefner, 2008). The influence of UREs slowly waned and the focus of university technology transfer gradually shifted to technology contracts and patent licensing (Chen et al., 2016). Nevertheless, strong financial incentives even today make many universities reluctant to give up their operations, so profit-making UREs still largely remain under their universities' control.

Technology Contracts

In fact, only a small number of faculty members actually get involved in UREs' business activities. Instead, according to Xue (2006), much research funding comes from technology contracts or contractual agreements between faculty and firms, which explains why Chinese universities devote so much attention to applied research. Contractual agreements therefore constitute another important mechanism for commercializing research and knowledge. A contract can be associated with patented, unpatented or unpatentable technology. Besides mature technologies that can be commercialized without further research, less mature or under-developing technologies can also be involved in such agreements.

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The prevalence of technology contracts has increased demand for university-based technology transfer offices to administer and market universities' intellectual property. TTOs help to market technology, monitor its application, and account for any revenue from university inventions (Henderson, Jaffe, & Trajtenberg, 1998; Steffensen et al., 1999). But perhaps more importantly, they function as intermediaries to transfer technology from the labs to firms (Markman, Phan, Balkin, & Gianiodis, 2005). They are a university's link to industry (Debackere & Veugelers, 2005; Siegel et al., 2003). This is not superficially different from TTOs' roles in other countries, but the knowledge or technology they deal with in China often differs from that in western contexts. In the United States, for example, technology transfer usually begins with a scientific discovery by a university professor, who decides whether to file an invention disclosure with the university's TTO. If he or she does, the TTO then assesses the economic potential of the research outcome and decides whether to patent and transfer the intellectual property rights (IPR). If a patent is awarded, the TTO begins to market the IPR, whether through licenses to private firms or by establishing a spin-off in which the university holds shares. Thus, the key role of TTO professionals is often as arbiters between higher education and industry (Powers & McDougall, 2005). In China, however, patent licensing accounts for a very small proportion of technology transfer and is limited to universities with strong engineering disciplines. Technological knowledge transferred through contracts is often task-specific and not patentable. The involvement of faculty members is essential through the entire transfer process. The TTO plays only an ancillary role and mainly focuses on contract management.

It is important to note that UREs and TTOs are separate entities in Chinese universities with distinct organizational goals.[10] UREs have their particular product lines and technological fields. They run like normal business firms in almost every respect. TTOs act as agents for the university administration and manage intellectual property-related collaborations between university scientists and firms. With respect to research commercialization, the roles of the TTO and any UREs are complementary rather than mutually exclusive.[11] Since Chinese UREs are directly managed by the university administration, an arrangement rarely seen elsewhere, it raises a question about how and to what extent operating UREs influences the performance of contractual agreements which are actually at the discretion of individual scientists.

THEORETICAL FRAMEWORK AND HYPOTHESES

Analytical Framework

In his discussion of the mandates of modern universities, Etzkowitz (2003: 119) has suggested that university entrepreneurship can be considered both endogenous and exogenous. It is endogenous because internal research activities generate innovations which facilitate technology transfer. It is also exogenous in the sense that outsiders seeking academic resources can affect the research conducted by university scientists. This points to two sets of factors which may jointly determine the performance of university technology transfer. On the one hand, the conventional supply-push (or forward) linear model of innovation emphasizes the importance of knowledge generation within universities.[12] According to that model, the more knowledge scientists create, the more technology is available for transfer. On the other hand, technology transfer can operate in reverse, starting from the needs of knowledge users. Such reverse demand-pull implies that commercial needs will affect research conducted by university scientists and any eventual technology transfer. For example, Thursby and Thursby (2002) found that increased business reliance on external R&D is an important reason for the dramatic increase in technology transfer in the 1990s. Despite the fundamental difference between the science push and business pull models, interfaces such as TTOs and incubator facilities can promote both forward and reverse influences. As more and more research universities become entrepreneurial, an interactive model incorporating both push and pull seems increasingly prevalent (Etzkowitz, 2003).

In the early days, forming UREs was regarded in China as an institutional solution to cope with the wide gap between universities' knowledge supply and industry's knowledge demand (Eun et al., 2006). As TTOs gradually dominate university-industry linkages, collaboration between university scientists and outside firms has come to be facilitated mainly by TTOs. Following this reasoning, we build on the interactive model and propose to explore the determinants of technology transfer performance from both supply and demand sides.

On the supply side, the key factor that influences technology transfer performance is the amount of knowledge that could potentially be transferred, although transfer itself does not happen automatically. In this analysis, technology transfer was quantified in terms of contract counts. In a technology contract, knowledge that is stipulated either for sharing or for transfer usually needs to be customized or developed. The knowledge involved in licensing a patent, by contrast, has been generated at least a few years earlier. The ability to customize or generate new knowledge is crucial for universities. We thus regard university research capacities embodied in human resources as a key supply-side factor.

On the demand side, although the importance of commercial needs and user feedback is emphasized for effective technology transfer, it is not easy to quantify the strength of such needs. Knowledge seekers can actually come from everywhere, but in terms of sponsored research, geographic proximity seems to be important. Mansfield (1995) found that firms tend to choose local universities when they sponsor applied research, and he argued that for effective collaboration on research activities, personal face-to-face interaction between academics and firm personnel is necessary. This is further corroborated by Broström (2010: 1311) who, through interviews with R&D managers, found that links with nearby universities are more likely than distant links to contribute to short-term R&D projects, to generate innovation and to facilitate learning at the firm. Resonating with the well-acknowledged fact that knowledge spillover is geographically localized (Audretsch & Stephan, 1996; Jaffe, Trajtenberg, & Henderson, 1993), Mansfield and Lee (1996) have observed that local firms are significantly more likely than distant firms to be among the first to apply the findings of university research.

Geographic proximity is also important from the perspective of social and personal relationship. Harmon et al. (1997) observed that technology transfer occurs mainly between university inventors and existing contacts in the business community. Siegel et al. (2003: 42) subsequently showed that personal relationships are more important than contractual relationships in university technology transfer. Social and personal relations are often locally embedded and geographically limited. Spatial proximity reduces the cost of informal communication and increases the frequency of social and professional contacts, as Saxenian (1994) has argued. It also serves to build social relations and trust and facilitates knowledge diffusion and information dissemination. Bishop, D'Este, and Neely (2011) have shown that geographic proximity facilitates the exchange of tacit and context-specific knowledge between universities and industry.

In addition to the ample evidence presented in studies based on developed countries, similar arguments have also been substantiated in the case of China. Using Chinese patenting information, Hong and Su (2013) concluded that geographic distance is an important constraint on university-firm collaboration in China. Kafouros, Wang, Piperopoulos, and Zhang (2015) further clarified that in a large country like China geographic proximity is even more important than elsewhere for building university-industry linkages. This study therefore emphasized commercial needs emanating from firms located in the same region as a focal university.

Research has shown that the commercial value of academic knowledge varies to some extent among firms of different size, with different ages, and in different industries. Large and small firms possess different resources and capabilities and respond to their environment differently (Dean, Brown, & Bamford, 1998). Prior studies have documented a noticeable difference in using public research between large and small firms, although the results are mixed. Some researchers argue that small firms can make better use of university knowledge (Acs, Audretsch, & Feldman, 1994). Others suggest that large firms generally use more public research (Cohen, Nelson, & Walsh, 2002), and are more likely to engage in cooperation with a university (Veugelers & Cassiman, 2005). Although small firms are not all new, new or entrepreneurial firms are nearly all small, and they have been shown to attach more importance to academic knowledge than established ones (Audretsch & Lehmann, 2005; Soh & Subramanian, 2014; Steffensen et al., 1999). The importance of university research also differs among industries. University knowledge is regarded as critical for fostering the development of high-tech sectors (Bramwell & Wolfe, 2008; Owen-Smith, Riccaboni, Pammolli, & Powell, 2002; Saxenian, 1994). Firms in high-tech

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industries are more likely to forge university links than others (Cohen et al., 2002; Segarra-Blasco & Arauzo-Carod, 2008).

In China most indigenous firms operate far behind technology frontiers, making collaboration with universities a promising way for them to develop their innovation capabilities (Kafouros et al., 2015). Whether and to what extent they are able to utilize university-generated technology effectively heavily depends on their absorptive capability. In their large-scale survey of Chinese manufacturing enterprises, Motohashi and Yun (2007) found that large and medium-sized enterprises (LMEs) make use of university technology more frequently than small firms. Small firms' ability to collaborate with universities is limited by their lack of internal R&D capabilities. Like their western counterparts, small entrepreneurial firms in China are more proactive in utilizing university technology than other less entrepreneurial small firms. This is evidenced by the large number of entrepreneurial firms incubated in university-run science parks (Xue, 2006). In regard to industries that favor university technology, manufacturing enterprises have been the dominant source of demand for university-generated technology during China's transition process. Chinese government has been pushing for university-industry links as a promising way to develop high-tech industries, a top priority (Wu, 2010). In this study, we therefore focused entirely on manufacturing firms seeking new technology. We further distinguished between hi-tech LMEs and small entrepreneurial firms, regarding those two groups of firms as the primary users of university-generated research. Our baseline assumption was that both the supply-side and demand-side factors predict technology transfer as measured by the number of contracts signed.

URE Eminence as a Reflection of Strong Entrepreneurial Culture

Scholars have long debated whether and to what extent university technology should be exploited commercially (Argyres & Liebeskind, 1998; Lee, 1996; Rothaermel et al., 2007). Because of the inherent cultural differences between universities and industry, much concern has been raised among scholars as to whether close university-industry cooperation might interfere with the academic freedom to pursue long-term, disinterested, fundamental research (Buenstorf, 2009; Crespi, D'Este, Fontana, & Geuna, 2011), and the debate surrounding the defining role, mission and identity of universities has never abated (Etzkowitz, 2003; Just & Huffman, 2009). Jacob, Lundqvist, and Hellsmark (2003: 1564), for example, have observed that university researchers in Sweden are reluctant to commercialize their findings because they fear that earning too much profit would be bad for the university's image. Even in the US, where strong university-industry links are widely accepted, exploiting university research is not encouraged in some research-intensive universities (Feldman & Desrochers, 2003). Wu (2010) has observed that, among the top universities in China, many faculties remain skeptical about whether academic pursuits should co-exist with commercial ones. Given that

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tension between a university's commitment to the intellectual commons and the exploitation of university research for profit, university support for entrepreneurship is crucial for the transfer of academic technology.

China's UREs in fact reflect of a strong entrepreneurship ethos in the host universities that operate them. Earlier, UREs were not only controlled by the universities, but actually managed by university administrators. Their top management teams usually consisted of faculty members. Since the profit generated from running UREs was an important financial source for the host universities, they had an incentive to devote significant resources to their UREs' development, including land, buildings, personnel and goodwill. The measures taken by the universities signaled that commercializing research was strongly supported and encouraged. Individual researchers at universities managing UREs, even if they were not directly involved in the UREs' operation, sensed the spirit of entrepreneurship. The very existence of an eminent URE thus manifested the university's strong support for the commercialization of the technology generated in its halls.

Such a strong entrepreneurial culture in turn should encourage researchers to actively pursue collaboration with outside firms. First, the existence of a URE signifies the institutional legitimacy of research commercialization and declares that a close link between the university and industry is welcomed and respected. Owen-Smith and Powell (2001) found that the incentives for faculty members to disclose inventions are related to a university's entrepreneurial culture, specifically whether the university supports or opposes commercializing technology. Kenney and Goe (2004) have argued similarly.

Secondly, UREs' highly visible commercialization activities help to reduce anti-entrepreneurial peer pressure which, as documented by Goldfarb and Henrekson (2003), obstructs technology transfer out of universities. The presence of entrepreneurial role models should in some cases stimulate university researchers to engage in commercial activities. For instance, after comparing the differences in technology transfer between Europe and the US, Schmiemann and Durvy (2003) suggested that the effectiveness of technology transfer in European universities might be enhanced by giving technology transfer more visibility and prestige.

Thirdly, as university administrators become more familiar with and knowledgeable about business culture through the operation of UREs, they should be better positioned to cope with the possible conflicts of interest between university and industry. University policies or institutions that support entrepreneurship are then more likely to be deployed, facilitating technology transfer (Caldera & Debande, 2010).[13] Feldman and Desrochers (2003) have shown that universities with a practical orientation are more willing than others to develop programs or expertise to satisfy their institutional mission. The nature of organizational ambidexterity in such universities is helpful for scholars to commercialize their research (Chang, Yang, & Chen, 2009). Such cases are in fact abundant. Wu (2010: 216) presented several illuminating cases about how universities re-organized their administrative units to provide better business support service in China.

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Taking UREs as representing a university's entrepreneurial spirit, it follows that:

Hypothesis 1: URE eminence will positively moderate the relationship between a university's research capacity and the number of technology transfer contracts it signs.

URE Eminence as a Signal of Research Quality

For potential university knowledge users, UREs' visibility and eminence also function as a signal of academic quality and the potential commercial value of university research due to a 'halo effect' (Sine, Shane, & Di Gregorio, 2003). That should help to recruit firms to forge university-industry linkages (Di Gregorio & Shane, 2003). In practice, of course, not all UREs are successful. Among the 42 UREs listed on the Chinese stock markets at the end of 2001, 33 were associated with top research universities[14] (Eun et al., 2006, Table 1). In 2004, three quarters of the total sales of all UREs were contributed by UREs associated with one of the top 20 research universities (Xue, 2006). In this respect, the eminence of UREs signifies that the host universities are more likely to be prominent in research quality. The glorious stories of Founder, Lenovo, and Tongfang, for example, have been repeatedly broadcast in mass media as role models of academic technology transfer. That has broadened the impact of the associated universities and their technologies among industrial firms. As successful UREs go public, their signaling or demonstration effect becomes even more pronounced, thus attracting more external attention to a wider range of university technologies (Bonardo, Paleari, & Vismara, 2010).

Scholars have proposed at least three explanations for why firms are willing to seek to collaborate with or to sponsor research at universities ranked well for research quality. First, scientists working in such universities are usually more productive and also more innovative than their peers elsewhere. The quality of a university's faculty not only relates positively with the formation of start-ups and their post subsequent performance (Powers & McDougall, 2005), but also directly contributes to corporate innovations (Mansfield, 1995: 64). For firms seeking to collaborate, more inventions or innovations means more opportunities for commercialization. And the technology that top university researchers develop is likely to be more commercially valuable and hence more attractive to firms seeking collaboration. Nerkar and Shane (2007) have argued that pioneering technology is more likely to be commercialized. Using Chinese firm-level data, Kafouros et al. (2015) verified that the quality of academic research positively moderates the contribution of academic collaboration to collaborating firms' innovation performance.

Secondly, top researchers and prominent scholars often occupy central positions in scientific networks (Breschi & Catalini, 2010; Lissoni, 2010). By actively cooperating with university researchers in R&D, firms can be connected to

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Table 1. Descriptive statistics and correlation matrix of variables

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1 *Technology Contract Count*													
2 *Ln(URE Revenue)* $_{-1}$	0.29**												
3 *Ln(Univ. R&D Personnel FTE)*	0.31**	0.51**											
4 *Hi-Tech LME R&D Intensity*	0.01	0.02	−0.02										
5 *Entrepreneurship Intensity*	−0.07	−0.20**	−0.11*	−0.15**									
6 *Ln(Academic Papers)*$_{-1}$ [a]	0.19**	0.39**	0.52**	0.12**	−0.02								
7 *Ln(Patent Grants)*$_{-1}$ [a]	0.32**	0.55**	0.52**	−0.10*	−0.21**	0							
8 *Dummy Science Park*	0.29**	0.51**	0.49**	−0.02	−0.17**	0.34**	0.50**						
9 *Dummy Polytechnic*	0.04	0.02	−0.17**	0.09*	−0.14**	−0.09*	0.12**	−0.05					
10 *Dummy Agro-Forestry Univ.*	−0.08	−0.15**	−0.01	0.00	0.06	−0.06	−0.16**	−0.12**	−0.38**				
11 *Dummy Medical Univ.*	−0.01	−0.16**	−0.26**	−0.05	0.04	−0.20**	−0.28**	−0.10*	−0.29**	−0.10*			
12 *Dummy Hi-Tech Zone*	0.12**	0.19**	0.30**	0.06	−0.27**	0.14**	0.21**	0.31**	0.02	0.03	−0.05		
13 *Ln(Normalized Firm Numbers)*	0.02	0.02	0.05	−0.49**	0.15**	−0.12**	0.20**	0.01	−0.12**	−0.03	0.11**	−0.12**	
Mean	41.42	3.57	6.02	1.78	19.51	0	0	0.38	0.51	0.12	0.07	0.83	5.92
Std. Dev.	90.24	2.29	0.86	1.05	4.44	1	1	0.49	0.50	0.33	0.26	0.37	0.75
Minimum	0	−8.48	3.09	0	8.36	−2.87	−1.77	0	0	0	0	0	4.64
Maximum	643	9.75	7.93	5.28	29.87	3.17	3.03	1	1	1	1	1	7.82

Notes: Number of observations: 584. * $p < 0.05$; ** $p < 0.01$. Maximum VIF: 2.74, Mean VIF: 1.72. [a] Orthogonalized values.

wider scientist and/or inventor networks in which their collaborating researchers are embedded (Bramwell & Wolfe, 2008). Being embedded in a large network facilitates the inflow of innovative information from more sources, which enhances a firm's innovative capacity (Laursen & Salter, 2006). In prior studies, scientists' interpersonal networks have been found to be positively associated with commercialization and technology transfer in the biotech industry (Stuart, Ozdemir, & Ding, 2007). Luo, Koput, and Powell (2009) have convincingly argued that such scientific links increase a firm's social and intellectual capital, further contributing to its innovation performance (See also Subramaniam & Youndt, 2005). Given the positional advantage of prominent scholars in scientific networks, the spillover effect from collaborating with them should be larger than with ordinary researchers.

Thirdly, research collaboration with prominent universities can enhance a firm's legitimacy and prestige. Bishop et al. (2011: 36), for example, have documented how collaborating with top quality universities benefits a firm in terms of training personnel and the successful market introduction of new products or processes, apart from just generating more patents. Luo et al. (2009) have noted that university scientists not only serve a productive function but also play a symbolic and legitimating role which helps firms attract R&D and finance alliance partners.

Apart from a university's prominence, firms are more willing to collaborate with universities that have a strong entrepreneurial culture, since administrators in such universities are more familiar with how to manage contracted business projects. Firms can reasonably expect to encounter less cultural conflict in collaborating with researchers at these universities. So overall, universities with successful UREs tend to attract more attention from firms seeking to collaborate, which in turn gives them greater exposure to potential collaboration opportunities and increases their chances of building extensive linkages with firms.

Competition for University Technology

Although these arguments should hold for both large, established innovating enterprises and small entrepreneurial firms, there are distinctive differences between those two groups. With respect to research contracts, Shane (2002) has summarized six different ways in which universities interact differently with large firms compared with smaller ones. They range from the willingness to engage in a research contract to the spatial proximity of firms. UREs' eminence may thus have disparate effects on collaborative research activities with the two groups of firms.

In competing to collaborate with university researchers, small entrepreneurial firms are at a competitive disadvantage due to their liabilities of both smallness and newness. Large firms' credibility and status usually makes them preferred by university scholars, because collaborating with them is less risky in commercial terms

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and the scholars can gain more influence in their fields or in industry through such collaboration. Moreover, large firms have more resources for R&D. Small entrepreneurial firms are normally constrained in terms of resources and do not have strong internal R&D capabilities (Cohen & Klepper, 1996). As a result, they often lack the absorptive capacities needed to benefit from high-quality research conducted by prominent scholars (Laursen & Salter, 2004; Thursby & Thursby, 2004). Goldfarb and Henrekson (2003: 647) have published empirical evidence that the business contacts that keep good relationships with university scientists work mainly for large firms. Motohashi and Yun (2007) have presented similar evidence based on a survey of Chinese enterprises.

Small firms' disadvantages might be especially acute in dealing with a high-profile university. The scientists at such universities have higher opportunity costs than their peers in low-profile universities and may not want to take risks with resource-constrained small firms. At the same time, the technology developed in a top university is likely to be relatively radical or embryonic and to require a lot of continuous investment to commercialize, which may be beyond the capability of a small firm. In reality, Wu (2010: 217) has described how a highly-ranked university discourages faculty from collaborating with small firms due to the low technology content of the services they need.

Small entrepreneurial firms are also distinct from large established firms in the nature of the technologies they are seeking. In order to compete, some entrepreneurial firms prefer to source either very innovative or ready-to-use technology (Nerkar & Shane, 2003). However, universities are more likely to commercialize such technologies through their UREs or by taking equity in their spinoffs rather than through contracts.[15] UREs will thus crowd out entrepreneurial firms' special needs for university technology. The success of a URE may turn out to be a damper on small, new firms' collaboration with a university's scholars.

Allowing for differences between the two groups of firms seeking university technology, we formulate the following two hypotheses:

Hypothesis 2 URE eminence will positively moderate the relationship between local hi-tech LMEs' needs and the number of technology contracts signed.

Hypothesis 3: URE eminence will negatively moderate the relationship between the needs of local small entrepreneurial firms and the number of technology contracts signed.

Figure 1 illustrates the framework developed in these hypotheses.

METHODS

Data

In evaluating the performance of university technology transfer, we chose individual universities as the units of analysis. The hypotheses were tested using data from

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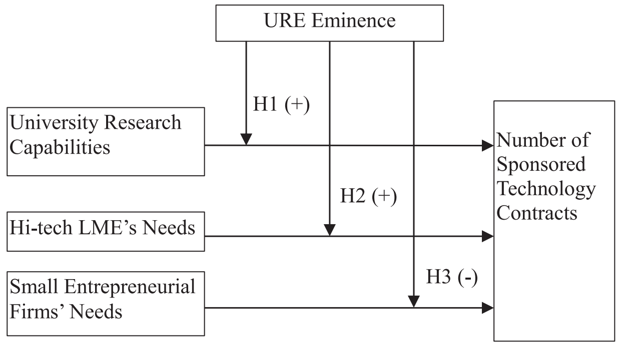

Figure 1. Proposed theoretical framework

China covering the period from 2002 to 2006. Multiple sources of official statistics released by the Chinese government were used. Specifically, the university-level information on technology contracts, total research investment, published papers, and patents granted came from the annual statistical reports on Chinese universities' science and technology activities compiled by the Ministry of Education.[16] Most of the information about UREs came from a series of statistical reports prepared by the Association of Chinese University-Run Enterprises (ACURE) for the years between 2001 and 2005. Information on university-sponsored science parks was obtained from the Ministry of Science & Technology's website. Data on hi-tech LME R&D and small entrepreneurial firms were collected from regular statistical yearbooks published by China's National Bureau of Statistics (CNBS).

Seeking to explore any moderating role of URE eminence, our sample covered only those universities having technology-based UREs.[17] Because of missing data in some years, the panel constructed was unbalanced. The universities studied were not, of course, a random sample of all Chinese higher education institutions, but together they account for the vast majority of university technology transfer activity in China. In 2005, the universities in the sample accounted for 85.3% of the contract count and 90.4% of the contractual value.

Dependent Variables

We used the number of contracts between university scientists and external knowledge users to quantify technology transfer. In prior research, Agrawal and Henderson (2002) observed that patents represent only a very small proportion of the knowledge that transfers from MIT. The Carnegie Mellon survey of R&D laboratories has shown that consulting contracts are one of four most important channels of knowledge flow (Cohen et al., 2002). Thursby and Thursby (2004) have pointed out that when inventions are too embryonic, firms are likely to pursue the invention by sponsoring faculty research. Thus, the use of contract count as our

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dependent variables was designed to capture a wide range of universities' technology transfer.[18]

Explanatory Variables

University research capacity. The availability of human capital with appropriate knowledge and know-how is necessary for technology transfer. After all, university scientists are the actual signers of technology contracts with external parties. University faculty are a primary source of the experts with suitable research training and qualifications normally crucial for the development of cutting-edge innovation. Although it is tempting to use the absolute number of a university's faculty members as the measure of its research capacity (Caldera & Debande, 2010; Powers & McDougall, 2005; Thursby & Thursby, 2002), such a crude measure suffers from a serious shortcoming. Entrepreneurial universities have multiple missions (Etzkowitz, Webster, Gebhardt, & Terra, 2000); conducting research is not the faculty's only mission. They also have teaching and social service obligations. The actual time and effort devoted to research varies greatly among university scientists. In practice, R&D personnel are often reported in terms of full time equivalent (FTEs) which is the total number of R&D personnel weighted by the proportion of their time each of them spends on R&D work. Following Crespi et al. (2011), this study used the natural logarithm of FTE R&D personnel denoted as *Ln(Univ. R&D Personnel FTE)* as the measure of a university's research capacity.[19]

URE eminence. In China, UREs operate in different sectors, and are not necessarily technology-based.[20] In terms of their signaling and demonstration effect, however, technology-based UREs should be more relevant and important than others. Moreover, it takes time for the signaling and demonstration effects of URE eminence to work. In view of these considerations, we used the natural logarithm of technology-based URE revenues in the previous year, $Ln(URE\ Revenue)_{-1}$, as the measure of operational success and a proxy for URE eminence.

Hi-tech LMEs' needs. The magnitude of the commercial needs of local hi-tech LMEs was measured using the average R&D intensity of high-tech LMEs in the province where a university was located. In empirical studies, R&D intensity is often employed as a proxy for technology competence or absorptive capacity (Cohen & Levinthal, 1990), which is regarded as being critical for firms to effectively absorb and utilize external knowledge (Thursby & Thusby, 2004). For example, Segarra-Blasco and Arauzo-Carod (2008) found that firms with a high absorptive capacity are more likely to engage in R&D cooperation with universities. From a university's point of view, Friedman and Silberman (2003) showed that proximity to regions with a concentration of high-tech firms increases the productivity of TTOs. Chapple, Lockett, Siegel, and Wright (2005) examined the performance

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of the TTOs of 50 UK universities and found that universities located in a region with higher R&D intensity are more efficient in generating new licenses. Those findings provide solid evidence for the effectiveness of employing industrial R&D intensity as a proxy for the commercial need for university-generated knowledge, a key demand-side factor.

Since R&D activities in most small firms are not institutionalized and are conducted only sporadically (Cohen & Klepper, 1996), industry-level R&D information was aggregated only for LMEs in China, according to the practices of CNBS. The average R&D intensity of local high-tech LMEs, denoted as *Hi-Tech LME R&D Intensity*, was defined as the ratio of R&D expenditure to industry output for all high-tech LMEs located in the same provinces as the focal university (multiplied by 100).

Small entrepreneurial firms' needs. Among small firms, newly established ones are usually more entrepreneurial and more aggressive in sourcing or utilizing outside technology. The technology demand arising from small and entrepreneurial firms was treated as a second important demand-side factor. Specifically, we used *Entrepreneurship Intensity*, defined as the percentage of entrepreneurial firms among the small firms operating in the same province as a focal university, to gauge the magnitude of this factor. The counts took in only manufacturing firms. The number of small firms was drawn from the Annual Survey of Chinese Manufacturing Firms.[21] In accordance with the practice suggested in the Global Entrepreneurship Monitor program (Reynolds et al., 2005), a firm was considered entrepreneurial if it had been founded within the previous 42 months.[22]

Control Variables

In order to isolate the effect of URE eminence as a reflection of research quality, it was necessary to explicitly control for the quantity of each university's research outputs.[23] For this purpose, the natural logarithm of the number of scholarly articles, *Ln(Academic papers)*, was included in the estimations along with the logarithm of the number of patents granted *Ln(Patent grants)*. To allow for possible time-lag effects, those two variables were both lagged by one year.

In addition, we employed several dummy variables to represent a university's status. The first set of dummies accounted for the disciplinary nature of each university. In accordance with the conventional classification in the Chinese university system, we distinguished between four generic types of universities: (1) Comprehensive universities where faculty members conduct research in many fields including the natural and social sciences, medicine, law, the liberal arts, and engineering; (2) Polytechnic universities which focus on engineering; (3) Agronomy-Forestry; and (4) Medical colleges. The comprehensive universities (31% of the sample) were used as the reference base. About half of the universities

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were in the second category. The third and fourth types accounted for 11.2% and 7.4% of the sample, respectively.

Science parks represent another mechanism universities use to promote technology transfer. Caldera and Debande (2010) found that universities with a science park have better technology transfer performance than those without. To allow for the impact of knowledge agglomeration close to universities, we included a dummy variable to indicate whether a university had established a science park accredited by the Ministry of Science and Technology.

In addition, we incorporated two variables to control for location effects. The first was a dummy indicating whether there is a high-tech development zone in the city where a university was located. The second quantified the extent to which a university was exposed to potential cooperating firms. It was the natural logarithm of the number of local firms normalized by the number of universities in the region, denoted as *Ln(Normalized Firm Numbers)*.

Technology transfer performance may vary over time as a function of various environmental changes. To allow for such unobservable time effects, we incorporated four-year dummies with the year 2002 as the reference.

Due to scale effects in university research capacity, several variables were assumed to be strongly correlated. Any multicollinearity would inflate standard errors and render estimations unstable. In order to deal with multicollinearity, we followed prior research (Sine et al., 2005) and orthogonalized the two highly correlated variables, *Ln(Academic papers)_1* and *Ln(Patent grants)_1* using the *orthog* command in the STATA software package to partial out the common variance. The orthogonalized measures uncorrelated with each other were used in the estimations. Table 1 presents summary statistics and pairwise correlations for all variables. The usual multicollinearity test shows that all of the variation inflation factors were less than 2.74, indicating that collinearity was not a concern in the analyses.

RESULTS

Since the dependent variable in this analysis was the discrete number of technology contracts, econometric techniques designed for count panel data are appropriate for estimation and inference. As can be noted in Table 1, the variance of the technology contract count was much larger than its mean, indicating overdispersion in the data. In such cases, negative binomial models are more appropriate than Poisson models which assume equality of the mean and variance (Cameron & Trivedi, 2013). Negative binomial regression techniques for panel data (Hausman, Hall, & Griliches, 1984) were therefore applied and findings from both fixed- and random effects model specifications will be reported. One problem with fixed-effects models is that universities with only one observation in the data would be excluded. To make full use of the sample's information, we draw inferences and discuss findings mainly based on the random-effects

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specifications. The findings from the fixed-effects models were, however, actually similar.

Except for interaction terms, all of the variables were mean-centered in the estimations. Three interaction terms were created in order to examine the hypothesized moderations of URE eminence. They were *Ln(URE Revenue)_1*'s interactions with *Ln(Univ. R&D Personnel FTE)*, *Hi-Tech LME R&D Intensity*, and *Entrepreneurship Intensity*. We first regressed the products against the two constructing variables, and then used the estimated residuals in subsequent estimation. This procedure does not affect the statistical significance of the interaction terms but can largely alleviate the threat of collinearity arising from the interaction terms.

Main Findings

Table 2 reports the coefficients of negative binomial regressions based on the whole sample of 195 universities. Column (1) is the base case where only the control variables are included. The three proposed predictors and the moderator are added in column (2). It is clear that all three main predictors are statistically significant, which justifies our maintained assumption that a university's technology transfer performance is determined jointly by its research capacity and local demand. The moderator, however, is not statistically significant, suggesting that URE eminence does not directly influence the number of contracts.

With all three interaction terms included, the estimations using random-effects models are reported in column (3). The estimated coefficients of two of the interaction terms – *Ln(URE Revenue)_1* × *Ln(Univ. R&D Personnel FTE)* and *Ln (URE Revenue)_1* × *Hi-Tech LME R&D Intensity* – are positive and statistically significant (p-value = 0.007 and 0.002, respectively). The interaction term *Ln(URE revenue)_1* × *Entrepreneurship Intensity* demonstrates no statistical significance (p-value = 0.519), however, implying that URE eminence does not moderate the impact of local small entrepreneurial firms' needs. We also report the estimations from the fixed-effects models in column (4), (5), and (6). The results are almost the same.

It is important to note that, due to the nonlinear nature of these models, the estimated coefficient of an interaction term cannot be interpreted in the same way as in a linear model. When it is not statistically significant, it is proper to claim the non-existence of a moderation relationship. But when it is significant the statistical significance or the magnitude of the moderating relationship cannot be inferred directly from the estimated coefficient of the interaction term (Wiersema & Bowen, 2009). Instead, the secondary moderating effect should be considered as the true effect of the focal variable contributing to the overall moderation (Bowen, 2012). Following the advice of Wiersema and Bowen (2009), we would need to compute the marginal effects of *Ln(Univ. R&D Personnel FTE)* and *Hi-Tech LME R&D Intensity* on the number of contracts at different values of *Ln (URE Revenue)_1*, with all other variables set to their mean values. Since *Ln(URE*

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Table 2. Negative binomial regressions of technology contract counts

	Random Effects			Fixed Effects		
Coefficients	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Log(Univ. R&D personnel FTE)		0.231*	0.233*		0.315**	0.290**
		(0.095)	(0.094)		(0.113)	(0.111)
		0.015	*0.013*		*0.005*	*0.009*
Hi-Tech LME R&D intensity		0.186**	0.168**		0.152*	0.108
		(0.051)	(0.051)		(0.062)	(0.063)
		0.000	*0.001*		*0.014*	*0.084*
Entrepreneurship Intensity		0.036**	0.036**		0.034*	0.032
		(0.013)	(0.013)		(0.016)	(0.016)
		0.005	*0.005*		*0.032*	*0.051*
Log(URE revenue)$_{-1}$		−0.009	0.009		−0.011	0.014
		(0.034)	(0.032)		(0.039)	(0.036)
		0.779	*0.786*		*0.771*	*0.690*
Log(URE revenue)$_{-1}$ *X*			0.079**			0.085*
Log(Univ. R&D personnel FTE)			(0.029)			(0.037)
			0.007			*0.019*
Log(URE revenue)$_{-1}$ *X*			0.066**			0.101**
Hi-Tech LME R&D intensity			(0.021)			(0.024)
			0.002			*0.000*
Log(URE revenue)$_{-1}$ *X*			−0.003			−0.003
Entrepreneurship Intensity			(0.005)			(0.007)
			0.519			*0.643*
Log(Academic papers)$_{-1}$	0.034	−0.063	−0.085	−0.079	−0.180*	−0.244**
	(0.064)	(0.073)	(0.074)	(0.080)	(0.087)	(0.089)
	0.599	*0.389*	*0.251*	*0.324*	*0.039*	*0.006*
Log(Patent grants)$_{-1}$	0.103	0.045	0.039	−0.134	−0.211*	−0.227*
	(0.071)	(0.089)	(0.088)	(0.084)	(0.101)	(0.099)
	0.143	*0.613*	*0.662*	*0.109*	*0.037*	*0.022*

Table 2. Continued

	Random Effects			Fixed Effects		
Coefficients	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Dummy Science Park	−0.158	−0.071	−0.092	−0.277	−0.200	−0.194
	(0.129)	(0.132)	(0.134)	(0.152)	(0.154)	(0.156)
	0.223	*0.589*	*0.491*	*0.068*	*0.195*	*0.214*
Dummy Polytechnic	0.055	0.205	0.276	−0.244	0.014	0.122
	(0.137)	(0.146)	(0.148)	(0.188)	(0.201)	(0.205)
	0.688	*0.160*	*0.063*	*0.194*	*0.946*	*0.552*
Dummy Agro-Forestry Univ.	−0.356	−0.350	−0.303	−0.263	−0.215	−0.094
	(0.201)	(0.203)	(0.207)	(0.280)	(0.285)	(0.295)
	0.076	*0.084*	*0.144*	*0.348*	*0.451*	*0.750*
Dummy Medical Univ.	−0.541*	−0.425	−0.410	−0.633	−0.407	−0.338
	(0.256)	(0.262)	(0.265)	(0.407)	(0.424)	(0.435)
	0.035	*0.105*	*0.122*	*0.120*	*0.337*	*0.437*
Dummy Hi-Tech Zone	0.181	0.193	0.265	0.083	0.088	0.232
	(0.173)	(0.178)	(0.181)	(0.306)	(0.305)	(0.308)
	0.297	*0.278*	*0.144*	*0.786*	*0.772*	*0.451*
Log(Normalized Firm Numbers)	0.158	0.254**	0.240**	0.062	0.184	0.163
	(0.085)	(0.088)	(0.088)	(0.126)	(0.130)	(0.128)
	0.062	*0.004*	*0.006*	*0.624*	*0.159*	*0.203*
Log likelihood	−2365	−2352	−2343	−1336	−1328	−1316
Wald Chi2	24.59	51.98	78.76	15.27	33.97	64.26
Observations	584	584	584	569	569	569
Number of universities	196	196	196	181	181	181

Notes: Standard errors are shown in parentheses. *P* values are displayed below the standard errors in italics. Year dummies and constant terms were included in all of the regressions, but are not reported for brevity. ** $p < 0.01$, * $p < 0.05$.

Revenue)_1 was not itself statistically significant and all of the variables had been mean-centered, it can be shown mathematically that these marginal effects are always positive and significant, independent of the value of the moderator variable (See the appendix for a detailed explanation). Hence H1 and H2 were supported. But since the estimated coefficient of *Ln(URE revenue)_1* × *Entrepreneurship Intensity* was not statistically significant, H3 must be rejected. In combination, we find that the moderating impacts of URE eminence are distinct between LMEs and small entrepreneurial firms. It seems that although Chinese universities operating eminent UREs collaborate more with LMEs, they do not discriminate against small entrepreneurial firms in terms of transferring technology.

The estimated coefficients in Table 2 allow estimating the size of the moderating effects of URE eminence. With all of the variables set at their mean values, a one standard deviation increase in *Ln(Univ. R&D personnel FTE)* predicts an 18.9% increase in the expected number of contracts. If *Ln(URE revenue)_1* is set at one standard deviation above its mean, however, the same increase in *Ln(Univ. R&D personnel FTE)* increases the expected number of contracts by 39.0% (equivalent to 8.3 more contracts). Similarly, if *Hi-Tech LME R&D Intensity* increases by one standard deviation, the expected number of contracts will increase by 19.8% when the moderator is set at its mean and by 40.4% when it is one standard deviation above the mean, a difference of 8.5 contracts.

As an additional graphical illustration, Figure 2 depicts two interaction plots based on the results reported in column (3) of Table 2. In each subplot the relationship between the supply or demand factor and the predicted multipliers of contract count is compared between the two cases where the moderating variable *Ln(URE Revenue)_1* is set at one standard deviation above and one standard deviation below its mean, assuming all of the other variables take their mean values. Since the dispersion parameters of negative binomial distributions are randomly distributed in a random-effects estimation, they were set at unity to facilitate comparison and interpretation. What is aligned on the vertical axis of each interaction subplot is therefore not the predicted mean, but a multiplier which should be multiplied by a university-specific dispersion parameter to obtain the conditional mean.

In subplot (a), graphical support for Hypothesis 1 is clearly evident. Hypothesis 1 proposes that URE eminence has a positive moderating impact on the contribution of university research capacity. This is revealed in the interaction plot by a stronger positive relationship between *Ln(Univ. R&D personnel FTE)* and the predicted mean multipliers at the higher value of *Ln(URE revenue)_1*. Similarly, the relationship between *Hi-Tech LME R&D Intensity* and the predicted mean multipliers is more prominent at the higher level of URE eminence in subplot (b), lending graphical support to Hypothesis 2 pertaining to the positive moderating effect of URE eminence on the contributing role of local high-tech LMEs' demand.

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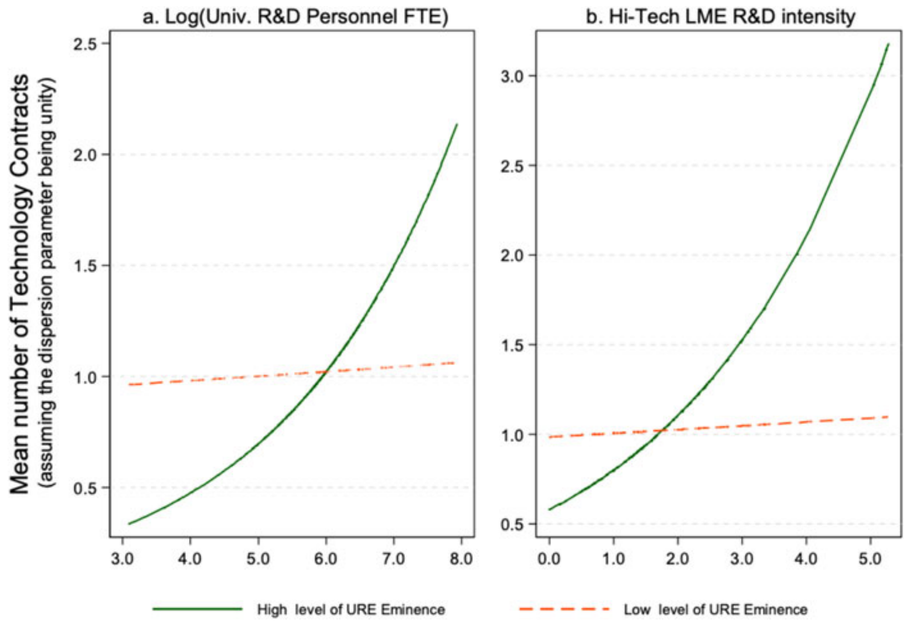

Figure 2. An illustration of the moderating impacts of URE eminence

Robustness Check

Although it is claimed that URE eminence reflects the quality of a university's research, in reality, UREs' revenue is not the best available indicator of the difference in research quality among universities. The count of paper citations is very often used instead (Powers & McDougall, 2005). We did not use that measure for two reasons. First, during the period studied many Chinese universities had a very small number of international publications each year. The average citation number per paper thus would have fluctuated wildly, making it an unreliable indicator in this particular case. Second, the citation information reported by Thomson Reuters (now Clarivate Analytics) is rarely known to most Chinese firms, because few Chinese firms published academic papers in international journals. Firms were therefore unlikely to have incorporated this measure into their collaboration decisions. Nevertheless, we can take advantage of this information to conduct an additional check to see whether URE performance does play a signaling role.

Specifically, we constructed an additional variable, *Ln(Average Citations)*, to gauge university research quality in our additional analysis. Based on the Essential Science Indicators (ESI) reported by Thomson Reuters, we obtained information on the average citation count received by academic articles published between 2002 and 2006 by scientists from a focal university. The average citation count was updated up to August 31, 2012. We used its natural logarithm as a proxy for a university's research quality. It merits noting that the citation counts reported by ESI take in all papers published during the five years from 2002 to 2006. They

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are time-invariant during the sample period. Since this information is available only for a small group of universities, the check was based on a subsample of 81 universities.

To see whether URE eminence is an effective signal of university research quality, we first checked the correlation between *Ln(URE Revenue)_1* and *Ln (Average Citations)* and found that URE eminence was strongly associated with average citation count. In the next step, we formulated three interaction terms with *Ln(Average Citations)* as the new moderator and examined whether and to what extent the moderating effects of URE eminence are mediated by the new moderator. Table 3 lists results.

In column (1) of Table 3, when only the moderating effects of URE eminence are considered in the subsample, the main results are similar to those with the whole sample in Table 2. When the potential moderator of research quality is taken into account separately in column (2), only the interaction term *Ln(Average Citations) × Hi-Tech LME R&D Intensity* is statistically significant (p-value = 0.000). That suggests that research quality moderates the importance of high technology LMEs needs only. When the moderations of both URE eminence and research quality are incorporated into the model in column (3), URE eminence is no longer significantly moderating the relationships between Hi-tech LME's needs and technology transfer performance (p-value = 0.543), but the coefficient of *Ln (URE Revenue)_1 × Ln(Univ. R&D Personnel FTE)* remains its significance (p-value = 0.000). Similar results were obtained with fixed-effects models, as the last three columns of Table 3 show clearly.

These consistent findings imply that whatever URE eminence conveys to high-tech LMEs, it is submerged by the direct information citations convey. When such clear information about research quality is available, URE eminence has little to add. On the other hand, these results do reveal that URE eminence is able to signal research quality when better information is missing or unavailable. That supports our proposition that URE eminence is a reflection of a university's research quality and that it conveys a message about the commercial values of a university's technology. In this respect, UREs serve as models of universities' entrepreneurship. It is also important to note that no matter whether or not research quality is explicitly taken into consideration, the estimated coefficient of *Ln(URE Revenue)_1 × Ln(Univ. R&D Personnel FTE)* is always positive and significant. This is not surprising if URE eminence reflects a strong entrepreneurial culture at a university. So, the additional analyses also support our argument about university entrepreneurship culture.

Table 4 further checks the robustness of our findings with several alternative specifications. In China, it is widely accepted that universities entitled to participate in the government's 'Project 985' or 'Project 211' are more research intensive and prestigious. In column (1), we incorporate two indicator variables, *Dummy_211* and *Dummy_985*, to represent such participation and obtain similar results. Since the two dummies are highly intercorrelated and also correlated with *Ln(Univ. R&D*

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Table 3. Robustness check - Accounting for research quality

	Random Effects			*Fixed Effects*		
Coefficients	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Log(Univ. R&D personnel FTE)	0.255	0.251	0.287	0.287	0.252	0.252
	(0.171)	(0.167)	(0.173)	(0.189)	(0.183)	(0.188)
	0.135	*0.133*	*0.097*	*0.129*	*0.167*	*0.180*
Hi-Tech LME R&D intensity	0.110	0.085	0.034	0.114	0.054	0.012
	(0.070)	(0.072)	(0.073)	(0.076)	(0.077)	(0.079)
	0.120	*0.243*	*0.641*	*0.133*	*0.482*	*0.877*
Entrepreneurship Intensity	0.038*	0.019	0.025	0.048*	0.021	0.037
	(0.018)	(0.019)	(0.019)	(0.021)	(0.022)	(0.022)
	0.036	*0.329*	*0.194*	*0.021*	*0.335*	*0.092*
Log(URE revenue)$_{-1}$	0.071		0.086	0.113		0.165**
	(0.050)		(0.054)	(0.060)		(0.064)
	0.160		*0.109*	*0.059*		*0.010*
Log(URE revenue)$_{-1}$ X Log(Univ. R&D personnel FTE)	0.186**		0.218**	0.176**		0.217**
	(0.059)		(0.061)	(0.066)		(0.071)
	0.002		*0.000*	*0.007*		*0.002*
Log(URE revenue)$_{-1}$ X Hi-Tech LME R&D intensity	0.063*		0.020	0.090**		0.026
	(0.029)		(0.033)	(0.032)		(0.035)
	0.030		*0.543*	*0.006*		*0.461*
Log(URE revenue)$_{-1}$ X Entrepreneurship Intensity	−0.012		−0.010	−0.007		−0.002
	(0.009)		(0.009)	(0.009)		(0.009)
	0.172		*0.266*	*0.471*		*0.816*
Log(Average Citations)		−0.640*	−0.663*		−1.276**	−1.289**
		(0.289)	(0.284)		(0.392)	(0.393)
		0.027	*0.019*		*0.001*	*0.001*
Log(Average Citations) X Log(Univ. R&D personnel FTE)		0.035	−0.140		−0.317	−0.602
		(0.436)	(0.437)		(0.536)	(0.550)
		0.935	*0.748*		*0.554*	*0.273*

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Table 3. Continued

	Random Effects			*Fixed Effects*		
Coefficients	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Log(Average Citations) X Hi-Tech LME R&D intensity		0.743**	0.688**		0.934**	0.820**
		(0.202)	(0.219)		(0.240)	(0.261)
		0.000	*0.002*		*0.000*	*0.002*
Log(Average Citations) X Entrepreneurship Intensity		0.013	0.029		−0.001	−0.009
		(0.043)	(0.044)		(0.046)	(0.049)
		0.767	*0.510*		*0.989*	*0.848*
Log(Academic papers)$_{-1}$	0.029	0.052	0.007	−0.080	−0.002	−0.061
	(0.103)	(0.096)	(0.100)	(0.109)	(0.101)	(0.102)
	0.778	*0.587*	*0.946*	*0.463*	*0.986*	*0.548*
Log(Patent grants)$_{-1}$	0.128	0.172	0.136	−0.023	0.077	−0.002
	(0.108)	(0.102)	(0.106)	(0.119)	(0.109)	(0.115)
	0.235	*0.092*	*0.202*	*0.846*	*0.481*	*0.986*
Dummy Science Park	0.117	−0.009	0.014	0.107	−0.063	−0.014
	(0.166)	(0.169)	(0.172)	(0.186)	(0.191)	(0.194)
	0.480	*0.957*	*0.933*	*0.564*	*0.741*	*0.941*
Dummy Hi-Tech Zone	−0.668*	−0.518	−0.517	−1.361*	−0.800	−1.113
	(0.339)	(0.354)	(0.351)	(0.574)	(0.552)	(0.602)
	0.049	*0.143*	*0.142*	*0.018*	*0.147*	*0.065*
Log(Normalized Firm Numbers)	0.306*	0.258	0.267*	0.301	0.193	0.158
	(0.123)	(0.136)	(0.134)	(0.156)	(0.178)	(0.177)
	0.013	*0.057*	*0.046*	*0.054*	*0.277*	*0.371*
Log likelihood	−1415	−1416	−1407	−915	−910	−902
Wald Chi2	72.04	58.20	88.07	62.49	64.43	86.77
Observations	319	319	319	318	318	318
Number of universities	81	81	81	80	80	80

Notes: Standard errors are shown in parentheses. *P* values are displayed below the standard errors in italics. Year dummies, university type dummies and constant terms were included in all of the regressions, but are not reported for brevity. ** $p < 0.01$, * $p < 0.05$.

Table 4. Robustness check – Alternative specifications

Coefficients	*Including University Status* (1)	*Including Region Dummies* (2)	*Using volume measures* (3)	*Using Hi-tech measures* (4)	*Three-year Small Sample* (5)
Log(Univ. R&D personnel FTE)	0.292**	0.346**	0.225*	0.243*	0.235*
	(0.093)	(0.104)	(0.095)	(0.095)	(0.101)
	0.002	*0.001*	*0.018*	*0.011*	*0.020*
Hi-Tech LME R&D intensity	0.141**	−0.101	−0.009	0.142**	0.233**
	(0.051)	(0.085)	(0.041)	(0.052)	(0.063)
	0.005	*0.238*	*0.819*	*0.006*	*0.000*
Entrepreneurship Intensity	0.039**	0.037	0.534**	0.012	0.036*
	(0.013)	(0.022)	(0.129)	(0.012)	(0.014)
	0.002	*0.083*	*0.000*	*0.290*	*0.013*
Log(URE revenue)$_{-1}$	0.021	−0.018	−0.015	0.007	−0.009
	(0.032)	(0.034)	(0.031)	(0.032)	(0.035)
	0.514	*0.599*	*0.640*	*0.820*	*0.791*
Log(URE revenue)$_{-1}$ *X*	0.094**	0.065*	0.074**	0.074*	0.079*
Log(Univ. R&D personnel FTE)	(0.029)	(0.030)	(0.028)	(0.029)	(0.033)
	0.001	*0.031*	*0.007*	*0.011*	*0.017*
Log(URE revenue)$_{-1}$ *X*	0.059**	0.077**	0.032	0.073**	0.067**
Hi-Tech LME R&D intensity	(0.021)	(0.021)	(0.018)	(0.021)	(0.025)
	0.005	*0.000*	*0.069*	*0.000*	*0.008*
Log(URE revenue)$_{-1}$ *X*	0.001	−0.007	−0.021	−0.006	−0.001
Entrepreneurship Intensity	(0.005)	(0.005)	(0.034)	(0.005)	(0.006)
	0.906	*0.161*	*0.531*	*0.197*	*0.813*
Log(Academic papers)$_{-1}$	0.041	−0.083	−0.051	−0.079	−0.053
	(0.077)	(0.074)	(0.072)	(0.074)	(0.080)
	0.595	*0.259*	*0.474*	*0.282*	*0.511*
Log(Patent grants)$_{-1}$	0.233*	0.050	0.054	0.030	0.073
	(0.096)	(0.091)	(0.088)	(0.088)	(0.100)

Table 4. Continued

Coefficients	*Including University Status* *(1)*	*Including Region Dummies* *(2)*	*Using volume measures* *(3)*	*Using Hi-tech measures* *(4)*	*Three-year Small Sample* *(5)*
	0.015	*0.585*	*0.539*	*0.732*	*0.468*
Dummy Science Park	0.102	−0.122	−0.104	−0.148	−0.225
	(0.140)	(0.138)	(0.129)	(0.133)	(0.160)
	0.468	*0.377*	*0.423*	*0.266*	*0.161*
Dummy Hi-Tech Zone	0.435*	0.484**	0.272	0.210	0.320
	(0.187)	(0.184)	(0.178)	(0.180)	(0.188)
	0.020	*0.009*	*0.127*	*0.244*	*0.089*
Log(Normalized Firm Numbers)	0.217*	−0.694	−0.470**	0.215*	0.282**
	(0.088)	(0.385)	(0.171)	(0.089)	(0.098)
	0.013	*0.071*	*0.006*	*0.016*	*0.004*
Dummy_211	−0.619**				
	(0.203)				
	0.002				
Dummy_985	−0.642**				
	(0.202)				
	0.001				
Dummy Regions		Included			
Log likelihood	−2332	−2302	−2345	−2345	−1922
Wald Chi2	104.5	167.3	66.62	73.83	66.97
Observations	584	584	584	584	489
Number of universities	196	196	196	196	196

Notes: Standard errors are shown in parentheses. *P* values are displayed below the standard errors in italics. Year dummies, university type dummies and constant terms were included in all of the regressions but are not reported for brevity. ** $p < 0.01$, * $p < 0.05$.

1. To avoid sample attrition, all of the specifications are estimated with random-effects models.
2. In column (3), the variables Hi-Tech LME R&D Intensity and Entrepreneurship Intensity are replaced by Ln(Hi-Tech LME R&D) and Ln(Number of Entrepreneurial Firms), respectively.
3. In column (4), the variable, Entrepreneurship Intensity, is replaced by Hi-Tech Entrepreneurship Intensity.

personnel FTE), the negative coefficients of the two dummies seem to indicate that it is not advisable to include all these highly correlated variables.

One might imagine that universities located in different regions and institutional contexts have different strategies in commercializing their technology. To account for this, province-level region dummies were created to control for such regional differences. Column (2) of the table shows that this made no difference.

Our main specification used two ratios to proxy for the strength or intensity of local demand. As an additional check, they were replaced with two volume measures, *Ln(Hi-Tech LME R&D)* and *Ln(Number of Entrepreneurial Firm)*. The results in column (3) show that the conclusion about H1 still hold, although the coefficients of *Ln(URE revenue)_1* X *Ln(Hi-Tech LME R&D)* is marginally significant now (p-value = 0.069).[24]

Regarding the local needs from small entrepreneurial firms, one may argue that only technology-driven firms should be considered, in light of our focus on technology-based UREs. In fact, though, entrepreneurial firms' lines of business are often subject of adjustment in their infant stage. To capture their needs for university technology, their lines of business were ignored in favor of their entrepreneurial nature. Nonetheless, to check whether focusing on a narrow set of high-tech small entrepreneurial firms would change the conclusions, a new variable, *Hi-Tech Entrepreneurship Intensity*, was constructed as the proportion of entrepreneurial firms among small firms in the hi-tech industries. *Entrepreneurial Intensity* was replaced with this new variable, and the results are reported in column (4). It can be seen that the main conclusions still hold.

Finally, this analysis was based on a non-random sample. It included only those universities with URE revenue reported by ACURE, raising concerns about sample selection. Since inclusion was based on a fixed rule (whether a university operated technology-based UREs) and since our dependent variables were observed for all universities, the use of a random sample from one subset of universities did not actually induce selection bias.[25] However, because of a number of missing values of *Ln(Academic papers)_1* and *Ln(Patent grants)_1* in 2002 and 2003, we could have incurred a sample selection issue due to nonrandom missing observations. Dropping the 95 observations in those two years produced a smaller but more balanced three-year sample. The results based on this subsample are reported in column (5) and are consistent with the main findings, which further mitigates concerns about selection bias.

DISCUSSION

In this article, it is argued that URE eminence signals a strong entrepreneurial culture, as well as research quality at a university. Based on a panel dataset covering 195 universities between 2002 and 2006, the moderating effects of URE eminence on the relationship between the number of technology contracts and the two sets of contributing factors are investigated empirically. Consistent findings from

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multiple models and alternative specifications reveal strong support for the argument pertaining to the signaling and demonstration effect of URE eminence.

Contributions

This study advances scholarly understanding of the role that UREs play in Chinese university systems. Whereas much of previous discussions of Chinese UREs has emphasized financial and ownership risks they bring to a university (Xue, 2006), their potential for promoting university entrepreneurship has been insufficiently treated. This study's linking UREs with enhanced TTO performance provides a different view of URE eminence and broadens our knowledge of UREs in China. Our findings complement prior work that has stressed the importance of an entrepreneurial culture and doing good-quality research for technology transfer from a university (Jacob et al., 2003; Kenney & Goe, 2004; Mansfield, 1995; Thursby & Kemp, 2002). URE eminence allows for both effects to manifest themselves.

This work also has implications for organizational design in entrepreneurial universities (Etzkowitz, 2003; Jacob et al., 2003). The theoretical framework developed in this analysis is consistent with the interactive model of university entrepreneurship. It highlights the important role of TTOs and incubator facilities as interface capacities (Debackere & Veugelers, 2005; Siegel et al., 2003) and validates the idea that UREs also serve as intermediaries and are important organizational resources that facilitate research commercialization.

The findings add to prior literature on the relationship between firm size and the use of university technology (Acs et al., 1994; Cohen et al., 2002). The data show that LMEs have an advantage over small entrepreneurial firms in sourcing technology from high-profile universities. By incorporating the impact of research quality, this analysis has enriched our understanding from a university's perspective.

Finally, this study has shed further light on the importance of absorptive capacity for firms sourcing academic knowledge. In particular, it has shown that the magnitude of absorptive capacity's effect on firms' incentive to utilize university knowledge is related to the quality of the university's research. This insight emphasizes the importance of research quality in university technology transfer (Bramwell & Wolfe, 2008; Stuart et al., 2007), and it also bridges between the two streams of literature on absorptive capacity and on university entrepreneurship.

Limitations and Future Research Implications

There are a number of limitations to this study that can be explored in future research. First, since UREs represent a unique phenomenon in Chinese university systems, the framework developed here may not be helpful for understanding university entrepreneurship in other contexts. The findings suggest, however, that this

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point is potentially a fertile area for future research. In European countries and the US, spin-offs are a popular mechanism for transferring academic technology (Di Gregorio & Shane, 2003). Whether spin-offs have a similar signaling or demonstration effect is certainly an interesting topic worthy of study. Future research can enhance the external validity of the findings in this analysis by examining the effect of spin-offs in other settings.

Second, this study considered external needs emanating from manufacturing firms only. Firms in service and other industries also have great demand for university technology. Ignoring their needs may cause an underestimation of the real effect of URE eminence. The type of technology transferred, and the rate of technology commercialization will presumably vary among sectors. Future work can seek to understand the potential implications of URE eminence for technology sourcing by firms in sectors other than manufacturing.

Third, due to data unavailability, we have not controlled for TTO-level variables. The analyses were also based on a short panel spanning only five years, which constrained our ability to infer any causal relationships. In particular, it is empirically difficult to distinguish between entrepreneurial culture and university strategy or policy. Although they implicitly were treated equally in these analyses, it is possible that the effect of URE eminence is confounded with that of university strategy. One should thus keep these caveats in mind when interpreting the study's results. Future work could advance understanding of both effects by examining the issue with a statistical matching method.

Fourth, since the unit of analysis was the university, the main findings have been inferred based solely on secondary data. Consequently, how URE eminence impacts individual scientists' incentives, orientations, and behavior has not been investigated in detail. Further insights can probably be gained by investigating the demonstration and signaling effect of URE eminence on the level of the individual scientist or firm.

Implications for Practice

Although it is not wise for university administrators to get involved in managing UREs by themselves, operating UREs does convey to both faculty and knowledge users a message that helps to facilitate direct technology transfer between faculty and external firms. Considering that many Chinese universities have recently divested URE operations and refocused on their research mission, to what extent that such divesture has affected research productivity is worth serious study.

For large firms seeking high-quality research from university collaborators, it is probably wise to collaborate with a university which is operating successful UREs. In such universities an entrepreneurial culture has been cultivated to foster knowledge sharing and learning between the university and firms. It is also more likely that the research conducted by scientists at such universities is of higher quality. Faculty members there are also more productive and more

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prone to commercialize their research. Firms can expect fewer cultural conflicts. Compared to their larger counterparts, small entrepreneurial firms are at a disadvantage in collaborating with top universities. To be able to do so, small firms are advised to exploit incentive mechanisms such as equity sharing to counteract the disadvantage.

CONCLUSION

As an important technology transfer mechanism, UREs represent a unique feature of academic entrepreneurship in Chinese university systems. This study has shown that URE eminence positively moderates the impact of university research capacities and the needs of large, local high-tech firms. The findings not only enhance scholarly understanding of the role of UREs in China, but also advance our knowledge of UREs as important organizational resources in university entrepreneurship more generally.

NOTES

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[1] The three terms technology contract, research contract and contractual agreement will be used interchangeably in this analysis.

[2] To put discussions into context, the statistics we used throughout the article refer to our observation period 2002–2006 only.

[3] According to Ministry of Education of China (2006), the count ratio of patent licenses to contracts was 0.115 in 2005 and in terms of value it was 0.234.

[4] In scholarly literature, different terms have been used for such enterprises, including university-owned enterprises, university-initiated spin-offs (Kroll & Liefner, 2008), university-affiliated enterprises (Zou & Zhao, 2014), and university-operated enterprises (Chen et al., 2016). Eun et al. (2006) provided a detailed account for their prevalence in China. Zou and Zhao (2014: 666) described the evolution of UREs at one prestigious Chinese university.

[5] For example, among the 173 university entrepreneurship articles reviewed by Rothaermel et al. (2007), none exhibited an explicit focus on China.

[6] Although almost all universities in China are state-owned, only 51% of university revenues came from the government in 2005. Industry funding accounted for 41%, while students' tuition contributed less than 8% (Ministry of Education of China, 2006).

[7] Thursby and Kemp (2002) have argued that a university's poor research quality implies it is more efficient in commercial activities. In terms of scholarly publications, even prestigious universities in China do not produce as much high-quality research as their western counterparts (Xue, 2006).

[8] Several leading business groups in China originated from UREs. For example, Founder and Tongfang were established by Peking University and Tsinghua University, respectively.

[9] A university president or vice president usually chairs the board of a large URE to ensure its state ownership in the 1990s (Wu, 2010).

[10] According to Ministry of Education of China (2006), URE revenues in total were about 1.02 billion RMB in 2005, less than the total income of technology contracts, the 1.28 billion RMB.

[11] It should be noted that university scientists sometimes also sign technology contracts with UREs associated with their universities. The share of these contracts, however, is quite small. In the case of Tsinghua University, one of the most prestigious universities in China, for example, only about 10% of technology contracts come from its UREs.

[12] See Balconi et al. (2010) for a discussion of the validity of the linear model.

[13] Tsinghua University, for example, allowed a group of university professors to devote their full energy to commercializing a new technology with Tongfang, one of its UREs. That led to the introduction of one of Tongfang's most successful products. Moreover, promotion criteria were specially formulated for that group of professors to substitute for the conventional emphasis on scholarly publications (Guangming Daily, April 3, 2004).

[14] Universities engaging in the government's '985' project are officially regarded as the top research universities in China. By the end of 2001, there were 29 universities in the '985' project.

[15] The general manger of a URE interviewed told the author that they have a screening process which assesses the innovativeness of technologies developed by the faculty. They try to select the most innovative ideas to commercialize.

[16] The series of reports contains rich university-level information on human capital, R&D investment, patents, papers, and technology contracts. Such information was reported to China's Ministry of Education by the universities annually.

[17] With respect to research commercialization, universities without technology-based UREs are likely to be fundamentally different from those operating UREs. Any moderating effect of URE eminence would thus be predicated on the existence of a URE.

[18] Contract values were not used as the dependent variable for two reasons. First, about 11.8% of the observations had a contract value of zero because the contract count was zero for those observations. It would have been difficult to handle those zeros with contract value as the dependent variable. Secondly, the amount of money actually received from research contracts is often paid by installments and subject to change. The reported contract values are thus likely to be inaccurate, especially for those embryonic or explorative projects. Nonetheless, several linear panel data models were estimated using the logarithm of contract value as the dependent variable after dropping the zero observations. Although the results are not really comparable with those of the main analysis, we do find some support for H1 or H2, depending on whether random- or fixed- effects models were specified. In any case, H3 was not supported.

[19] Patents or paper counts were not used because we tried to capture the capacity available for research, not the outcome of university research. *Ln(Univ. R&D Personnel FTE)* can in fact be considered a proxy for a university's size.

[20] In 2005 over 40% of the UREs studied were operating in non-technology lines of business such as running a hotel, publishing or providing logistics services.

[21] The definition of small firms follows the convention of Chinese statistical practice. See Li and Mitchell (2009: 376) for a description of classification criteria.

[22] Reynolds et al. (2005) classified a firm as being established if it had paid salaries and wages for more than 42 months.

[23] Ideally, it would be better to use the number of research paper citations as a direct control for research quality. The citation information was not available, however, for most non-research-oriented universities in China.

[24] As has been explained, the local demand for university technology is more likely to emanate from R&D-intensive and/or entrepreneurial firms. The main specification used ratio measures rather than volume measures simply to emphasize the importance of R&D and entrepreneurship intensity while controlling for regional scale with the *Ln(Normalized Firm Numbers)* variable. Since volume measures of R&D investment and entrepreneurial firm counts are strongly associated with a region's scale, the use of volume measures will likely contaminate the estimations and weaken the findings. For example, the correlation coefficients between *Ln(Normalized Firm Numbers)* and the two volume measures *Ln(Hi-Tech LME R&D)* and *Ln(Number of Entrepreneurial Firm)* in these data were 0.49 and 0.89, respectively. Besides the significance of *Ln(URE revenue)*$_{-1}$ X *Ln(Hi-Tech LME R&D)* being marginal, the estimated coefficient of *Ln(Normalized Firm Numbers)* in column (4) is negative, suggesting that using volume measures is not preferred.

[25] Our models were specified only for the subset of universities having technology-based UREs in operation, which is a subpopulation of all Chinese universities. Since we had an arguably random sample from this subset of universities, according to Wooldridge (2010: 795), selection bias was not an issue in this case.

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APPENDIX I

Let x_1 and x_m be an independent variable and a moderator, respectively. Assume that the dependent variable y is related to x_1 and x_m in a negative binomial (NB) model as follows: $\Upsilon = E[y] = e^z = e^{(\beta_0+\beta_1 x_1+\beta_m x_m+\beta_{1m} x_1 x_m)}$. The marginal effect of x_1 is given by: $\frac{\partial \Upsilon}{\partial x_1} = e^z \cdot (\beta_1 + \beta_{1m} x_m)$. By definition, the total moderating effect of x_m on this marginal effect is given by: $\frac{\partial^2 \Upsilon}{\partial x_1 \partial x_m} = e^z \cdot \beta_1 \beta_m + e^z \cdot \beta_{1m}[1 + (\beta_1 x_1 + \beta_m x_m + \beta_{1m} x_1 x_m)]$. The nonlinear nature of NB models implies that $\frac{\partial^2 \Upsilon}{\partial x_1 \partial x_m}$ is not 0 even if the coefficient of $\beta_{1m} = 0$. For this reason, the conventional test for moderating effects which involves checking if $\beta_{1m} = 0$ in linear models is no longer valid in nonlinear cases. According to Bowen (2012), the total moderating effect $\frac{\partial^2 \Upsilon}{\partial x_1 \partial x_m}$ can be decomposed into two parts: (1) a structural moderating effect, $e^{\bar{z}} \cdot \beta_1 \beta_{\mathrm{m}}$, where $\bar{z} = \beta_0 + \beta_1 x_1 + \beta_{\mathrm{m}} x_m$ and is the value of z evaluated at $\beta_{1m} = 0$; and (2) a secondary moderating effect, $(e^z - e^{\bar{z}}) \cdot \beta_1 \beta_{\mathrm{m}} + e^z \cdot \beta_{1m}[1 + (\beta_1 x_1 + \beta_m x_m + \beta_{1m} x_1 x_m)]$.

Bowen (2012) proposes that the true moderating effect due to adding the moderator to the model should be tested based on the values of the secondary moderating effect calculated at different values of x_m with all other variables set at their mean values. In our case, $\beta_m = 0$ and all of the variables have a mean value of 0 after having been mean-centered. The secondary moderating effect can be rewritten as: $e^z \cdot \beta_{1m}$. Since e^z is always positive, we can therefore make inferences based on the significance of β_{1m} directly.

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Xibao Li (lixibao@sem.tsinghua.edu.cn) is Associate Professor of Management at School of Economics and Management, Tsinghua University. He is a research fellow at National Entrepreneurship Research Center and Research center for Technological Innovation, Tsinghua University. His research interests mainly focus on Management of Innovation and Technology-based Entrepreneurship.

Justin Tan (jtan@schulich.yorku.ca) is Newmont Chair in Business Strategy at the Schulich School of Business, York University. His research interests include strategic management, innovation, entrepreneurship, and corporate social responsibility. His research has been supported by Ford Foundation, Social Science and Humanities Research Council of Canada, and National Science Foundation of China, and published in *Strategic Management Journal, Organization Science, Journal of Management, Journal of Management Studies, Journal of Business Venturing, Entrepreneurship Theory and Practice*, among others.

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