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What Accounts for Successful University-industry Research Collaboration? Insights from Project-level Evidence in China

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What Accounts for Successful University-industry Research Collaboration? Insights from Project-level Evidence in China

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Abstract

The importance of examining factors important to achievement of UI collaborations in varied institutional contexts receives increasing attention from both academics and policy makers. Based on three university-industry (UI) collaborative projects, this paper qualitatively examines factors contributing to UI collaboration achievement in China. The analysis shows that increasing industrial R&D investment, improving industrial connection of university research and promoting deep academic involvement in all stages of research application are particularly important to achieve UI collaborations in China where the industrial investment in research and development (R&D) is still low. This case study also highlighted theoretical insights in: the importance of interactive-natured UI relations in enhancing industrial innovation, the crucial role of individual-level factors, and the necessity of taking a systematic perspective on studying UI collaboration. This study sheds more insights into factors crucial for achievement of UI collaborations, particularly in the context characterized with low industrial absorptive capacity.

Key words: University-industry Collaboration, Academics, Firms, China

1. Introduction

The knowledge-based nature of competition and the increasing need of multi-disciplinary knowledge for innovation constitute the main rationales for university-industry (UI) cross-boundary interactions[1] (Cohen et al. 2002; Gerybadze and Reger 1999). Accordingly, academics and policy makers have paid growing attention to the interactions between academic and industrial spheres.

A number of gaps are found in the literature. This research aims to fill three of such gaps. First, existing research lacks the discussion on the interactive nature of UI linkages such as collaborative R&D, contract research and consulting. Majority of the literature has focused on the mechanisms of direct commercialization of university technologies, such as patenting, licensing or formation of spin-offs, as main indicators of UI interactions (Perkmann and Walsh 2007; 2009). However, increasing authors have noted a less prominent role of such direct mechanism of commercializing Intellectual

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Property (IP) to the interactive nature of UI relationships in promoting innovation (Cohen et al. 2002; Mowery and Sampat 2006; Agrawal and Henderson 2002; Schartinger et al. 2002). Second, the literature lacks systematic understanding on factors influencing UI collaboration. The majority of existing research approached this issue by focusing on drivers for UI linkage participation, i.e. factors related to initiation of collaboration, but neglected the examination of factors pertaining to the outcomes of the collaboration. Furthermore, the existing literature took either the viewpoints of firms or those of university or department, but not taking both perspectives (Mora-Valentin et al. 2004) and also excluding the individual researchers from analysis (except a few studies such as D'Este and Patel 2007; Agrawal and Henderson 2002). However, UI linkages can only be achieved through grounded interactions between individual academics and firms. Thus, it is necessary to examine what really matters in the process of university researchers working with industry at the 'street level' (Woolgar 2007).[2] Third, most arguments in the existing literature draw from the western contexts as taken-for-granted institutional settings, thus failing to provide insights into how differed institutional structures shape the way UI collaboration is conducted (Perkmann and Walsh 2007; Owen-Smith 2005). The institutional environment and social economic conditions in the Chinese context are quite different from its western counterparts and this difference will potentially provide more insights into important factors associated with UI collaborations.

Project-level case studies will provide in-depth insights into what really happens in UI interactions (Harryson et al. 2007; Brostrom 2012). Given the gaps in the extant literature in understanding how macro institutional and organizational factors interact with local specificities at the 'street' level, this study looks at Chinese successful experience of UI collaboration and poses the research question as "Under what conditions can achievement of UI collaborations be realized in the context of China"? In this study, achievement of UI collaborations refers to the commercialization of university research via UI collaborative projects. It will examine important factors to achievement of UI collaborations, integrating analysis on macro level institutional frameworks, organizational level of university/firm, and individual level of academics. Ultimately, this study adds more evidence on the dynamics of UI collaboration achievement from the context of China.

This study adopts the qualitative method of case study based on multiple successful cases of UI collaborative projects involving engineering schools of Shanghai Jiao Tong University (hereafter SJTU) of China and industrial firms labeled as Project D, Project M and Project G (See Appendix A for more information on these case projects). The case data were collected mainly through semi-structured in-depth interviews and supplemented with document review such as newspapers, university/faculty reports and brochures.

Although a consensus exists on the difficulty of measuring achievement of UI collaborations due to inter-organizational diversity and objectives, achievement of UI collaborations defined in this paper is similar to Barbolla and Corredera (2009)'s: achievement of UI collaborations refers to the commercialization of university research outcomes. Commercialization means university inventions are exploited with the objective to reap financial rewards and is often an outcome or follow-on activity of UI collaborations (Perkmann et al. 2013). Based on this definition, I chose the three cases of collaboration with the help from university-level and school-level UI administrative staff. These informants were considered most familiar with the whole situation of UI collaborations within their own premises. In the first two cases, the joint research inventions were finally commercialized while in the last case, university inventions were successfully sold to a third party for the pilot-scale experiment which means only one step away from commercialization.

I used the cases of SJTU's experiences because of its prominent research strength on engineering, especially materials science and mechanical engineering and its location in Shanghai. Shanghai had quick expansion of private technology firms due to the incentives and support from the Shanghai government, and being the home to many R&D centers of multinational corporations (MNCs), indicates well a demand pull from industry side for UI linkages (Fan 2003; Wu 2007). All these may have offered SJTU a significant advantage to make closer linkages with industry at the first place. In addition, SJTU also positions ahead of the national trend of promoting UI linkages in terms of internal efforts as will be discussed in Section 3. Therefore, choosing SJTU's experience of UI collaborations is able to provide important insights into what is really going on between Chinese research universities and industry in terms of research collaborations. Nevertheless, in order to better interpret the entire picture, field research data on Tsinghua University and Zhejiang University, another two elite research universities in China, also supplement the discussion when necessary.

This research chose the engineering disciplines because the incremental advances in these technological or industrial fields are almost exclusively the domain of industrial R&D activities (Mowery and Sampat 2006). The significance of inter-industry differences in the effect of university research on industrial innovation is emphasized by many studies (e.g. Cohen et al. 2002). For example, in the fields such as pharmaceuticals and biomedical, university research advances affect industrial innovation in a more significant and direct way. Different from those fields, engineering has high-levels of UI collaboration (Schartinger et al. 2002; Perkmann and Walsh 2009). Meanwhile, engineering encompasses a set of disciplines with similar rules for novelty, priority and reputation as in basic sciences (Merton 1973). Thus choosing engineering-related research projects helps understand the bulk of collaboration between universities and firms.

The rest of the paper is organized as follows. Theoretical discussion on what has been known in the literature about varied factors affecting success of UI collaboration will be elaborated in Section 2. Section 3 examines the institutional and organizational context of China in which case projects took place. Specifically, it looks from the perspectives of national policies and legislative contexts, public funding and programs, industry needs and university responses. Section 4 presents methodology. The findings of the case study will be presented in light of the theoretical framework in Section 5.

Section 6 gives discussion and theoretical implications based on the Chinese case study. And Section 7 concludes with policy implications.

2. Factors Pertaining to UI Research Collaboration, from Various Perspectives

The literature approached factors pertaining to UI collaborations from different perspectives. Research examining the macro institutional arrangement and university level factors constituted the crucial part of the literature. Policy context, legislative environment, public funding schemes and programs are vital factors to influence UI collaborations at the macro level (Baldini et al. 2006; Hatakenaka 2004). An anecdotal example is the passage of the Bayh-Dole Act in the U.S. to grant federally-funded inventions to universities which positively led to increasing of activities in patenting and licensing (Shane and Soyama 2007; Mowery et al. 2004; Kenney and Patton 2009).[3] Shrinking public funding and public programs or initiatives specialized in subsidizing UI collaborative projects can make universities more active in UI collaboration (Baldini et al. 2006; Feldman and Kelley 2006; Perkmann and Walsh 2007).

Studies also show that university polices are important in predicting faculty's engagement of UI linkages (e.g. Schartinger et al. 2002; Friedman and Silberman 2003; Wu 2010). For example, Grimpe and Fier (2010), through comparing US and Germany UI relationships in a survey of 800 university scientists, argued that macro institutional environment and university policies (particularly evaluation system and incentives) cause differences in academics' response towards informal technology transfer engagement. The importance of university incentives and institutional structure for promoting academic commercialization was also highlighted by Wu (2010), the latter of which was also stressed by Di Gregorio and Shane (2003), Siegel et al. (2003) and Friedman and Silberman (2003).

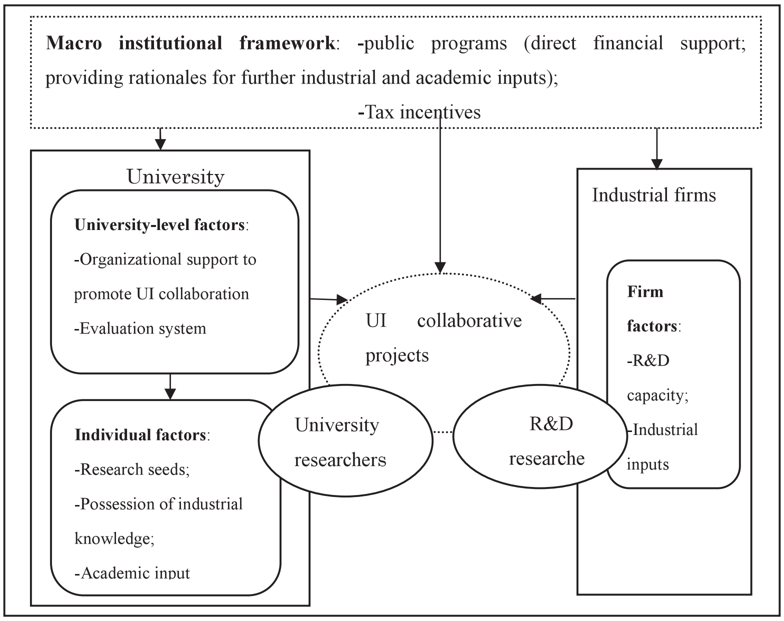
Research also examined from the perspective of the industry on the factors pertaining to the achievement of UI collaborations. Among others, the absorptive capacity that firms have is the issue most cited. For example, Barbolla and Corredera (2009) concluded that in addition to corporate partner's strategic and functional characteristics, its capacity to assimilate new knowledge is identified as key elements for attaining an effective technology transfer. The crucial role of collaborating firms' capacity to absorb and apply results of collaboration was also argued by Kodama (2008) when analyzed the innovation system of industrial clusters in Japan and by Ham and Mowery (1998) when studying the research collaborations between the US government laboratories and industrial firms. In addition, industrial inputs in terms of R&D investment and management support were proved as important to UI collaborations (Ham and Mowery 1998).

Furthermore, a few studies examined the role of characteristics of individual university researchers in ways of UI interactions (Bercovitz and Feldman 2003; Agrawal and Henderson 2002; D'Este and Patel 2007). For example, past experience of UI interactions, academic status (being a professor)

(Bercovitz and Feldman 2003; D'Este and Patel 2007) and fund raising (Landry et al. 2005) are major characteristics of individual researchers linking to interactions with industry. Some others argued for the positive role of academic backing for research commercialization even after firm's licensing of university technologies (Jensen and Thursby 2001; Cohen e al. 2002). Thus, quality of research, possession of industrial knowledge and academic input can have distinct impact on academics' interactions with industry.

The review of the existing literature generates useful insights. Although majority of the literature narrowed their analysis on direct mechanisms of technology transfer, which only presents partial UI interactions, they show positive impact of institutional and organizational factors on UI collaborations. Since similar institutional and organizational changes are taking place worldwide to promote UI linkages, how such factors interact with specificities of local context becomes an important issue (Mowery and Sampat 2006; Lundvall and Borras 2006; Baldini et al. 2006), particularly when those factors have been of significance mainly in the western settings (Woolgar 2007; Perkmann et al. 2013). Based on the existing literature, the author developed the conceptual framework for this study of Chinese experience as Figure 1 shows. The findings of case study in Section 5 on factors important to UI collaboration achievement in China are presented in line with the conceptual framework, integrating perspectives from macro level of institutional framework, organizational level of universities and firms, and individual level of academics.

Figure 1 Conceptual Framework



Source: Developed by author based on Perkmann et al. (2013: 430).

In the following section, the paper discusses the China's context. It will first present the evolution of policy environment and legal context relevant to UI interaction and introduce major governmental programs subsidizing UI collaborations. Then it will examine the industrial needs and organizational responses to the external environment change at universities through the case of SJTU.

3. National Context and Universities' Responses to UI Relationships in China

3.1. Policy and Legislative Contexts

The institutional changes in policy and legislative frameworks relating to UI collaboration were chiefly focused on how university research outcomes (IP) were defined, managed and evaluated. Building organizational settings and management system of IP within universities were first requested in 2002 as MOE and Ministry of Science and Technology (MOST) jointly issued "Suggestions on Fully Taking Advantage of University Science and Technology (S&T) Innovation". Since then, universities started to set up organizational settings to manage university IP and commercialization activities. In the same year, universities were authorized the ownership and management of research outcomes generated from governmental S&T projects, as in the U.S. "Bayh-Dole Act". The purpose was to improve university and academics' proactivity to patent and exploit commercial application. However, the organization units managing university research outcomes have no specialized fund coming from the government and the actual impact on commercialization was not assured (Ye et al. 2015).

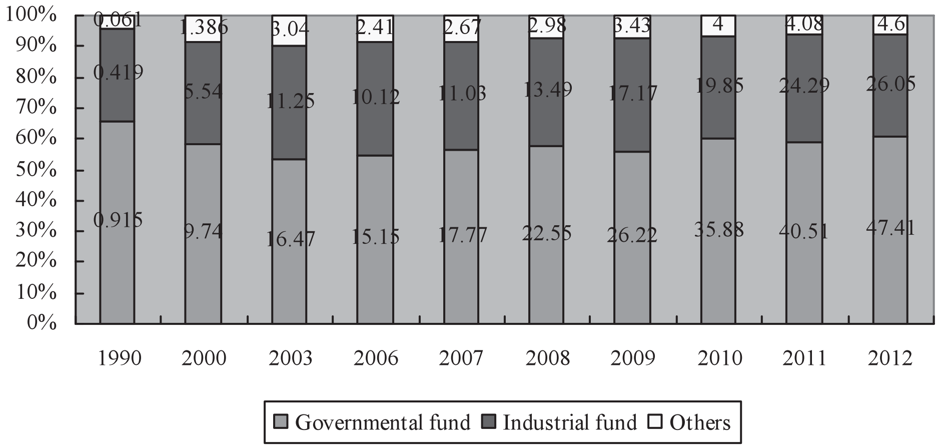
With respect to changes brought to individual academics, in order to promote university patenting activities and commercialization, in 1999, "Regulations on Promoting Transformation of Scientific and Technological Outcomes" clearly noted the incentives to reward academic researchers no less than 20 percent of the income resulted from technology transfer and since 2002, patent started to be used as one of the indicators for academic evaluation and governmental S&T grants. Strengthening laws of IPR protection was also one of critical steps to make better use of university IPR.[4]

In general, the policy and legislative frameworks relating to UI collaborations have been adjusted to formalize university IPR management and ultimately improve effective enforcement of technology transfer and promote university-industry collaborations.

3.2. Government Funding and Public S&T Programs

Although there were cuts in governmental funding since the 1990s, it still constitutes the most important source for university research in China (see Figure 2). An increased proportion of public programs to subsidize UI collaborations was also observed.[5] For instance, the proportion of UI collaborative projects in public projects increased from 12.4 percent in the 9th "Five-year Plan" (1996–2000) to 21.9 percent during the 10th "Five-year Plan" (2001–2005) (MOST 2009a). Such projects usually focus on new and high-technologies and have articulated orientation for application. The public

Figure 2 R&D Funding of Higher Education Institutions (HEIs) by Sources, in Selected Years (billion Yuan)



Source: China Statistical Yearbook on Science and Technology, various years. Retrieved at http://www.stats.gov.cn/tjzs/tjsj/tjcb/tjzl on April 5, 2014.

programs are increasing in number, but the competition is very fierce.

In addition to direct subsidy to support UI collaborations, there were also supplementary initiatives, such as enhancing regional innovation environment by strengthening property rights, establishing high-tech parks and encouraging entrepreneurship via spin-offs from universities (Chen and Kenney 2007) and the "211 Project"[6] and "985 Project"[7] to improve teaching and research conditions (Kroll and Liefner 2008).

Although many authors agree that up to now, UI collaboration remains weak and transfer of university research results to industry has been problematic (Lai and Shyu 2005; Kroll and Liefner 2008), these crucial steps have significant implications for UI collaborations in China.

3.3. Industry Needs

Increasing R&D expenditure indicates a larger propensity of UI collaborations since universities were gradually seen as a cheaper substitute for internal R&D (Hatakenaka 2004). In China, since the 1990s, industrial firms were increasingly encouraged to increase R&D expenditure via various public programs and preferential tax policies (Su 2000). The "Law on Enterprise Income Tax" issued in 2008 clearly indicated a reduction of tax rate from 25 percent to 15 percent for new and high-tech firms since they are the bulk of innovation actors. They are also eligible to exclude expenditure on UI collaboration from tax calculation. Also, these firms are requested to spend no less than 4 percent of their revenue on R&D annually, either internally or externally. As a result, industrial R&D expenditure has grown significantly. For example, the industrial R&D expenditure rose to 75.7% of national R&D expenditure in 2011. Also, as indicated in Figure 2, especially since 2000, the industrial share persisted at about one third of the HEIs' research funding. This also means stable linkages between universities and industry have been established.

However, two characters with respect to the industrial R&D expenditure patterns should be noticed: a high ratio of R&D expenditure by foreign capital firms and a low share of high-tech firms' R&D expenditure. According to MOST (2009b), the share of R&D expenditure of foreign capital firms increased from 23.2 percent in 2003 to 29.1percent in 2007, and although it dropped ever since it still kept over 20 percent. The ratio of high-tech enterprises' R&D expenditure was only 25.8 percent in 2007, much lower than over 40 percent among developed countries. The overall R&D capacity of industry in China is still low as in 2012, only 13.7 percent of firms (including foreign-owned enterprises) in China conducted R&D activities (China Statistical Yearbook, 2014). These facts regarding the R&D expenditure and research capacity of the industrial firms will definitely have important implications on UI linkages of China.

3.4. Universities' Responses

The Chinese higher education system has witnessed shifts to encourage research commercialization. Driven both by the top-down institutional changes and bottom-up needs to multiply funding resources, significant changes have taken place within universities (Wu 2010; Ye et al. 2015). Notably, Technology Transfer Centers (TTCs) and patent office to formalize IPR regulation have been established. For example, National Technology Transfer Center (NTTC) of SJTU and Tsinghua University, set up in 2001, were two of the first six centers authorized by the central government to take charge of university invention disclosure, patent application, evaluation of market value, patent licensing and sales.[8] Currently, most universities have set up similar organizational arrangements.

SJTU even took a further step in adjusting organizational settings to enhance UI collaborations. Proposed by the acting Secretary of Party Committee of SJTU to further facilitate research exploitation, Research Institute for Advanced Industrial Technologies (RIAIT) in 2009 was established.[9] RIAIT resembled NTTC in terms of its function to promote university IP commercialization, but put a sole focus on advanced technologies with significant application prospect. It discovers and nurtures technologies and seeks for external resources, public or private, to facilitate commercialization. Taking RIAIT as a model, more than 30 similar organizations emerged in other universities and local governments shortly after its establishment.[10]

In addition to changes in organizational settings, universities also installed incentive systems to promote UI collaboration and commercialization since the late 1990s. SJTU has been encouraging patenting activities and in 2003 and 2007, it revised the IP reward system and faculty evaluation system, shifting the locus from 'quantity' to 'quality'. Incentives were also in place, clearly authorizing the research team a share of 60 percent of the income out of the research commercialization.

Nationally speaking, indeed, a rapid upsurge in patenting activities was observed since the late

1990s. The universities invention patents increased from around 200 in 1995 to 14,872 in 2009 (Science and Technology Commission of MOE 2011). However, universities suffer from a low rate of return. For example, among the total contract value of approximately 0.45 billion Yuan for patent sale in 2008, the net income was only 0.21 billion Yuan. The net income from patent sale also declined in 2003, 2005 and 2007 (ibid). The incidence of UI collaboration has also been increasing. Although it is difficult to trace records on the volume of projects for varied types of UI relationships, growing industrial funding contributed to university research. Taking the School of Mechanical Engineering of SJTU as example, industry funding has grown from 88.67 million Yuan (approx. 14.5 million in US dollars) in 2005 to 186.4 million Yuan (approx. 30 million in US dollars) in 2013.[11]

We can see that, despite the low return of university IP commercialization, universities have been making efforts to promote research application and UI collaborations.

4. Methodology

This study uses three cases of UI collaborative projects. The project level data analyzed here is utilized to explore the similarities among the projects in conditions important for final achievement of UI collaborations. The Data of the case projects were collected during the period between March 2011 and June 2014. In total, 40 interviews were conducted to 36 informants in China from universities, firms and government, including government officers with UI-related responsibilities, UI administrative officers at universities (also those from Tsinghua University and Zhejiang University), involved academics, other faculty members not particularly related to selected projects (also including those from Tsinghua University and Zhejiang University), and R&D executives or other key personnel of partner firms who are familiar with and have decision making power regarding the project. Some key informants have been interviewed repeatedly. Most of the interviews lasted between 45 and 90 minutes. The interviews were all audio-recorded and then transcribed.

The interviews were semi-structured because it can make sure that similar lines of information were collected from the stakeholders of all projects and meanwhile leave room for revision based on the answers given by the interviewees. The principal four groups of informants, namely university UI administrative officers at universities, university research leaders of the case projects, R&D executives or other key R&D personnel from the partnering firms, government officers in charge of UI collaboration, were asked respective lists of questions for the following information. University personnel in charge of UI collaborations were asked for the generic information regarding university-level policies, organizational settings, strategies and challenges in relation to promoting UI collaboration and regulations on academics' evaluation. This was to know whether the university-level context promoted or hindered academics' interaction with the industry and how it exactly took effect. Academic research leaders were asked to inform the drivers for joining the project, responsibilities taken along the stages of project implementation, ways of interactions with the industrial R&D personnel and problems encountered if there was any. They were also asked about their normal experiences of working with the industry and also the kinds of assistance or confinement if they received from the university in terms of conducting research collaborations with the industry. The purpose of acquiring the information was not only to specify the relevant elements at the individual level, but also to know mechanisms through which university-level institutional context influences academics' responses towards UI interactions.

In terms of the industrial firms, in order to obtain information about the firm's characteristics and R&D inputs, the R&D related informants of the partnering firms were asked to chiefly explain strategies of R&D investment, determinants of participation, responsibilities assumed, inputs made, mechanisms of interactions with the academics, any support received from the government and challenges that faced in UI collaborations. The informants from the government agencies in relation to UI collaborations were interviewed to give generic information mainly on the status of development with respect to UI linkages, relevant national strategies and challenges faced by the country to promote UI linkages.

The information collected from groups of informants was synthesized for each project and was analyzed in light of the theoretical framework discussed in Section 2.

5. Case Study

5.1. A Brief Introduction of Case Projects

Among the three projects, two projects (Project D and Project M) were publicly subsidized. Project D was conducted jointly by the academic team of School of Mechanical Engineering and 12 firms in response to the initiation by the Shanghai Municipal Economic Commission (SMEC) to develop Dimethyl Ether (DME)[12] fueled vehicles in 2006.[13] The research focus, which was related to the DME-fueled engine system, was taken over by the academic team of about 20 members including 7 full professors and a team from the diesel engine company comprising of two researchers, two application engineers and one technician. Eventually the project's major outcomes included 6 national Invention Patents, dozens of academic papers and new product.

Project M was about the localization of foreign proprietary technology through UI collaboration. Chlor-alkali industry is a basic chemical industry whose products, chlorine and caustic soda, play significant role in the national economy. The core device of the industry is ion-exchange membrane electrolyzer. Despite decades of the nation's efforts on developing the key technology for the core device, it was still under monopoly by two foreign companies. In order to localize the technology, the academic team under the leadership of Professor Z of SJTU started collaboration with one private chemical firm S in 2003. After 8 years, they successfully commercialized the technology of ion-exchange membrane. This technology can also be applied in new energy automobile industry, since the sulfonic acid resin ion-exchange membrane is the key material for fuel cell development. Therefore, the application prospect of this technology is promising.

Being the only case without public subsidy, Project G exemplifies how academics strived to acquire industrial funding to commercialize university research. This project started in 2009 when the academic leader Z1 from School of Materials Science and Engineering confronted lack of public funding to continue research on developing Activated Peptide and Graphene as low carbon and environment-friendly materials. The firm Y agreed to establish a five-year joint lab and provide annual 0.3 million Yuan (approx. US $48 thousand). However, the firm was more like an investor rather than joint research conductor. The academic team conducted the research solely and the firm was kept informed of research progress through meetings or reports. Finally, in total five invention patents were granted and two of them were undergoing transfer negotiations with estimated 20 million Yuan (approx. US $3.2 million) market value to a third party for commercialization. The university RIAIT provided organizational support in assessing the technology value and identifying potential firms for commercialization.

5.2. Important Factors Contributing to the Achievement of UI Collaboration

The case study examining the crucial factors pertaining to successful realization of UI collaboration presents how factors from macro institutional, organization-level and individual perspectives were relevant in the context China. The following subsections elaborate on the findings.

5.2.1. Macro Institutional Factors

5.2.1.1. Financial Support via Public Programs

The availability of public subsidy to support R&D activities of the joint project was particularly important for the following two aspects. First, the availability of public subsidy assured continuous academic research. In total, ten million Yuan (approx. US $1.6 million) of public funding was provided for Project D and more than 0.1 billion Yuan (approx. US $16 million) for Project M for research and its application.[14] Continuous research was required to transfer university technology to real application

Table 1 Industrial R&D Projects by Sources, 2009

Sources of projects	Self-reliance	Subsidized by local governments	Subsidized by central government	Others
194,000 R&D projects in total	80%	7.8%	6%	6.2%

Note: The firms in the survey only included those with annual sales revenue of over 5 million Yuan (approx. US $0.84 million).
Source: Major statistics on Second National R&D Survey by National Bureau of Statistics (2010). Retrieved at http://www.stats.gov.cn/tjzs/tjsj/tjcb/tjzl on May 16, 2015.

and academic research provided strong intellectual support. The public subsidies, mainly utilized to improve R&D facilities, enabled further academic research and product development.

Second, the public research funding has greatly reduced industrial R&D cost. Majority of the R&D activities are self-funded by firms in China. As shown in Table 1, the industrial R&D projects receiving public subsidy (from central and local governments) only reached around 14 percent in 2009. The public subsidies in Project D and Project M have greatly relieved firms' burden on initial investment in applying the university technology.[15] In fact, government support also pointed to infrastructure improvement for industrialization. The government granted another 0.13 billion Yuan (approx. US $21 million) to develop the industrial park of fluorine and silicone material, within which the collaborating firm resumes the main responsibilities of innovation activities.

For the two previous publicly subsidized projects, the positive impact of public support was evident. Nevertheless, the Project G, although receiving no public subsidy, reversely implies how important acquisition of public funding is for academics to apply research. Despite a compromise on co-ownership of the IP generated from the project, the academic team leader Z1 expressed clearly that without the financial support from the firm, the progress of technology development was not possible to be generated.[16]

When academics have no chance to get public subsidies as this case shows, industrial funding becomes the only optimal substitute for research funding since no regular research funding is available to faculties in China's university system. Thus, it is important to note that for innovation and commercialization, public subsidy can play a significant role if the application process is too costly to rely solely on industrial fund.

5.2.1.2. Public Programs as Strong Rationales for Further Inputs

Being publicly subsidized projects indicates the strategic importance and social awareness of the R&D activities of the projects, thus it provided strong rationales to induce consistent inputs from both academic and industrial participants.

For academics, acquisition of public grants is another key indicator for academics' evaluation other than academic papers and patents, thus it means more organizational support from university.[17] For example, in Project M, because of the social significance of the research, the university supported two million Yuan (approx. US $0.32 million) out of the "985" Program budget to the academic team to improve research facilities. Also, it received a bigger quota of doctoral students to help with the research. The situation was similar in Project D. Such university support was critical to motivate the academics to work on the commercialization.

It also strongly motivated further industrial R&D investment. Firms in Project D and Project M invested heavily not only in the sense of monetary terms, but also human resource and management support. In Project D, the increasing strategic importance of the replaceable energy for automobile industry made the firm believe that it can take first-mover advantage which led to the project.[18] For

Project M, the project's focus was on localizing the foreign monopolized technology of ion exchange membrane which was of significant strategic importance to the national economy. This strategic importance convinced the firms of the continuous government support in the following infrastructure investment for the industry development. The signals governmental projects conveyed in terms of technological investment guidance strongly encouraged firms to collaborate with universities and invest more on R&D.

5.2.1.3. Tax Incentives

Preferential tax policies also motivated industrial investment on UI collaboration. As already noted in the Section 3, the 2008 Law on Enterprise Income Tax, in addition to a reduction of tax rate from 25 percent to 15 percent, new and high-tech firms (main actors of innovation in China) are also eligible for excluding R&D expenditure on UI collaboration from tax calculation. In addition, firms fitting to this category of firms are requested to annually spend around 4 percent of their sales revenue on R&D, either on internal R&D or joint R&D with external entities, such as universities.

The partner firms of the case projects were all eligible for the tax incentives. It was confirmed by the firms in the case projects that, such preferential policies factually urged their decisions to take part in UI collaborations. As one case firm N of Project D pointed out that, they have to calculate the annual R&D expenditure carefully in order to fulfill the requirement of being new and high-technology firms. They sometimes even have to purchase university patents for that purpose.[19]

Table 2 The Amount of Tax Deduction and Ratio of Firms Qualified for Tax Incentive in the Changzhou City of Jiangsu Province

Tax incentive	2011 (million Yuan)	2010 (million Yuan)	Increase rate (%)	No. of firms qualified	Ratio of qualified firms (%)
Tax deduction for new and high- tech firms	6699.125 (approx. US $1116.5 million)	7014.569 (approx. US $1169.1 million)	− 4.5	188	51.23

Source: Du and Wang (2013: 65).

The tax incentives are important to promote industrial R&D investment, however, the requirements for firms to enjoy the incentives are very strict[20], and the proportion of firms can actually enjoy the tax incentives is low (Wang et al. 2013; Du and Wang 2013). For instance, Du and Wang (2013), based on a survey of the total 367 new and high technology firms under the supervision of the State Administration of Taxation in the Changzhou city of Jiangsu province, found that only about half were qualified for the tax incentives in 2011 as Table 2 shows.

5.2.2. University-level Factors Contributing to UI Collaboration Achievement

5.2.2.1. Organizational Support in UI Collaborations

The university support in Project D and Project M focused on the improvement of research facilities for the academic team and a bigger quota of doctoral students to help with the research which significantly motivated academics' commitment to the project. The larger the volume of public grant, the more organizational support academics can obtain from the university. The encouraging attitude and organizational support of RIAIT were more important for Project G. As noted earlier, the university has been strongly promoting research application and UI collaboration (within which the establishment of RIAIT was one critical step). The academic team leader Z1 actively sought for external funding via UI collaborations was profoundly motivated by the university's encouraging attitude for UI collaboration. The leader even set up an office at the engineering school in 2011 to specially promote UI collaboration. In addition, RIAIT offered to help identify suitable transferees to commercialize technologies generated from the project. This would be very difficult if relying solely on the academic team.

Such supportive organizational arrangements of the university towards UI collaboration were especially crucial to encourage those researchers with insufficient governmental research funding to participate in UI collaboration.

5.2.2.2. Academics' Evaluation System

The system of how academics are evaluated and promoted would directly influence academics' responses to industrial linkages. The current system values most the volume of public research grants and academic output mainly in the form of academic papers. It causes academics to prefer public grant to the industrial one. As confirmed by all the academic informants of the study, in accordance to the evaluation system, they would definitely go for public funding as primary source of research funding.

In Project D and Project M, the circumstance has been favorable for the university researchers because they were funded sufficiently for research performance by both public and private sources. They were significantly motivated to commit to the joint projects. On the other hand, in Project G, the industrial funding was highly appreciated by the academics due to the lack of public research grant. However, the academic team had to reconcile on the co-ownership of IP generated from the project.[21]

Nevertheless, the system valuing academic outputs and public grants would likely make approaching industrial funding less preferable if public funding is guaranteed, particularly when collaborating with firms with low capacity of research which demands more time on the down-stream activities.

5.2.3. Industrial Factors that Contribute to UI Collaboration Achievement

5.2.3.1. Industrial Inputs

Consistent industrial inputs in terms of finance, human resource and management support were proved to be important. In all projects, firms invested heavily on equipping the research facilities which was indispensable for research application. For instance, the firm in Project M devoted an annual 10 percent of sales revenue to R&D activities during the project.[22] In addition to the direct financial investment, firms in Project D and Project M also allocated a R&D team to fully cope with the project.

As shown in Table 3, the most two important factors that large and medium-sized firms in China consider hindering further innovation were related to human and capital investments. Thus, the intense inputs that firms of the case projects made in terms of capital and human resources were particularly important to the achievement of UI collaborations.

Table 3 Most Cited Factors Hindering Industrial Innovation in China, 2005

Major factors hindering innovation activities	Lack of S&T human resources	Lack of funding	High cost of innovation	Long-span of return from innovation
Ratio of firms cited as an important factor (%)	69.86	56.85	56.2	43.8

Note: The firms surveyed in Wang (2008) included 2655 Large-and Medium-sized firms (29774 nationwide in 2005).
Source: Based on Wang (2008).

What worth noting was the importance of management support by the firms. The management support was important because it guaranteed consistent industrial commitment for the project. In Project D, the top managers organized regular meetings to monitor the progress of the project, based on which more expenditure was invested. In Project G and Project M, academic leaders were entrusted with full responsibilities of the research agenda. The management support was particularly intense in Project M. The firm authorized the academic leader complete leadership of its research institute[23] which assumes all the R&D activities. As the academic leader Z noted, "...it is not common to see such prominent support among UI collaborations which was really important".[24]

5.2.3.2. Industrial Absorptive Capacity

The firm's research capacity or absorptive capacity was important to absorb and apply external knowledge (Cohen and Levinthal 1990). The extent of absorptive capacity can be measured by R&D intensity and the existence of R&D unit (Bougrain and Haudeville 2002). Both firms in the case projects had own R&D unit and high R&D intensity (4 percent in Project D and Project G, 10 percent in Project M). The absorptive capacity of the case firms were high compared to the average level in China. For example, according to the National Bureau of Statistics (2010), only 6.98 percent of industrial firms owned R&D unit and the average industrial R&D intensity was merely 0.8 percent in 2009.

The relatively high absorptive capacities enabled firms in Project D and Project M to conduct work of less academic values. For example, the efficiency testing and noise check were chiefly conducted at the firm's labs in Project D. In Project M, the industrial research institute was the indispensable force during the 8–year long journey of technology application. This helped significantly relieve the burdens of academics. While in Project G, the partner firm's status as a new and high-technology firm itself was positively related to the long-term vision regarding R&D investment, which positively led to the initiation of the project. Such vision on R&D investment may not be easily seen from firms with minimal R&D capacity.

Therefore, it was really helpful for achievement of UI collaborations if firms had high absorptive capacity. This enabled academics to concentrate on research of more academic value, thus motivating academics to actively participate in UI collaboration. However, given the current status of industrial development in China, most domestic firms have not devoted such commitment to R&D capacity building.

5.2.4. Factors of Individual Academics Contributing to UI Collaboration Achievement

The case study shows that university research seeds of high industrial application, sufficient industrial knowledge of academics and consistent intellectual support were equally important to successfully achieve industrial application of university technology.

5.2.4.1. Academic Research Seeds with High Propensity of Industrial Application

The case study finds that it is crucial for academics to have technologies with prominent potential of industrial application. The promising prospect of technology application in the case projects dramatically stimulated industrial interest and commitment to commercialize them.

In Project D, the increasingly obvious strategic importance of the replaceable energy has significantly prompted firms' decisions on participation, hoping that they can take first-mover advantage in this field in the foreseeable future. For Project M, the critical significance of this project to localize the technology of ion exchange membrane served as fundamental rationale to explain the firm's enormous inputs to the joint cause. The firm aimed at extending the industrial chain to develop high value-added products via development of the ion exchange membrane business as the firm's strategy. In Project G, the firm F was specialized in electrical devices whose core technological domain was not close to the research of this project. However, one of the important reasons urged the firm to participate in UI collaboration was its confidence on the technology's huge market potential given its originality and applicability.[25] The firm's management group believed that the application of the environment-friendly materials and technology was promising and such orientation fitted well to the national strategy and firm's needs for future development.

The importance of technology applicability was also verified by the fact that, under-development of technologies was the most significant reason that caused innovation failures in large-and medium-sized firms in China as shown in Table 4 (Wang 2008). Given the low research capacity of the industry in China, the prospect of industrial application of university research becomes particularly important to achievement of UI collaboration.

Table 4 Most Important Reasons that Caused Innovation Failures in China, 2005

Major reasons	Technology is not well developed	Replacement by new technologies	Shortage of S&T human resource
Ratio of firms cited as an important reason (%)	71	55	53

Source: Wang (2008).

5.2.4.2. Consistent Intellectual Support and Possession of Industrial Knowledge

The case study strongly suggests that consistent intellectual support in the form of direct involvement along the whole process of research application is necessary to finally achieve UI collaboration. Although academics were relieved from most of the less-valued work, their direct involvement from basic research to product development was proved to be indispensable.

For example, in Project D, in addition to the theoretical building regarding DME-related burning system, fuel injection and supply system, academics were also deeply involved in the engineering process which was conducted mainly at the firm. The academic team members regularly visited the firm and joined with industrial researchers in the experiments. For Project M, the deep involvement of academics in the project was even more critical for the final achievement. The technology of ion exchange membrane was new to the firm, so the academic team was directly involved in all the stages of application from theories, engineering to equipment technologies. In Project G, the academic team also covered all the stages of the application process.

The industrial knowledge generated from previous of UI collaboration has greatly helped academics provide useful intellectual support in different stages of collaboration. All the key academics in the projects had plenty of experience in working with industry before the project started. In Project G, the academics' previous experience in industrial application even successfully led to the initiation of the project. The academic team had always paid attention to research applicability. This message was crucial to finally convince the firm of the prospect of collaboration.[26]

The necessary involvement of academics in all the stages of technology application and the importance of industrial knowledge of academics imply that the absorptive capacity of firms was still not strong enough to chiefly rely on itself to apply university research.

6. Discussion

The case study as presented above strongly indicates that factors at macro institutional, university-level and individual levels take effect on promoting UI collaboration in a systematic way. Attributing the achievement of UI collaboration to any one of them seems unreasonable. Principally, the study characterizes conditions important to achievement of UI collaboration in China as follows.

First, in line with the existing literature, the macro institutional context was important to promote achievement of UI collaborations by means of public subsidies, preferential policies and guiding function for industrial investment. Because the industrial R&D investment is low and chiefly self-relied in China, the financial assistance via public subsidies and tax incentives is particularly important funding source to supplement industrial R&D investment. The public-nature of projects also played as a crucial guiding role to induce firms' R&D expenditure since further public support for infrastructure development can be anticipated after the application of the university technologies. The articulated orientation of application in public-natured projects also functioned as a principal leverage to alleviate difficulties aroused from value differences between the two parties (Colyvas 2007). This is particularly important to facilitate UI collaborations in China where industrial absorptive capacity is still low and the value difference can be significant.

Nevertheless, since both public programs and tax incentives apply strict audition process on applicants, the number of those to actually benefit from the public support is quite limited. Thus, the impact of the macro institutional factors should be less important in a broader context.

Second, on industrial factors, consistent with Ham and Mowery (1998) and Costa Povoa and Rapini (2010), input in capital, human resource, management support and absorptive capacity were vital for achievement of UI collaborations. However, in China, the input of the case firms was exceptional and most domestic firms have only very limited research capacity. The low industrial R&D investment was probably resulted from shortage of funding, underdevelopment of technologies or poor connection between university research and industrial needs (Wang 2008). Thus, the university efforts to promote more application-oriented research should be helpful to induce industrial investment.

Third, university factors of support for academic research-encouraging attitude towards UI collaborations and organizational support via such as RIAIT were important, though indirectly, to achievement of UI collaboration. This somehow asserted with the extant literature that university institutional arrangement could be instructive to promote academics' involvement in UI collaboration and commercialization (Link and Siegel 2007; Woolgar 2007; Thursday and Thursday 2004; Wu 2010). But the university support came only when the academics' activities were evaluated such as being public programs in the cases of Project D and Project M. The evaluation system of academics emphasizing academic output and acquisition of public projects in China was not preferable for promoting UI collaborations. Seeking for industrial funding is more like a second choice for academics when looking for research resources. This was also verified by the chief university administrator of SJTU in charge of scientific research that, usually the case, academics resort to industrial funding only when no public funding is available or the quota for public subsidy has been full that year.[27] But since no regular institutional funding is available to support university research in China, the industrial funding can be the optimal funding source of academic research when no public subsidy is obtained.

Fourth, the important individual factors of academics contributing to achievement of UI collaboration included consistent intellectual support covering the whole process of research application, research seeds of high value in application and knowledge on industrial application. The importance of continual academic backing for industrial innovation was also suggested by the existing literature (such as Jensen and Thursby 2001; Cohen et al. 2002). However, the Chinese case study suggests the importance of a higher extent of academic support which covered all stages of research exploitation from basic research to product development. Thus, given the low industrial research capacity in China, it should be more important to have research seeds close to industrial application, academics with sufficient industrial knowledge and deep involvement of academics even in latter phases of research application.

Fifth, two sets of incompatibilities exist in the context of UI collaborations in China. The first exists in the literal contents and the actual implementation of the policies and laws relevant to UI collaborations. The case study shows the importance of application of university inventions (or patents) to stimulating industrial participation of UI collaborations. But most patents are at embryonic stage and can not be put to use instantly given the current research capacity of firms in China (Zheng et al. 2008; Su and He 2009). The gap between university patent and industrial needs has critical implications for policy implementation. For example, the firm N of Project D pointed out that it even bought university patents only for fulfilling responsibilities of being a new and high technology firm, rather than seeking for commercial application. Some others also complained that university researchers are still doing research in the "ivory tower". Of course poor enforcement of laws of IPR protection in China may negatively influence firms' attitude towards R&D investment, but the weak relevance of university research to industrial needs aroused no less concern among firms. Therefore, although policies or regulations are in place to promote industrial application of university research via UI collaborations, in real situation the "false collaboration" may emerge, in which firms may purchase university patents, but actually no further application is performed.

The second incompatibility points to the university's institutional arrangements. Those to promote UI collaboration did not go hand in hand with others that profoundly influence academics' participation in UI collaboration, especially the academics' evaluation system. Academic works such as papers, awards and public grants rather than industrial connection are more evaluated. This causes two problems. First, academics may not pay sufficient attention to industrial application, which has already aroused discontent from the industry.[28] Although SJTU and some others started stressing the applicability of patents, the situation is not easily altered. Second, this causes hesitation of academic researchers when considering collaborating with firms (Colyvas 2007) of low R&D capacity and no public subsidy. Academics might not spend time and resources on working with industry that are not directly conducive to academic outputs (Calderini et al. 2007). As complained by the university researcher W of Project D that, firms of low research capacity tend to expect too much on the ready-on-shelf products which is not what university researchers should provide.[29] This is also verified by majority of the academic informants in this study (SJTU and Zhejiang University). In addition, if firms of low research capacity seek collaborations with academics of insufficient research funding, it will cause what Carayol (2003) called as "dysfunctional" collaboration, in which academic researchers reconcile their academic research agenda for preserving funding. Reasonably, given the particular importance of academics' involvement in UI collaborations and the existing evaluation system of academics in China, it is extremely challenging for the country to motivate academics' involvement in the latter phases of research application such as product development.

The case projects suggested indirectly the importance of research resources of academics in driving them to participate in collaboration with the industry. However, what worth noting is that, financial consideration should not be the only rationale to motivate academics to join in UI collaborations. It is important that academics should be more encouraged from the perspectives such as training students, keeping abreast with the technological development of the industry and applying university research. As the case projects all indicated the strong desire of academics in putting their research results for application, these rationales should be helpful for UI collaboration to develop in a fruitful and sustainable way.

Finally, this case study on the experience of China provides additional insights into understanding the issue of UI collaborations in the following three main aspects.

First, this study strongly suggests the necessity of deep academic engagement in UI collaborations. This academic involvement is easier to be guaranteed if undertaken in a formalized form of collaboration such as UI joint research based on contracts. Therefore, when the industry is not yet ready to take over further development of university technologies, it is more important to foster UI collaboration than focusing solely on mechanisms of direct technology transfer. Thus, this study supports the claim in the recent literature of the importance of interactive-natured UI relations to industrial innovation (Cohen et al. 2002; Mowery and Sampat 2006; Agrawal and Henderson 2002; Schartinger et al. 2002).

Second, research on UI relations has strongly emphasized the role of institutional settings at the macro level and technology transfer operations at the university level, such as university TTOs (Di Gregorio and Shane 2003; Siegel et al. 2003; Friedman and Silberman 2003), individual level factors of academics were under-studied. However, this study shows a high supplementation between academic involvement and the (low) industrial R&D capacity in applying university technologies. Hence, consistent with the few studies (D'Este and Patel 2007; Perkmann et al. 2013), this study critically suggests the need for more research on individual academics and also the connection with those at the macro and organizational levels in examining achievement of UI collaboration.

Third, this study also highlighted the importance of applying a systematic perspective on investigations of achievement of UI collaboration. Focusing on any single aspect will easily give lopsided and misleading messages. For example, as informed from the fieldwork, increasing university patenting activities may not be due to a "commercial" sense of academics or willingness to work with industry as indicated by Perkmann and Walsh (2009), but rather because of the pressure to fit for evaluation indicators or university rankings, and to meet the requirements for public programs.

7. Conclusion

As the existing literature lacks investigations on UI collaboration in contexts other than western countries, this case study should be able to provide additional insights by focusing on the actual settings of UI collaborative projects in China. The three cases included both projects with public subsidy and those without. This research contributed to the understanding in terms of how institutional framework of promoting UI collaboration interacts with local specificities from the under-studied context of China. The case study shows that, increasing industrial R&D investment, improving industrial connection of research and promoting deep academic involvement in all stages of research application are particularly important to achieve UI collaborations in China. Public subsidies and preferential policies can be particularly useful to stimulate industrial investment for UI collaboration. At the university level, institutional arrangement can also facilitate achievement of UI collaboration indirectly by supporting academic research and connection with industry. However, the challenges to successfully achieve UI collaborations in China are still severe in that most firms still suffer from shortage of funding, public or private, to improve industrial absorptive capacity and academics are confined by the unfavorable evaluation system to produce more application-oriented research outcomes and to deeply involve themselves in UI collaborations.

This research suffers limitation in the limited sample size. Data collection on large numbers of UI projects could be very challenging since universities tend to treat information on industrial connection as a sensitive issue. Nevertheless, to what extent the arguments of this research can be generalized in a broader spectrum should be further verified by using larger sample data. Future research should explore factors contributing to UI collaboration achievement by examining experiences of more research universities in UI collaboration and also the UI projects that have not yet reached final research application.

Finally, this study provides practical policy implications as follows. First, the government should set up more preferential policies and initiatives to encourage firms to take a long-term vision on investing in-house R&D and strengthen industrial absorptive capacity. Also, intellectual property protection policies should be refined and implemented in a more strict way to reduce firm's risk of investment. Second, given the critical role of individual level factors, it is important for policy makers and university administrators to recognize that, more policy measures should address individuals, in addition to those concerning university practices and structures. In addition to generating pure academic knowledge, currently, linking university research to industrial needs should be no less important for universities to contribute to the economy where the industrial capacity in R&D investment is still low.

Notes

1 This research refers UI interactions as the collaborative work between universities and industry in research rather than the generic collaborations on education and other aspects.

2 Even within the few studies working at the project level to investigate key factors pertaining to UI collaboration performance, they tend to take a management perspective which can't fill the gap mentioned above. See Mora-Valentin et al. (2004) for details.

3 There were also doubts on the linkages between the institutional change and the subsequent university performance on commercializing IP (e.g. Siegel et al 2007; Grimaldi et al. 2011).

4 It was explicitly stressed in the National Guidelines on Medium- and Long-term Program for Scientific and Technological Development (2006–2020).

5 Major public programs are "973 Program" aiming for front-line basic research, "863 Program" for research and development of high-technologies, "Torch Program" for developing high and new technology industries and "National Spark Program" for developing agricultural economy by science and technology. All the programs contain certain ratio of projects specialized for UI collaboration.

6 The Project 211 was entitled High-level Universities and Key Disciplinary Fields including 107 universities. Each university was allocated 400 million Yuan to improve teaching, learning and research.

7 Project 985 was entitled World Class Universities and was initiated in 1998. During the Phase I (1999–2003), central government allocated special funding of 14 billion Yuan to 34 universities and the Phase II (2004–2007), special funding amounted to 18.9 billion Yuan to 39 universities. SJTU was in both phases.

8 The other five universities with same authorization are Tsinghua University, Xi'an Jiaotong University, East China University of Science and Technology, Huazhong University of Science and Technology and Sichuan University.

9 The temporal Secretary of Party Committee of SJTU Ms. Ma decided to promote UI collaboration through new organizational settings when she knew with shock that some 3-year projects of as large as 90 million Yuan (approx. US $14.5 million) budget merely ended up with production of some academic papers and patents or equipment machines which were stocked in the lab with no application after the project finished.

10 Personal interview to the Vice Director Prof. B of the Division of science and technology management and also Director of RIAIT at SJTU, Shanghai, 6 May 2014.

11 Annual Report of Scientific Research of School of Mechanical Engineering, various years. Retrieved at http://me.sjtu.edu.cn/Default.aspx on March 25, 2014.

12 DME is considered as one of the new eco-energies and has huge potential to replace oil as the energy of vehicles in the future because it's more cost-efficient and has lower emissions.

13 As finalized in May 2012, the Executive Meeting of the State Council passed the "Guideline for Development of New Industries of National Strategic Importance in Twelfth Five-Year Plan," stating the development orientation and main tasks for the seven new strategic industries, including new energy vehicle industry.

14 In Project D, the research was supported under the "973" Program before the project started in 2006. For Project M, it received ample governmental subsidies as key project of "863" program in 2004 and the Key Project in the National Science & Technology Pillar Program during the Eleventh Five-year Plan in 2006. It also received research funding and rewards from provincial and municipal governments in 2005 and 2006 respectively.

15 For instance, in Project M, the process from raw materials to the final stage of perfluorinated ion exchange membrane generation is extremely complex and the production equipment required can last in an array of thousands of meters in length. The cost was too large to rely solely on the firm.

16 Personal interviews with the academic research leader Prof.Z1 of this project, Shanghai, 17 August 2012; 2 March 2013.

17 In Chinese university system, all teaching faculties are employed based on appointment system which is bound in contract. The contracts are to be renewed every three years according to the academic performance evaluation which means that even full professors have to meet certain quantitative and qualitative requirements of academic

work which is much different from the tenure system of the west. This explains why academics put so much importance to acquire public-subsidies rather than pure industrial funding.

18 Personal interview to the R&D director J of the diesel engine firm XP in Project D, Shanghai, 5 March 2013.

19 Personal interview to the R&D director R of firm XQ in Project D, Shanghai, 6 March 2013.

20 The new and high technology firms that can enjoy the tax incentives should be in the industries of national strategic importance and own at least one patent invention or more than six utility-model patents. Besides, indicators in the aspects of technology transfer capacities, organizational management capacities of the R&D unit and development propensity are also applied for the audition process (Wang 2013).

21 It would have been impossible to share the IP ownership if the academic team had not encountered severe shortage of funding because the academic team had already contributed much effort in basic research before the project started.

22 The firm's decisions on such heavy investments were inspired by chiefly three factors. One was the successful prior experience of UI collaboration that the firm had engaged. When the firm was facing a severe shortage of high-level S&T personnel in the 1990s, the firm turned to UI collaboration for external assistance which eventually brought huge economic return. For instance, the collaborative project with Tsinghua University started in 1999 to perform research on green refrigerant. Within less a year, they came up with high-quality products which were also affirmed for promotion as green substitutes by the environment agencies of the U.S. and European countries. In the following years, the products were ranked top in terms of scale of production, technology and market share globally.

23 The firm has always paid particular attention to capacity building of the R&D team through offering incentives and competitive salaries. It was also the first private firm which established its own research institute and currently a total of 356 full S&T personnel are working in the institute, among which 31 hold doctoral degrees and 61 master degrees.

24 Personal interview to the university research leader Prof. L1 of Project M, Shanghai, 5 June 2014.

25 Personal interview to the R&D executive manager H2 of the firm, Shanghai, August 20, 2012.

26 Personal interview with the academic research leader Prof. Z1 of Project G, Shanghai, 17 August 2012; 2 March 2013.

27 Personal interview to the informant Prof. B (Vice-director of Division of science and technology management and also Director of RIAIT at SJTU), Shanghai, 6 May 2014.

28 When asked about the utilization of university patents in the firm, the firms interviewed have the shown concerns about "quality" of university patents, complaining that they are too academic and not applicable.

29 Personal interview to the informant Prof. T of Project D, Shanghai, 16 August 2012; 8 March 2013.

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Appendix A: Basic information of the case projects studied in the paper

Projects	Funding Sources	Project Goal	Type of Partners	Initiation	Type of Interaction	Main Outputs	Type of Project
Project D	Governmental funding (municipal; 10 million Yuan) and industrial matching funding (varied ratios, the biggest amount 10 million yuan)	Commercializing Dimethyl Ether (DME) Fueled Vehicles	Large State-owned enterprises and large private firms (in total 12); New and high-tech with R&D unit	Academic-within context of organizationally established long-term collaboration; joint application to public programs	Collaborative research	Prototypes; Patents; academic papers; PhD. Students	Developing technology; Testing ideas; solving problems
Project M	Governmental funding (central and municipal) and industrial funding;	Commercializing Perfluorosulfonate Ionomr Membranes	Large private firm; New and high-tech with R&D unit	Academic with no previous collaboration experience with the firm	Collaborative research	Final products; Patents; academic papers; PhD. students	Developing technology; testing ideas; Solving problems
Project G	Industrial funding	Production technology of Graphene, Nano-structure Silver-powder and Stainless Steel Surface Diamond-film	Medium-sized private firm; New and high-tech with R&D unit	Academic with no previous collaboration experience with the firm; academic searching for research funding	Contracted research with no industrial R&D participation	Patents; Academic papers	Developing technology

Source: Based on author's field interview.