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Published in:
Proceeding of RND Management conference

Publication date:
2012

[Link back to DTU Orbit](#)

Citation (APA):

Li-Ying, J., Wang, Y., & Salomo, S. (2012). External Knowledge Acquisition Needs a Hand? The Dual Effects of Industry-University Collaborations on High-Tech Firms' Innovation Capability in China. In Proceeding of RND Management conference

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External Knowledge Acquisition Needs a Hand? The Dual Effects of Industry-University Collaborations on High-Tech Firms' Innovation Capability in China

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Submission number: Paper 16

Abstract

Purpose

Firms have been increasingly investing in external knowledge acquisition to enhance their competitiveness and innovative performance. Among different external partners, universities have become one of the most important ones (Cohen et al., 2002). Collaborating with universities is especially imperative for firms innovating in the technology frontier (Baba et al., 2009). However, the rapid development of industry-university collaboration in some developing countries (e.g., China) has demonstrated some unique characteristics that are different to those presented in developed countries. These unique characteristics urge scholars to re-exam the role of industry-university collaboration for firms' innovation in developing countries. We propose that industry-university collaboration in developing countries has dual roles with regard to firms' innovation capability: 1) to serve as a direct source of knowledge input, i.e. some indigenous technological inventions, and, 2) to facilitate firms' technological learning with respect to absorbing, adapting and diffusing acquired foreign technologies to local market. The purpose of this paper is to test the effect of these two roles on firms' innovation.

Research question

How can Chinese industrial firms' collaboration with universities directly contribute knowledge inputs and at the same time effectively facilitate innovation through external technology acquisition?

Methodology

Our study uses patent counts to measure innovation capability. In line with prior research, we use negative binomial regression model together with a Hausman specification test to determine whether a random- or fixed-effects model should be employed.

Data

We employ a unique dataset on technology in-license from the Chinese Intellectual Property Office (SIPO) in this study. According to the ‘Administration of Record Filing of Technology Licensing’, the SIPO is authorized to fill the records of technology licensing in China. A record contains more valuable information: names of licensor, licensee, and licensed patents, contracting number, date, and license type. So far, the available licensing data to public starts from 2000 to 2009. We limit our sample to those firms who engaged in foreign technology licensing-in activities during 2000 to 2003, which resulted in a sample of 91 Chinese licensee firms in high-tech sector. This period is chosen in order to obtain an appropriate duration that allows learning to take effect. In other words, a 5-year moving window is used to observe the effect of licensing and industry-university collaboration on firms’ innovation capability.

Results

The results show that industry-university collaboration not only has a direct positive effect on but also positively moderate the effect of inward foreign technology licensing on firms’ technology capability.

Keywords: industry-university collaboration; technology license; China

Introduction

Universities play a role for innovation and development not only through its impact on the economic environment by direct licensing or contract research but also through an indirect impact on the local economy through different linkages that they have with industry (Love and McNicoll, 1988; Bleaney et al., 1992). Until recently, researchers have demonstrated the emergent and uprising industry-university collaborations in some developing countries, such as China (Chaminade, 2011; Eun, et al., 2006; Motohashi & Yun, 2007). For instance, according to the official statistics, since 2000 the share of co-invention by science and industry has been sharply increasing at a level of 10 % in Chinese firms' patent portfolios. What can explain this new phenomenon and what is behind the increase of university-industry collaboration in developing countries? Neither the extant literature on industry-university link nor the theoretical argument on firm catch-up strategy seems sufficient to count for this emergent trend. That is because, on the one hand, the findings in the extant literature on industry-university link were largely based on data of industry-university collaborations in the Western advanced economies, which may present very different features compared to the emerging economies (e.g., Wright, et al., 2008). The extant literature found a strong link between knowledge flows from academic research and firm innovative performance when firms are largely equipped with strong absorptive capacity (Furman, et al., 2006; Henderson, et al., 1998; Zucker, et al., 1998). However, most of latecomer firms in developing countries neither innovate on the frontier of technology nor have strong absorptive capacity to source scientific knowledge in universities (Cohen et al., 2002; Fu & Gong, 2011; Griffith, Redding, & Van Reenen, 2003; Hobday, 1995; Laursen & Salter, 2004; Veugelers et al., 2005). Instead, firms in emerging countries generally stay behind the technology frontier and mostly adopt mature technologies developed elsewhere, and their innovations intend to be incremental rather than radical (Barnard & Chaminade, 2011; Van Dijk & Bell, 2007). Thus, we need new empirical inputs from developing countries to fully understand the industry-university linkage effect on innovation.

On the other hand, from the perspective of firms' catch-up strategy, the general idea of technological catching-up of latecomer firms has to be predominantly driven by multinational companies (MNCs) and their knowledge spillovers to a local site, while universities are perceived only as facilitators through providing human capitals and conditioning the environment for inward foreign direct investments (Liefner, Hennemann, & Lu, 2006). It is also suggested that the role of universities will only kick in when firms are at a late stage of

innovation capability catch-up, i.e., innovation, but not in the stages of acquisition, assimilation (Kim's, 1999). However, although the extant literature has widely discussed the role of university-industry linkage with some very general supporting observation (Liu, 2005; Chen and Qu, (2003); Liefner, et al., 2006), we still do not know how exactly industry-university linkage facilitate firms in developing countries to innovate through external technological learning. Thus, a comprehensive and systemic examination of the role of universities in relation with firms' technological learning and innovation capability accumulation is lacking in the extant literature.

In general, industry-university collaborations are still not yet expected in the literature to be a popular phenomenon and major inputs for firms' innovation in developing countries. A more satisfactory and relevant account of firms' active engagements in industry-university collaborations, we suggest, should focus on the enabling function of such a linkage for firms to rapidly acquire and internalize knowledge resources that are needed to build up their innovation capabilities. Thus, we establish our analysis on the role of industry-university linkage through the lens of a resource based view (RBV), where connection with university serves a dual role to facilitate the innovation capability building by Chinese firms, while controlling for the internal and external conditions. More specifically, we propose that industry-university collaboration functions in two different ways in developing countries: (1) it assists firms to learn and adopt foreign technology to the local context and strengthen firms' absorptive capacity; (2) it plays a major role to directly supply knowledge source for firms' indigenous innovation, for which foreign technologies are more difficult to be adopted.

Given the research gaps that we have indentified, this study contributes to the literature on industry-university collaborations and firms' innovation management and competitiveness in terms of the following aspects: First, it contributes to a more comprehensive understanding of industry-university collaborations by extending the research scope beyond the current Western dominance in the literature with new insights from developing countries. Second, it adds to the literature on catch-up strategy of latecomer firms with a new perspective that universities can serve as an important knowledge resource for latecomer firms' technological development and thereby using knowledge generated by local universities can be an input for catch-up. Third, it reveals the drivers behind the establishment of industry-university collaboration at the firm level with regard to the imperative of firms' technological development. Last but not least, most of above mentioned prior studies are based on qualitative research methods with few exceptions (such as Motohashi & Yun, 2007; Guan, et

al. 2005; and Zhou, 2011). Thus, using a sample of Chinese indigenous firms from the high-tech industries, this study, to the best of our knowledge, is one of the first attempts using quantitative methods to investigate the effect of industry-university collaboration on firms' innovation capability in China.

This paper is organized as following: first, we review the literature about how firms catch-up strategies with regard to innovation capabilities. Then, we introduce the drivers behind the establishment of industry-university collaboration and the dual role thereof. Accordingly we develop our hypotheses. In section3, we describe the data and methods used in this study. Next, the empirical results based on the analysis are presented in detail. Finally, we discuss our findings and conclude by addressing some limitations of this study and suggesting directions for future study.

Theoretical background and hypotheses

Since the 1960s, with a increasing number of empirical studies on the catching-up development of Japan, Singapore, Taiwan, Hong Kong, and South Korea, this research stream has been well established. It has been widely accepted that developing countries' national catching-up is largely indicated by the technological and economic convergence between leading countries and latecomers (Mansfield, et al., 1982). Latecomer firms are those firms who are isolated both from advanced technology and markets (Gerschenkron, 1962). Technology and innovation of the latecomer firms are critical to the catching-up process (Freeman, 1995). The question of how a latecomer firm builds up technological capabilities and further become a competitive player in the global market is at the centre of research on firms' catch-up strategy (Hobday, 1995).

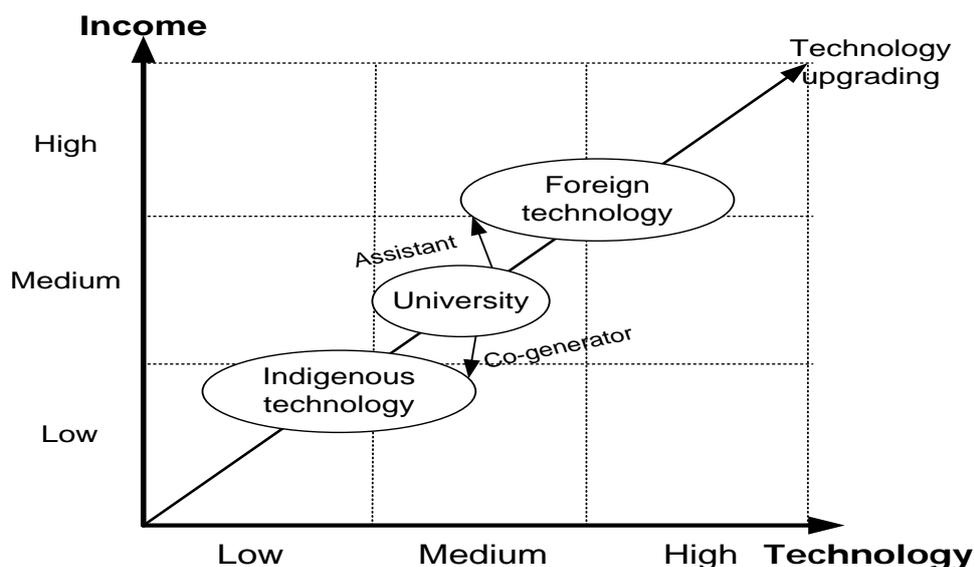
Based on the extant literature, we observed that in general latecomer firms have two options to develop their innovation capabilities and successfully catch up: (1) they are able to exploit the advantage of their late arrival by tapping into technologies developed by firms in advanced countries without the obligation to replicate the entire technological trajectory. Thus, they can accelerate their uptake and learning efforts using various forms of international technology diffusion channels, including the spillover effects of foreign establishments in a host country, state agencies and private technology brokers, benefiting from a favorable public policy towards an open system of external technology acquisition. In this way, latecomer firms may bypass the inertia that holds back some incumbent competitors in the advanced economies (Kim & Nelson, 2000; Mathews & Cho, 1999). Some East Asian and

South-East Asian countries have successfully demonstrated that absorbing and adapting technologies from advanced countries is the preferred approach over indigenous development. In this case, sufficient absorptive capacity in a local firm is found to be crucial as a means to ensure effective learning and enhance innovation capability (Cohen & Levinthal, 1990; Li & Kozhikode, 2008). (2) They can try to develop indigenous technology by filling the “blind spots” where foreign advanced technology is inappropriate. The development of indigenous technologies is consistent with particular social and technological conditions, which are specific to particular combinations of inputs determined by a country factor endowment (Basu & Weil, 1998). Technologies developed in advanced countries are normally characterized by capital augmenting or skilled-labor augmenting in the technology-intensive industries. Such technologies might be inappropriate or not directly applicable in developing countries, in which factor endowments are significantly different from those of advanced countries (Acemoglu, 2002). Fu and Gong (2011) documented that in some middle-income countries, such as China and India, which have accumulated a pool of knowledge and skills and successfully distinguished them from advanced countries as well as the least developed countries, local firms are more likely to generate “intermediate innovations” with a medium-level of technology intensity. These firms have gained returns on investment in the medium- and low-technology sectors and managed to sustain competitiveness in contrast to a strategy of relying on foreign technologies. The competitive advantage of such an indigenous innovation strategy through accumulating innovation capabilities within the blind spots where foreign technologies are not able to fulfill can be significantly augmented when the volume of demands is large.

However, for a nation as an aggregated innovation system to upgrade its technology profile and overall economic competitiveness in turn, latecomer firms in a developing country should collectively employ both strategic options, corresponding to the change of factor endowment and income levels in their countries. In Figure 1, we propose a framework where catch-up strategies for latecomer firms are reflected in relation to the levels of technology development and income of a developing country, and the role of industry-collaboration is illustrated accordingly. On the one hand, in the top-right corner, advanced technologies developed by the high income countries provides one of the options for some latecomer firms to catch-up. Here what latecomer firms need to focus on is acquiring external technologies through various capital or technology markets. On the other hand, in the bottom-left corner, medium- or low-level of technology indigenously developed by some local firms needs to be supported with

complementary knowledge and adopted by a sufficiently large market. In either way, latecomer firms have strong motivations to collaborate with universities, and indeed in most cases this collaboration becomes extremely necessary (Deolalikar & Evenson, 1989; Kim et al., 2000; Kumar, 1987; Lall, 2000; Liefner et al., 2006; Madanmohan, Kumar, & Kumar, 2004; Zhou, 2011). Firms are motivated in the first case because they need universities' assistance to absorb, adapt and assimilate foreign technologies; firms are motivated in the second case because they need direct knowledge inputs from universities to co-create new technologies that are adopted by the specific domestic demands. Corresponding to the motivations to collaborate with universities, we identify and discuss the dual role of industry-university in relation to innovation capability development of firms: (1) it assists firms to learn and adopt foreign technology to the local context and strengthen firms' absorptive capacity; (2) it plays a major role to directly supply knowledge source for firms' indigenous innovation, for which foreign technologies are more difficult to be adopted.

Figure 1: Latecomers' technology upgrading path and role of university



In order to deliberate on the dual role of industry-university collaboration in developing countries, we first need to base our arguments on a widely accepted notion that external technology sourcing directly impacts a firm's innovation capability (Schumpeter, 1934; Henderson and Clark, 1990; Kogut and Zander, 1992). If such a correlation is convincingly proven for latecomer firms, then we are able to hypothesize that industry-university collaboration not only has a direct impact on latecomer firms' technological capabilities but also positively moderates the impact of external technology sourcing on technological

capabilities. Thus, the hypotheses in this paper will be introduced in such an order accordingly.

First of all, scholars and practitioners have long recognized that innovative opportunities often lie outside of a firm's boundary. This is particular the case for technology deficient latecomer firms in developing countries. External sourcing of technology from abroad provides latecomer firms a visible and effective channel to directly access to foreign technology (Katrak, 1990). From a RBV, latecomer firms are motivated to in-sourcing foreign technologies because they reasonably expect high return on investment from direct access and application of these technologies. We take China for example, first, the inefficiency and ineffectiveness of Chinese industrial R&D during the 1980's and the 1990's have left China in a lagging position compared to other industrialized countries (Xue, 1997). Thus, learning from external technology sources through an effective technology market has been promoted in China as a primary means to catch up technological deficiency at a national level (Sun & Du, 2010). Second, technology in-sourcing (e.g., patent licensing transactions) usually involve more than a licensing contract itself. They are usually accompanied with related technology assistance, training and support. In this way, Chinese firms can benefit from international technology in-licensing because they can gain more from the interactive and multifaceted learning process attached to the transfer of technology (Chen & Qu, 2003). Thus, a positive 'learning-by-doing' effect is expected. It is especially the case for large Chinese firms, whose objectives of external technology acquisition are gaining technical strength and establishing potential international cooperative partnerships. In fact, it is usually required for foreign firms to introduce new IP by licensing patents to local partner firms if they plan to form joint ventures or minority holdings (Park and Lippoldt, 2004; Chen and Sun, 2000). Finally, a stimulated R&D effect can be commonly expected to happen succeeding the technology in-sourcing. In order to effectively utilize and further develop the insourced technology, technology recipients are usually urged to upgrade their R&D inputs through enrolment of new engineers and scientists and purchase of new machineries or equipments (Katrak, 1990). That, in turn, strengthens a recipient firm's technological capabilities and potentially leads to a higher propensity of generating new products and processes subsequently. Indeed, many researchers have stressed that inward licensing of foreign technologies offers indigenous firms in emerging countries a unique and valuable opportunity to gain access to state-of-the-art technologies and learn about the latest technological

developments (Chatterji & Manuel, 1993; Lall, 2000; Leone & Reichstein, 2011). Taken together, we predict,

Hypothesis 1: Inward foreign technology sourcing of a latecomer firm is positively associated with its innovation capability.

Besides inward technology sourcing, latecomer firms may sustain competitive advantages by developing indigenous technologies mainly at the medium- and lower- technology spectrum where foreign advanced technology is inappropriate (Fu et al., 2011). To develop indigenous technologies, firms usually do not and cannot go alone either. In fact, in addition to increase its internal R&D expense, latecomer firms need to direct access to knowledge inputs from local universities. Thus, collaboration with universities provides another channel for external technology sourcing. In fact, there are at least two emerging trends that make collaboration with local universities an attractive source of new knowledge. First, most innovative firms in emerging countries are relatively young compared to their Western counterparts and they do not have strong internal technology capabilities. Thus, instead of betting limited resources on expensive and risk internal R&D with limited experiences, they tend to adapt inward technology sourcing strategy with a rational cost-and-benefit calculation (Liu, 2005). Due to the fact that new technological inputs from local universities are adopted and developed based on local factor endowments and localized customer needs, they could also be superior to the foreign ones because the former is easier for firms to emulate and effectively absorb (Li & Kozhikode, 2008). Therefore, compared to in-licensing advanced technology abroad, even though the level of technological advance might not be so high, the net benefits by collaboration with universities are expected to exceed the costs pertaining to it. Second, many developing countries have demonstrated a rapid and significant increase of their scientific and academic output in both natural science and business research (Mudambi et al., 2008; Nguyen & Pham, 2011). Thus, the relevance and contribution of new knowledge input from universities in developing countries should not be underestimated.

Indeed, nowadays in most emerging countries, effective university search programs have predominantly thrived in science and engineering that are oriented towards local application, promoted problem-solving abilities of researchers and focused on technologies of interest to a well-defined domestic user community (Roberto & Nelson, 2006). All these efforts significantly decrease local firms' costs pertaining to knowledge search and innovation through their exposure to a large pool of university-generated knowledge (Zhou, 2011). This is consistent with the observations in some countries, such as China, in which technology

collaboration with universities has become one of the primary approaches for Chinese firms to innovate (Liu, 2005). They are able to acquire new technologies faster and easier and more quickly convert these into new products and services that are appropriate for the domestic market (Xu, 2011). Based on these argumentation and observations, we hypothesize accordingly,

Hypothesis 2: Industry-university collaboration experience of a latecomer firm is positively associated with its innovation capability.

Technology is not simply a set of blueprints, instructions, manuals, and patent rights or copyrights and external technology source, thus, will not benefit firms if they do not have capability to absorb, assimilate, apply and further diffuse the insourced technologies do not have full information and complete knowledge about the insourced technology. As a result, latecomer firms need assistance from external parties to strengthen their *absorptive capacity* and provide *complementary assets* (Li & Kozhikode, 2008). For this purpose, the second role of collaboration with universities steps in.

Universities can help latecomer firms to strengthen their absorptive capacity by compensating firms' insufficient technological capability and limited experience of external learning. Universities generally possess a relatively higher level of scientific knowledge, technology and technical services, which can be shared by collaborating industrial firms (Zhou, 2011). Knowledge and experience hold by universities can help latecomer firms to identify, evaluate, assimilate, transform and diffuse the insourced foreign technologies. The challenges associated with technology transfer from foreign technology partners to local latecomer firms particularly require assistance from local universities. First, technology transfer from abroad is constantly suffered from double sided moral hazard problems (Arora, 1996; Arrow, 1962). For example, the technology supplier may not send its best engineers over to the recipient firms to provide sufficient technical service or some important trade secrets may not be revealed to the recipients (Desai, 1988; Scott-Kemmis & Bell, 1985). Second, successful technology diffusion needs an environment in which interaction and communication between the technology supplier and recipient is crucial (Dyer & Singh, 1998). Cross-border technology sourcing, thus, easily suffers from the barriers of communications due to different languages, cultures and institutions (Lin, 2003). When transfer of tacit knowledge to the technology recipients is inevitably involved in external technology sourcing, the assistance role of collaboration with universities will be more than necessary. Finally, given the weak institutional protection of intellectual property rights in emerging countries, foreign

technology suppliers are generally reluctant to transfer their technical know-how to these countries (Teece, 1977).

Universities can also help latecomer firms to provide them *complementary assets* that is lacking internally or too expensive to purchase from the global technology market. Previous studies have suggested that novel innovations often result from a recombination of existing components of knowledge into new syntheses (Fleming, 2001; Kogut & Zander, 1992). The adoption of foreign technology can, thus, be conceived as a process in which an insourcing firm absorbs and integrates part of the insourced knowledge into its own knowledge base. This integration of these two hitherto separate knowledge bases may enhance the firm's knowledge base by augmenting the recipient's potential to generate inventive recombination for indigenous innovations (Ahuja & Katila, 2001). Thus, local firms will seek assistance from universities for compensating resources and technological capabilities, serving as a third knowledge base, which can be used to maximize the combinative potential that is based on the two hitherto separate knowledge bases of foreign technology supplier and local technology recipient (Gulati & Singh, 1998; Agrawal et al., 2008). Consequently, latecomer firms that rely on inward technology sourcing from foreign sources are expected to have stronger innovation capabilities if the additional supply of absorptive capacity and compensating assets from collaborating with universities is at a high level than those at a low level or without collaboration with universities. This leads us to hypothesize:

Hypothesis 3: Industry-university collaboration experience of a latecomer firm positively moderates the relationship between its inward foreign technology sourcing and innovation capability.

Methods

Sample and data

Inward technology sourcing can be realized through informal network, R&D collaboration and technology acquisition (Kang & Kang, 2009), of which patent licensing has been one of the most important vehicles by which latecomer firms in developing countries gain access to new technological knowledge that are complementary to their internal inventive activities (Marcotte & Nioist, 2000; Chen & Sun, 2000; Katrak, 1990; Tsai & Wang, 2007). A technology license agreement involves two parties with two different but related learning processes (Grindley & Teece, 1997). A firm's licensing activities, thus, are embedded in the overall strategic positioning of a firm (Kollmer and Dowling, 2004).

Technology licensing activities is visible, meaning in most countries one can easily identify and trace the firms that are involved with technology licensing. In our case, the dataset used for this study was obtained from the State Intellectual Property Office of China (SIPO). According to the Chinese legislation ('Regulations on Administration of Record Filing of Technology Licensing'), since 2001 the SIPO has been authorized to register technology licensing contract within three months after a contract is signed between the licensor and licensee. Each record of technology transfer registered at the SIPO contains information on: licensor's name, licensee's name, licensing patent number, patent name, contracting number and date, and license type (exclusive or non-exclusive). License agreements can be signed between individuals and firms in various forms. The licensors or licensees of a licensing agreement could be either Chinese or foreign individuals/firms, but all licensees are Chinese individuals/firms. So far, this dataset only includes technology transfer agreements that involved patented technology. The complete records from 2000 to 2009 are available to the public. In total, there were 15449 license agreements, which covered 36497 transferred patents. There were 6037 licensors (including 3332 individuals) and 6905 licensees (including 48 individuals) in total entered into license agreements in that period.

Prior studies reported that high-tech firms have a higher propensity to collaborate with universities (Roach, 2010). Following this suggestion, we focus on the high-tech sectors in China (Liu & Zhi, 2010). According to the authority of the Chinese State Statistical Bureau's industrial classification system, the Chinese high-tech industries are divided into 17 sub-sectors below five main categories. Specifically, it includes Medical and Pharmaceutical Products (with 3 sub-sectors), Aircraft and Spacecraft (with 2 sub-sectors), Computer and Office Equipment (3 sub-sectors), Medical Equipment and Meters (2 sub-sectors), and Electronic and Telecommunication Equipment (7 sub-sectors). Next, In order to generate a sample that is large enough for our research purpose and allow sufficient time for each licensee firm to learn from previously in-licensed external technology, we limit our sample firms to those that engaged in foreign technology licensing-in activities during the year of 2000 to 2003. This approach is in line with the well established literature that specified a period that the recipient firms need to absorb the licensed technology and develop it further into their own innovation capabilities. We set the learning time as a five-year period after the in-licensing. We thus took license agreements of Chinese firms in the high-tech sectors between 2000 and 2003, and then we observed the innovation capability of these sample firms within the five years after the licensing year up to 2008. Overall, we conducted our analysis

based on a panel dataset of 91 Chinese licensee firms in the high-tech sectors during the period 2000-2003 and survived at least up till 2008.

In the literature on industry-university collaborations, patent is a popular information source to analyze collaborative relationship between universities and industrial firms where multiple inventors from both universities and industrial firms are recorded in the information of a patent when a technical invention draws intellectual inputs from a group of inventors (Cohen et al., 2002). In our case, the SIPO licensing database only contains information of inventors' name, but there is no information on the address or the affiliations of each inventor. As a result, there is no way to distinguish different people with the same name (given the high level of similarity of Chinese names). Thus, this information is hard to be useful. However, an alternative way is to use the information of each patent applicant to analyze collaborative relationships in China (Motohashi et al., 2007). A co-patenting invention by multiple parties does not always demonstrate co-invention activities, but it truly stands for an organizational-level linkage regarding an invention of interest. For instance, a joint patent application by a university and a firm suggests that this invention was achieved by a certain level of industry-university collaboration activities in research and development. Therefore, we use co-patenting information in the Chinese patent application system to trace the collaboration relationships between universities and the industrial firms in our sample. Complementary data was collected through newspaper articles, annual reports, telephone calling and emails.

Measures

Dependent variable

Innovation capability (IC) denotes the learning output of the focal firms. Various measures have been used to measure innovation capability of firms. Scholars have discussed the strengths and weaknesses when using patent counts to measure innovation capability (Ahuja et al., 2001; Griliches, 1992; Singh, 2008). Although patent has its weakness in indicating the capability in the product-market side of an innovation process, at least it clearly represents a degree of newness in terms of technical improvement and methods of application that are new to the country. And the procedures and evaluation system patent application are standardized across all provinces and industries and constant in a relatively long time period. Therefore, we believe that patent data is an appropriate proxy to measure firms' innovation capabilities in China. In this study, we thus measure innovation capability by the total number of patent applications within the five years after the licensing year. Note that we use patents

applications rather than granted patents because the SIPO publishes patent data within several months after application, but patents may not be granted until several years later. Had we used granted patents in our analysis, we would have lost a great number of observations, compared to using patents application information.

Independent variables

Inward foreign technology sourcing (IFTS) is measured by the total number of in-licensed foreign patents that a firm's license contracts contained in a particular year.

Industry-University collaboration experience (IUCE) is measured by the number of different universities who collaborated with a focal licensee firm within the five years following the licensee firms' foreign licensing activities.

Controls

We control for several variables that are considered commonly in the literature on innovation management using patent statistics. First, prior studies have suggested that a firm that has access to multiple knowledge sources might benefit from the network effect and thus have better performance of learning (Levitt & March, 1988; Powell & Brantley, 1992). Thus, at the licensing portfolio level, we control for multiple license sources by using the variable of *licensor scale (LS)*, which is measured by the number of licensors that a licensee firm had in a particular year of licensing. Second, at a firm level, we control for three variables: *firm size (FS)*, *existing patent base (EPB)*, and *firm age (FA)*. *FS* is measured as the number of employees (in a natural logarithm form) of a firm in a particular licensing year. *EPB* is the cumulative number of Chinese patent applications within the five years prior to the in-licensing. This measure to some extent represents a firm's absorptive capacity before licensing in technologies (Cohen and Levinthal, 1990). *FA* is measured as the number of years between a firm's founding year and the licensing year. Next, In developing countries, firms are not only collaborating with universities, they also set up collaborative relationships with other types of research institutes and industry firms (Zhou, 2011). Thus, at a firm-relationship level we control for two variables respectively, namely, *collaboration with research institutes (CRI)* and *collaboration with industrial firms (CIF)*. The former is measured by the number of different partners from research institutes other than universities within the five years after the year of licensing; while the latter is measured by the number of different partners of industrial firms within the five years after the year of licensing. Finally, we also control for two macro-level variables that count for some effects of external contingencies: *market competition (MC)*

is used to reflect the influence of potential competition pressure on firms' innovation activities. This variable is operationalized as the number of licensees whose license agreements contain the same patents from a licensor within the two years after the year of licensing (Dodgson, 1991); and *province patent stock (PPS)* refers to the accumulative number of Chinese patent applications per million people in a licensee firm's local province within the five years after the licensing year. This variable controls for the differences in technological development across different provinces in China.

Estimation procedure

Our study uses patent counts to measure innovation capability. Models for count data have been prominent in economics and management (Cameron and Trivedi, 2005). The foundational building block in this modelling framework is the Poisson regression model (Greene, 2008). However, there is an implicit restriction on the distribution of observed counts in a Poisson model that the variance of the random variable is constrained to equal the mean. In studies using patent statistics, this condition is seldom met because of over-dispersion in the data, i.e., the variance largely exceeds the mean. Therefore, researchers commonly employ a negative binomial model which is an obvious choice for a basic count data (Hausman & Griliches, 1984; Stuart, 2000). Thus, in line with prior research, we use a negative binomial regression model meanwhile Hausman specification test is used to determine the choice between random- and fixed-effects models. This test indicates that a random-effects model is more appropriate for our study (see Table 2).

Results

The descriptive statistics and correlations between the variables are presented in Table 1. From the means and standard variances in Table 1 we see some variables having large difference between the mean and the standard deviations. This confirms the negative binomial regression is appropriate for our analyses. The independent variable is neither highly correlated with themselves nor with the control variables, except that the correlations between *collaboration with research institutes (CRI)* and *Industry-University collaboration experience (IUCE)*, *collaboration with research institutes (CRI)* and *innovation capability (IC)*, and *firm size (FS)* and *innovation capability (IC)* are 0.60, 0.58 and 0.57, respectively, which are high enough to suspect if there could be a multicollinearity problem. However, a multicollinearity diagnostic test shows that the highest Variance Inflation Factor (VIF) is 5.33,

which is below the critical point of 10 (Belsley, 1980). Robustness tests indicate that the results of models are consistent and unaffected by these correlations among the variables.

Table 1 Descriptive Statistics

| Variable | Mean | Std. Dev. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----------|--------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| 1. IC | 359.26 | 1669.94 | - | | | | | | | | | |
| 2. IFTS | 2.91 | 1.36 | 0.24 | - | | | | | | | | |
| 3. FA | 10.02 | 8.57 | 0.13 | -0.05 | - | | | | | | | |
| 4. EPB | 37.94 | 170.32 | 0.43 | 0.05 | 0.16 | - | | | | | | |
| 5. FS | 3.39 | 0.66 | 0.57 | 0.29 | 0.44 | 0.35 | - | | | | | |
| 6. PPS | 4.72 | 0.30 | 0.04 | 0.02 | -0.29 | -0.09 | -0.25 | - | | | | |
| 7. MC | 27.68 | 12.10 | -0.18 | 0.02 | -0.33 | -0.13 | -0.27 | 0.39 | - | | | |
| 8. IUCE | 0.64 | 1.28 | 0.50 | 0.05 | 0.41 | 0.32 | 0.44 | -0.11 | -0.16 | - | | |
| 9. LS | 1.12 | 0.33 | -0.04 | 0.41 | -0.01 | -0.06 | -0.02 | 0.13 | 0.24 | -0.02 | - | |
| 10. CRI | 0.11 | 0.31 | 0.58 | 0.28 | 0.30 | 0.50 | 0.48 | 0.06 | -0.13 | 0.60 | -0.03 | - |
| 11. CIF | 0.24 | 0.43 | 0.36 | 0.26 | 0.23 | 0.31 | 0.42 | -0.07 | -0.19 | 0.36 | -0.13 | 0.55 |

a. Number of observation = 101; Number of firms=91

Table 2 Negative binominal regression analysis results

| Variables | Model 1 | Model 2 | Model 3 | Model 4 |
|----------------------------|---------------------|---------------------|---------------------|---------------------|
| | IC | IC | IC | IC |
| Constant | 1.525** (0.653) | 1.661*** (0.599) | 1.728*** (0.615) | 1.442** (0.716) |
| EPB | 0.350** (0.175) | 0.398** (0.182) | 0.405** (0.176) | 0.379** (0.157) |
| FS | 1.261*** (0.243) | 1.153*** (0.248) | 1.121*** (0.239) | 1.069*** (0.236) |
| CRI | 0.505** (0.219) | 1.365* (0.701) | 0.071* (0.268) | 0.069* (0.268) |
| LS | 0.0587 (0.0478) | -0.041 (0.069) | -0.038 (0.067) | -0.152 (0.093) |
| FA | 0.298 (0.226) | 0.428* (0.240) | 0.285 (0.239) | 0.243 (0.216) |
| PPS | 0.442** (0.217) | 0.468** (0.212) | 0.514** (0.222) | 0.421** (0.201) |
| CIF | 0.314* (0.179) | 0.635** (0.415) | 0.276** (0.175) | 0.259** (0.174) |
| MC | -0.0110 (0.194) | 0.043 (0.203) | 0.064 (0.186) | 0.065 (0.171) |
| IFTS | | 0.391* (0.206) | 0.390** (0.196) | 0.345* (0.192) |
| IUCE | | | 0.620** (0.274) | 0.609** (0.252) |
| IFTS*IUCE | | | | 0.232** (0.126) |
| Hausman test | 8.91 | 11.08 | 11.36 | 12.75 |
| P-value | 0.35 | 0.27 | 0.33 | 0.31 |
| Log likelihood | -385.36 | -383.56 | -380.91 | -377.13 |
| Wald Chi2 | 157.43*** | 162.33*** | 171.64*** | 198.10*** |
| Log likelihood ration test | - | 3.60* | 5.30** | 7.56*** |

a. Standard errors in brackets

b. * significant at 10%; ** significant at 5%; *** significant at 1%

c. Number of observation= 101; Number of firms = 91

Table 2 presents the results of all estimated models with the log likelihood test and the Wald chi square test. The random effects as well as the outcome of the Hausman test for negative binomial panel data models are shown in Model 1, 2, 3 and 4. While Model 1 presents the basic model including only the control variables, Models 2, 3, and 4 include the explanatory variable, i.e., *inward foreign technology sourcing (IFTS)*, *Industry-University collaboration experience (IUCE)* and the interaction term of these two variables. All independent variables are standardized but not for the dependent variable.

Our Hypothesis 1 predicts that *inward foreign technology sourcing (IFTS)* of a latecomer firm is positively associated with its innovation capability. We found that the coefficient for *IFTS* in Model 2 is positive and significant ($\beta=0.391$, $p<0.10$). Next, our Hypothesis 2 predicts that *Industry-University collaboration experience (IUCE)* of a latecomer firm is positively associated with its innovation capability. Thus, we added the variable of *IUCE* into Model 3. We found that the coefficients for *IFTS* and *IUCE* in Model 3 are both positive and significant ($\beta=0.390$, $p<0.05$; $\beta=0.620$, $p<0.05$, respectively). Thus, Hypothesis 1 and 2 both found support. Finally, we predicted in Hypothesis 3 that the industry-university collaboration experience of a latecomer firm positively moderates the relationship between its inward foreign technology sourcing and innovation capability. Therefore, in the full model (Model 4), we further introduced the interaction term of *IFTS* and *IUCE* along with the main effects variables. We found that the coefficients for *IFTS* and *IUCE* in Model 4 are still both positive and significant ($\beta=0.345$, $p<0.10$; $\beta=0.609$, $p<0.05$, respectively), which further confirms the support for Hypothesis 1 and 2. We also found that the coefficient for *IFTS * IUCE* is also positive and significant ($\beta=0.232$, $p<0.05$). Thus, hypothesis 3 is also supported.

Although the control variables included are not of our central concern in this paper, some findings are still worth mentioning. First, consistent with our expectation based on the literature on absorptive capacity, a firm's accumulation of technological knowledge, measured by a firm's *existing patent stock (EPB)* can enhance its future technology capabilities. Second, *firm size (FS)* also found a positive and significant effect, meaning large firms in our sample have better performed in technological innovation, compared to small firms. However, this finding should be interpreted with caution because it is likely that large firms have stronger financial resource to spend on patenting, while small firms are usually limited in capital so that they will seek alternative ways to protect their intellectual properties.

Next, *province patent stock (PPS)* also shows a positive and significant effect on firms' innovation capabilities. This is in line with the extant literature that recognized that a firm's rich external technology endowment generates a positive spillover effect for innovation capability of firms. Finally, *collaboration with research institutes (CRI)* and *collaboration with industrial firms (CIF)* both show a positive effect on firms' innovation capability. Combined with our findings regarding the positive and significant main effects of inward foreign technology sourcing and industry-university collaboration experience, this finding further confirms that multiple external knowledge sourcing from various partners positively influences a latecomer firm's innovation capability building.

Discussions and conclusion

This paper is inspired by a relatively underdeveloped research area with regard to the industry-university collaborations in some developing countries, where the findings and insight suggested by the extant literature based on empirical evidence from the Western countries do not necessary count for the emerging phenomenon in developing countries. Our finding, on the one hand, is consistent with prior studies based on empirical evidence from advanced economies, suggesting that collaborations with universities has a positive effect on firms' innovation capabilities (Furman et al., 2006; Henderson et al., 1998). On the other hand, we suggest that in emerging countries, in China in particular, such a positive effect might be distinguished into two distinct but related roles: industry-university collaboration not only directly provides new and original knowledge inputs for latecomer firms but also contribute to a great extent to facilitate the absorption, adaptation, assimilation and diffusion of insourced foreign technologies. Our empirical analysis supported our hypotheses on the dual role of industry-university collaboration for latecomer firms in developing countries. These two roles underpin the most important mechanisms behind the rapid development of innovation capability of some latecomer firms in developing countries.

With this respect, our study supports the recent argument regarding the catch-up strategy of latecomer firms, which need to combine disparate knowledge resources abroad and in domestic market along their technological learning process to develop innovation capabilities (Chen et al., 2003; Fu et al., 2011; Liefner et al., 2006; Mathews et al., 1999). Specifically, in our case we found that Chinese high-tech firms are linked to foreign technologies and knowledge originally generated by local universities at the same time, where an interactive relationship between the two knowledge sources and innovation capability is expected. The

contribution of insourced technologies can be enhanced when latecomer firms collaborate with universities for assistance in order to compensate their lacking internal R&D capabilities. At the same time collaborating with domestic universities offers them the ability to generate relatively less advanced technologies, but appropriate for the local market needs.

As far as the competitiveness of latecomer firms is concerned, they should to expand their knowledge bases by linking them to multiple external parties, including industrial partners and universities, and try to reap a synthetic effect on innovation capability building by combing foreign advanced technology with domestic indigenous innovations. This further implies that firms do not necessarily need to enhance their capabilities in absorbing, adapting, assimilating and diffusing externally acquired technology by merely increasing their internal R&D expenses. In fact, there is an alternative option for firms to extend their base of absorptive capacity: collaboration with local universities. From this point of view, we recommend that latecomer firms need expanded their linkage with local universities to compensate their lacking internal R&D capabilities.

Moreover, we also found that the magnificence of effect differs between the dual roles of industry-university collaboration. To be more specific, in model 4, we observed that the positive and significant effect of industry-university collaboration alone is much stronger (exp [0.609]) than the one of the combination of industry-university collaboration and inward foreign technology (exp [0.232]). This suggests that the Chinese high-tech industries that licensed foreign technologies benefited more from the collaboration with universities with respect to building innovation capabilities when universities contribute direct knowledge inputs for product or service innovations rather than when universities work together with the firm to further develop insourced foreign technologies. This is a rather interesting finding because it seems to be contradictory with some findings in the prior studies, which suggested that one of the most common contribution of Chinese universities' collaboration with industry is to help specific local firms to adapt foreign technology for the domestic market and universities are not commonly viewed as a major source of technological innovation from the perspective of Chinese firms (Wu & Zhou, 2011). However, having carefully thought over our findings in relation with the findings in prior studies, we recognize that our finding is rather complementary and further enrich our understanding regarding the dynamics between industry-university linkages. That is, our finding probed the roles and the magnificence of roles of industry-university collaboration for a specific group of Chinese high-tech sector firms that have in-licensed foreign technologies. The insights that we can draw here is that

latecomer firms with a technological strategy through inward foreign technology licensing particularly needs support and knowledge inputs from collaborating local universities, even though universities in general are not commonly viewed as a major source of technological innovation for the overall population of Chinese firms.

Our study also has several limitations, which could exactly be the challenges for our future research. First, we focused on firms who licensed technologies from abroad, while there are many other channels (e.g., joint ventures, alliances, merger and acquisition, etc.) through which latecomer firms get access to foreign technologies. Similarly, we used co-patenting to trace the industry-university collaboration, while industry-university collaborations can take place through various ways, including informal channels. Thus, to what extent our findings can be generalized to other external technology sourcing methods and other types of industry-university collaborations remains to be further tested with different data. Second, our sample firms are those in the Chinese high-tech sectors, which are knowledge intensive and benefit to a great extent from various subsidies of the Chinese government. Thus, to what extent our findings can be applied to other industrial sectors remains unknown. Third, our sample firms are only those insourced foreign technologies. However, we do not know how firms that are dedicated to indigenous innovation without foreign technology inputs collaborate with local universities. Last but not least, in our research design we could not consider the characteristics of universities, while prior studies in the literature suggested that scientific institutes with a stronger orientation to applied research and/or lower teaching obligations are more inclined to get involved in collaboration with the industry (Arvanitis et al., 2008). Future study should address these limitations to enrich our understanding the fast growing role of industry-university collaboration in emerging countries.

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