



Find Them Home or Abroad? The Relative Contribution of International Technology In-licensing to “Indigenous Innovation” in China

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Find them home or abroad? The relative contribution of international technology in-licensing to 'indigenous innovation' in China**Abstract**

Innovation policy in China has been promoting 'indigenous innovation' by urging Chinese firms to strengthen their internal research and development (R&D) expenditures and to actively acquire external technologies only if they are advanced and necessary. This policy aims to gradually achieve technology excellence and reduce China's reliance on foreign key technologies. It is, however, still unclear *how international technology in-licensing by Chinese firms, compared with domestic technology in-licensing, has contributed to the indigenous innovation of Chinese firms* during the last decade and whether indigenous innovation policy will continue to make sense in the next decade. This study uses a unique panel dataset containing information on 178 Chinese firms that were active in technology in-licensing during 2000-2004 –and their patenting activities up to 2009 – to investigate this question. Our findings suggest that, given the importance of R&D, Chinese firms that in-licensed international technologies have performed better with regard to indigenous innovation than those that mainly in-licensed domestic technologies, even though the national innovation policy suggests otherwise. The strategic implications based on the findings for Chinese firms, foreign firms, and policy makers are discussed in detail.

Keywords: indigenous innovation, patent licensing, patent application, technological capability, China

Find them home or abroad? The relative contribution of international technology in-licensing to ‘indigenous innovation’ in China

1. Introduction

Technological innovation is an important driving force for regional and national economic growth and competitive advantage. Innovation depends largely on industrial firms’ technological capabilities in a region or a nation (Malecki, 1991). Firms can build their technological capabilities through internal research and development (R&D), internalizing external technologies by technology transfer, and from the spillover effects from other industrial firms (Sun, 2002). China clearly understands this process, and is determined to upgrade the driving force of its economic growth from labor-intensive manufacturing industries to more knowledge-intensive industries that are led by innovation-oriented firms (Altenburg et al., 2008; Alcorta et al., 2009). Ever since China joined the World Trade Organization in 2001, it has nurtured a clear policy to make Chinese firms more competitive against multinationals in both the domestic and global markets. China is determined to enhance the global competitiveness of its firms in order to be an ‘innovation-oriented’ country by 2020 and a ‘leading science power’ by 2050 (Chen and Li-Hua, 2011). China has ranked number one in the world in Georgia Tech’s High Tech Indicators for increased technological input and standing from 1993 to 2007 (Porter et al., 2009). Since 2006 the Chinese government has emphasized the strategic importance of ‘indigenous innovation’ (*zi zhu chuang xin*), which puts a premium on developing a self-sustaining innovation system by best utilizing the domestic technology market and maintaining a significant growth in internal R&D investment (Sun and Du, 2010). Some scholars have suggested that since 2001 China

has gone through a transition period that has featured ‘indigenous innovation’ (Xie and White, 2006) and leapfrogging in various technological areas (Chen and Li-Hua, 2011).

To most policy makers, scholars, and practitioners in China, there are two major postulates for Chinese firms to successfully transit towards ‘indigenous innovation.’ First, Chinese firms must strengthen their internal R&D in order to build sufficient absorptive capacity for innovation. A recent study on the sources of innovation for Chinese firms found that internal R&D contributed the most to the innovation performance of Chinese industrial firms (Sun and Du, 2010). Second, Chinese firms need to actively acquire external technologies and thrive in an open system of innovation. Scholars have found that both internal R&D and expenses on external technology transfer have positive effects on Chinese firms’ overall productivity (Hu et al., 2005). While there is an emerging trend of external technology acquisition by Chinese firms from both international and domestic sources (Deng, 2009), a balance must be struck between licensing in technologies from domestic and international sources to avoid relying too heavily on foreign technologies. While it is widely accepted that strengthening internal R&D is critical for ‘indigenous innovation,’ it is, however, still unclear how foreign (compared to domestic) technology sources have contributed to the generation of technological innovations by Chinese firms during the last decade – and whether the ‘indigenous innovation’ policy will continue to make sense for China in the next decade. This question is of strategic importance not only for Chinese firms and Chinese innovation policy, but also for international firms, regardless of whether they are competitors of (or collaborators with) Chinese firms. Therefore, the central question of this study is *how international technology in-licensing by Chinese firms, compared to domestic firms, has contributed to the indigenous technological innovation of Chinese firms*. This study focuses on the external acquisition of new technology through patent in-licensing by large Chinese firms.

The comparative contributions of domestic and international technology in-licensing by Chinese firms are examined in this paper by evaluating applications for new international patents by the same firms in a successive period. Patent applications contain reliable information that indicates (1) the generation of inventions that are industrially useful and non-obvious to an individual who is knowledgeable in the relevant technical field; (2) the ownership of intellectual property rights; (3) firms' technological portfolios and strategies (Ernst, 2003; Lin, et al., 2006), and (4) firms' strategies for product market internationalization if international patents are applied for (Ghemawat, 2003). International patent applications at the US patent office (USPTO), European Patent office (EPO), and Japanese patent office (JPO) are used because they fit well with the concept of 'indigenous innovation' by properly representing the quality and value of technology, and the product marketing strategy of Chinese firms (Gupta and Wang, 2011). A unique patent dataset collected from the State of Intellectual Property Office (SIPO) in China from 2000–2009 is used for the empirical analysis.

This paper is organized as follows. First, we describe the concept of 'indigenous innovation' in China in detail and explain why new international patent applications are a useful proxy for measuring the output of 'indigenous innovation'. Second, we explain the technology transfer process and the different implications of international and domestic technology licensing for Chinese firms. We expect that technology in-licensing from international sources is more significantly positively associated with new international patent applications made by Chinese firms. Third, we present the data and estimation methods, against which we test our expectation. Finally, after presenting the results, this paper concludes with an in-depth discussion of the strategic implications of our findings for Chinese firms, Chinese innovation policy makers, and foreign firms that have had (or will have) a business stake in China.

2. Background

2.1. 'Indigenous innovation' and Chinese firms' technological capabilities

China's National Science and Technology policy (2006–2020) initiated in 2006 signified a significant retreat from a policy report on 'indigenous innovation' (*zi zhu chuang xin*) that established guidelines intended to reduce the country's dependence on foreign technology. The Chinese Academy of Sciences conducted a 'Technology foresight toward 2020' study to identify the technological fields and subfields that will be of strategic importance for Chinese 'indigenous innovation' until 2020 (Mu et al., 2008). As a result, 'indigenous innovation' as a national innovation policy has had impacts beyond the scope of technological innovation. For instance, 'indigenous innovation' was first clearly linked to government procurement in 2009. The policy was to be carried out via a national catalog of industrial products that were identified as most desirable to develop in order to raise the nation's technological level. In order to qualify as 'indigenous innovation,' a product had to be produced by an enterprise that owned the intellectual property in China, had a trademark owned by a Chinese company, was registered in China, and embodied a high degree of innovation.

In January 2010, the Ministry of Science and Technology modified the policy to stipulate that in order to be eligible for accreditation, applicants must be manufacturing enterprises that are legal entities in China (including registered foreign-invested enterprises) and their products must comply with national laws, regulations, and technology policies. The Ministry's notice also stated that the product must be 'advanced' according to very general criteria. This blocking of foreign products from public procurement in China was finally resolved through political negotiation (Lubman, 2011).

It is important to understand that the underlying meaning of *zi zhu* in Chinese, which is translated as 'indigenous,' has multiple facets and profound implications. First, *zi zhu*

demonstrates a commitment to the total transition of national- and firm-level competences in China from imitation to innovation. Second, it requires new knowledge and innovations to be self-generated and self-managed by Chinese organizations. Third, *zi zhu* emphasizes ownership of intellectual property rights (IPR) by Chinese firms, which entitle the IPR holders to profit from their intellectual properties anywhere the IPR is protected. Finally, the concept represents national pride based on economic and technological independence from Western countries. Thus, 'indigenous innovation' as a national strategic innovation policy orientation puts a premium on strengthening Chinese firms' internal R&D capabilities and reducing their dependence on foreign technologies. Meanwhile, 'indigenous innovation' also represents innovation processes as the means – and innovation outputs as the ends – to achieving China's technological supremacy. The aim is that eventually, the innovation policy in favor of 'indigenous innovation' and Chinese firms' ensuing investment and innovation activities will enhance technological capabilities as a crucial composite for their core competences (Wang et al., 2004).

Although 'indigenous innovation' represents a national-level policy to be achieved by, for example, more internal R&D expenditure and more active external technology acquisition with less reliance on foreign sources, there has not yet been a well-established indicator for the outputs of 'indigenous innovation.' This paper uses patent data to capture the outputs of 'indigenous innovation' because patents have generally been regarded as a signaling mechanism for technology firms to credibly publicize information about their R&D focus, technology portfolio, strategic orientation, and potential market access (Lin et al., 2006; Ernst, 2003). Patents are also accepted as a good proxy for firms' ability to develop technological inventions, if used appropriately (Stuart and Podolny, 1996; Coombs and Bierly, 2006). Chinese firms may apply for new domestic patents at SIPO in China or at international bodies

in foreign countries. In this study we consider international patent applications at USPTO, EPO, and JPO to be a satisfactory proxy that more appropriately represents ‘indigenous innovation’ than Chinese domestic patent applications for several reasons. First, many patents registered at the SIPO are technological improvements based on foreign ‘prior arts.’ Thus, the quality and newness of these patents are not always guaranteed. In other words, it is uncertain whether a Chinese domestic patent is truly innovative or merely imitative. Second, international patent applications indicate a firm’s capability to generate new technological knowledge, seek protection and application of the newly generated technologies, and profit from them in the international markets (Ernst, 2003). International patent applications not only represent a firm’s application of new technical knowledge, but also reflect its strategy for geographical market expansion (Deng, 2009; Ghemawat, 2003). Third, the ownership of international patents – especially those granted by the USPTO, EPO, or JPO – will be regarded as a symbol of true ownership of technological advance that a firm or a nation can be proud of (Grupp and Schmoch, 1999). Therefore, in this paper Chinese firms’ international patent applications at the USPTO, EPO or JPO denote the *ends* of ‘indigenous innovation,’ while their domestic and international technology in-licensing represent one of the *means* towards ‘indigenous innovation.’ Given the importance of internal R&D, we are interested in which type of the means (i.e., international vs. domestic licensing) has contributed more to the desirable ends.

2.2. International vs. domestic technology licensing

External knowledge is crucial for building firms’ technological capabilities because it provides them with external sources of technology elements as strategic assets to produce a Schumpeterian ‘novel combination’ (Schumpeter, 1934; Nelson and Winter, 1982) and compensate for any gaps in competence (Henderson and Clark, 1990; Kogut and Zander,

1992). Technology transfer has been one of the most important vehicles by which firms in developing countries have gained access to technological knowledge from developed economies (Marcotte and Niost, 2000; Chen and Sun, 2000). Among others, patent licensing is the one of the most important means through which technology transfer is achieved. During the last two decades, patent transactions from developed economies to developing countries have significantly increased (Park and Lippoldt, 2004). Many forms of foreign direct investment (FDI) to developing countries have largely involved patent licensing. China (including Hong Kong) has received more FDI than any other developing country since 2008. The weakness of industrial R&D due to historical reasons in China has led to a huge demand for technology transfer based on an effective technology market (Xue, 1997). In general, Chinese firms are very interested in technological knowledge from developed countries (Samli and Kosenko, 1982).

Licensing agreements are one of the most important means of firms' external technology acquisition, through which they acquire technologies that are complementary to their internal inventive activities (Lichtentaler, 2008). A technology license agreement involves two parties with two different (but relative) learning processes (Grindley and Teece, 1997). On the one hand, the licensor exploits its knowledge externally by means of outward technology licensing. On the other hand, the licensee needs to internalize the in-licensed technologies through an exploitative or exploratory learning process (Cummings and Teng, 2003). A firm's licensing activities are thus embedded in its overall strategy and positioning (Kollmer and Dowling, 2004). From a recipient's perspective, especially for firms in developing countries, in-licensing technology can provide firms with strategic assets that are crucial to make up for any gaps in competence in order to achieve competitive advantage in domestic or international markets (Deng, 2009; Chen and Sun, 2000). The resource-based view maintains

that a firm's competitive advantage is based on its resources: assets, competences, and capabilities (Barney, 1991). While assets refer to physical resources, competences are bundles of skills, knowledge, know-how, systems, and technologies applied in the utilization and mobilization of a firm's assets (Hamel and Prahalad, 1994; Amit and Schoemaker, 1993). Without these competences, a firm would not have the capabilities to achieve its business objectives and eventually gain competitive advantages (McGrath et al., 1995; Teece et al., 1997). Thus, in-licensing of both international and domestic external technologies plays a crucial role in filling this gap in competences.

As mentioned before, the means for achieving 'indigenous innovation' include strengthening Chinese firms' internal R&D and acquiring new technologies externally that are crucial for building firms' core competences. For the latter, the national innovation policy has favored acquiring technologies from foreign sources only if they are significantly important and advanced. This makes sense because studies in industrial innovation in the 1990s suggested that lagging countries, such as Japan, Korea, and Taiwan, have followed a similar development path of 'importation-imitation-absorption-assimilation-original innovation' (Nelson, 1993). Evidence has shown that China is following a similar path and is still struggling between the importation, imitation, and absorption stages (Sun and Du, 2010; Deng, 2009). A recent theoretical contribution in the literature proposed that large firms in China tend to follow a learning pattern that starts from bilateral exploitation to unilateral exploitation or exploration, and then to bilateral exploration (Li, 2010). In other words, Chinese firms tend to build their technological capabilities by starting with collaborating with foreign partners and acquiring international technological knowledge that they are not able to obtain domestically, then assimilating and internalizing these acquired technologies into their

existing knowledge base and trying to ‘invent around’ in the local market, and finally opening up a much broader scope of inter-firm collaboration to explore new technological areas.

Between international and domestic in-licensing of technology, there are several reasons to claim that international licenses make a more significant contribution to Chinese firms’ ‘indigenous innovation’ outputs, especially in terms of international patent applications. First, the inefficiency and ineffectiveness of Chinese industrial R&D during the 1980s and 1990s 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 of catching up technological deficiency at a national level (Sun and Du, 2010). Second, patent licensing transactions usually involve more than simply a licensing contract. They are usually accompanied by related technology assistance, training, and support. In some cases, brand names and trademarks are transferred along with patented technologies (Park and Lippoldt, 2004). In this way, Chinese firms can benefit more from international technology in-licensing than domestic licenses because they can gain more from the interactive and multifaceted learning process attached to the transfer of technology (Chen and Qu, 2003). This is especially the case for large Chinese firms; their objectives for external technology acquisition are gaining technical strength and establishing potential international cooperative partnerships. In fact, foreign firms are usually required 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, from a transaction cost economy point of view, international technology transfer tends to be more costly than domestic transfer because it involves a greater effort to identify the technologies in the international market and negotiate the licensing terms. Therefore, Chinese firms will have stronger incentives to maximize the value of these in-licensed technologies, not only by

directly applying them to new product development but also by generating new patents for future applications. Furthermore, generating related new patents may also offset the loyalty of in-licensing by cross-licensing (Mansfield, 1994).

International technology in-licensing also urges Chinese firms to meet international product standards (Chen and Sun, 2000). Many Chinese firms were able to adopt ISO9000 worldwide quality standards and CE certification in the European market by importing key technologies from international origins (Yu et al., 2006). Moreover, the greater a firm's accumulated inward internationalization – in terms of technology know-how, management skills, and human resources – the stronger its motivations and capabilities to further acquire international strategic assets (Deng, 2009). In our case, these strategic assets are interpreted as using international patents to secure a competitive advantage in China and in the global market. A pool of international patents is usually a prerequisite for international product diversification, especially for large firms with an international expansion strategy (Hitt et al., 1997). Thus, we would expect that Chinese firms with more international technology in-licensing are more likely to apply for new international patents in developed countries. Therefore, at a macro-level, compared to domestic technology in-licensing, we expect that international technology in-licensing has been the major source of (and contributes more significantly to) 'indigenous innovation' outputs of Chinese firms during the last decade – and that this will continue to be the case in the near future. One could expect Chinese firms that mostly in-license patents from international sources to be more likely to build strong capabilities to make new technological inventions that have value to be protected in the domestic as well as the global markets.

3. Methods

3.1. Sample and data

The dataset used for this study was obtained from the SIPO. According to Chinese legislation ('Regulations on Administration of Record Filing of Technology Licensing'), since 2001 the SIPO has been authorized to register technology-licensing contracts within three months after the contracts have been signed between the licensor and licensee. Each record of technology transfer registered at the SIPO contains information on: licensor name, licensing patent number, patent name, licensee name, contracting number and date, and license type. License agreements can be signed between individuals and firms in various forms. The licensors 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 from the SIPO website (<http://www.sipo.gov.cn/>). In total, there were 15,449 license agreements, which covered 36,497 transferred patents. There were a total of 6,037 licensors (including 3,332 individuals) and 6,905 licensees (including 48 individuals) entered into license agreements in that period. Other scholars have used this dataset to study other relevant issues (e.g., Li-Ying, 2013; Wang et al., 2013).

The sample of Chinese firms is chosen for this study based on the following criteria. First, since in this study we are only interested in *firms'* technological capability, we excluded all license agreements with individual licensors or licensees. Second, we focused only on native Chinese firms, because foreign subsidiaries and joint ventures are usually influenced by their foreign parents or foreign partners regarding the direction of technology development (Katrak, 1990). Thus, we only included native Chinese firms in our sample and excluded licensee firms that were the subsidiaries of foreign firms in China in order to capture the 'indigenous' feature of innovation. Third, we focused on large Chinese firms in our sample (with more than 500 employees) because complementary information on these firms is more accessible and

reliable in China from public sources than that of small Chinese firms. Finally, a sufficient time lag is needed to allow licensee firms to undergo a learning process and demonstrate their innovation outputs after in-licensing technologies (Bell, 2006). Thus, we set a learning time of a five-year period after an in-licensing agreement. This approach is consistent with several prior studies that analyzed the effects of R&D efforts, external technology-oriented acquisitions, and strategic R&D alliances on subsequent patent applications (Ahuja and Katila, 2001; Cloudt et al., 2006; Eric, 2002; Hall et al., 1986). For instance, Ahuja and Katila (2001) and Hall et al. (1986) have shown a significant five-year lag for mergers and acquisitions and R&D efforts to affect patent outcomes. Therefore we used an observation window from 2000 to 2004 for a firm's licensing activities and a five-year moving window after that to observe a firm's subsequent patent applications. For example, if a firm licensed in technology in 2000, we expect that this firm could have learned and demonstrated improved innovation capability, which is measurable by calculating its patent applications, during the following five years (i.e., from 2001 to 2005). In this way, firms' licensing activities were observed from 2000 to 2004 and their corresponding patent applications were observed up to 2009.

Based on these selection criteria, we obtained a sample of 202 firms. We had to remove 24 firms from the list, as they did not survive the next five years due to bankruptcy or acquisition. Overall, we conducted our analysis based on a panel dataset of 178 firms that were active in technology in-licensing during 2000–2004 and survived at least until 2009. These 178 licensee firms included almost all the well-known Chinese firms, such as Huawei, Haier, BYD, ZTE, Datang, etc. While a number of firms had more than one in-licensing agreement, others had no in-licensing agreements in a particular year during the period 2000–2004. Therefore there are a total of 196 firm-year observations, resulting in an unbalanced panel dataset. In our sample, 56% of the licensing agreements were entered by licensor firms from

foreign advanced countries, including Japan, the United States, the Netherlands, Germany, and Austria. The most active licensors were Qualcomm Inc., Philips Electronics, and TDK Corporation.

The sample licensee firms come from various manufacturing industries according to the Chinese Industrial Classification (CIC) system, which was approved and disseminated by the National Standard Commission and took effect on October 1, 2002. The CIC categorizes Chinese industries into 20 sections, 95 divisions, 396 groups, and 912 classes, using a four-digit coding system. For our study we were able to identify the first two digits of the CIC code of a licensee firm, which yields 23 different industrial divisions across various sections. As far as the industrial distribution of firms is concerned, licensee firms in ‘Electric equipment and machinery’ (two-digit code: 40) accounted for about 53% of all the licensees in the sample, dominating the licensing activities. In second place, firms in ‘Chemical manufacturing’ (two-digit code: 26) accounted for 10%, followed by ‘Special purpose equipment manufacturing’: 8% (two-digit code: 36), ‘Electric and mechanic manufacturing’: 5% (two-digit code: 39), and ‘Medical manufacturing’: 4% (two-digit code: 27). These firms were based in 21 Chinese provinces or municipalities and are relatively concentrated in a few provinces; 84% are located in only five provinces, including Guangdong (39%), Beijing (17%), Jiangsu (12%), Shanghai (9%), and Zhejiang (8%).

In addition to the information on licensing, we also collected patent application data from the SIPO for each firm during study period. Exhibit 1 shows an overview of patent applications by all the licensee firms in the SIPO dataset from 2001–2009. The overall new patent applications filed by these firms in this period dramatically increased, especially during 2006 to 2009. However, domestic applications dominated the fast increase in new patent applications. Among all new patent applications, the number of international filings at the

USPTO, EPO, and JPO remains less than 10%, even though it increased during this period. This dataset of new patent applications by the sample firms is in line with national-level statistics, which state that over 95% of new patent applications by Chinese firms were filed domestically with the SIPO (Gupta and Wang, 2011). Therefore, it underscores the importance and appropriateness of employing international applications as an indicator of ‘indigenous innovation’ outputs.

Information on ‘firm age’ and ‘firm size’ could not be identified from the licensing data and patent application data. Thus, we had to refer to complementary information sources, collected through newspaper articles and annual reports during the study period. The age of all 178 sample firms was easily identified using this method, but the firm size of 21 sample firms could not be found using this method. We had to track down this information by telephone calls and emails.

Insert Exhibit 1 here

3.2. Variable measurements

3.2.1. Dependent variables

International patent applications (Y_i): Among all international patents, the US, EU, and Japanese patents were the most popular for Chinese innovative firms, and they represent the ownership of advanced technologies (Grupp and Schmoch, 1999). To allow us to have a detailed exploration of the comparative contribution of international and domestic technology in-licensing on ‘indigenous innovation,’ we use two different measures of the international

patent applications made by the sample Chinese firms. Note that we do not use granted patents, because patent data are usually published within 18 months after application (for US, European, and Japanese patents), while it may take much longer for a patent to be granted.

First, we use a count variable for the number of international patent applications at the USPTO, EPO, and JPO by a firm within five years after the licensing date to reveal a rich picture of the relationship between technology in-licensing and international patent applications. If a Chinese firm succeeded in applying for patents in any of these foreign patent offices within five years after the licensing date, we count the total number of patent applications; otherwise, we code the value of this variable as '0'. To truly represent Chinese firms' indigenous innovation, we operationalize this measure by excluding all patent applications that were co-patented with any foreign partners. Patent counts have been widely used to measure firms' technological capability in prior studies (Henderson and Cockburn, 1996; Pakes and Griliches, 1980; Trajtenberg, 1990). A count variable, as such, not only allows us to qualitatively assess *whether* a Chinese licensee firm managed to file new international patent applications, but also quantitatively assess *to what extent* a Chinese licensee firm did so.

Second, firms in a given country tend to file relatively more domestic patent applications due to the 'home advantage' effect (Criscuolo, 2006). If this the case in China, then a count-dependent variable of international patent applications does not sufficiently reveal its true extent in relation to firms' domestic patent applications. In other words, the importance of international patent applications as a proxy of Chinese firms' indigenous innovation needs to be understood in comparison with the scale of domestic patent applications. Therefore, a ratio of the number of US, European, and Japanese patents to the total number of patent applications of a firm within the five years after the licensing date is calculated as the second

measure of the dependent variable (Y_r). Patents that were co-patented with any foreign partners are excluded here as well. Note that we could alternatively use triadic patents, which are patents filed at the USPTO, EPO, and JPO simultaneously and registered at the Organization for Economic Co-operation and Development (OECD), as an indicator of indigenous innovations made by Chinese firms. However, we opt for not doing so for three main reasons. First, the most recent year for which the data on triadic patents is available is 2008, which does not fit well in the timeline in our analysis. Second, according to the OECD, in 2008 there were only 473 triadic patent filings from China. Thus, the small numbers of Chinese-made triadic patents in the sample will make it hard for us to find statistically convincing results. Last but not least, since we do not *compare* international technological innovation among different countries, using patent application data at the USPTO, EPO, and JPO does not suffer any possible bias based on the ‘home advantage’ effect (Criscuolo, 2006).

3.2.2. Independent variable

Ratio of international in-licensing (RIL): A firm in one observation year might in-license either foreign or domestic technologies. This variable is operationalized by dividing the number of foreign licenses by the total numbers of all a firm’s licenses for each observation year.

3.2.3. Control variables

We control for several variables that are commonly considered in the literature on innovation management using patent statistics. At the firm level, *Absorptive capacity (AC)* is usually measured by a firm’s R&D expenditure. However, due to the difficulties in obtaining R&D expenditure for Chinese private firms, we alternatively measure absorptive capacity by the number of Chinese patent applications during the five years prior to the in-licensing (Cohen

and Levinthal, 1990). This information was collected from the publicly available patent application data at the SIPO. *Firm age* (*AGE*) is the number of years from a firm's establishment to the year of licensing (Teece, 1977). *Firm size* (*SIZE*) is measured by the number of employees of a firm (using a natural logarithm form). To compensate for a potential simultaneity bias and to avoid endogeneity problems, we use the one-year-lagged value of *firm age* and *firm size* in the models (Hess and Rothaermel, 2011). *License scale* (*LicScale*) is the total number of in-licensed patents of a firm in a particular year from both foreign and Chinese in-licensing. This variable is not lagged because it needs to correspond to the independent variable. We introduce both the linear and squared terms of this variable because we are interested in whether excessive dependence on inward technology licensing may result in undesirable implications for Chinese firms' indigenous innovations. Moreover, different sectors have different propensities to apply for patents (Bas and Sierra, 2002). Therefore, we also control for industry effects using a dummy variable, *Firm Sector* (*SECTOR*). In our study, more than 50% of the licensee firms are from the 'Electric equipment and machinery' industry (two-digit code: 40), which has received considerable support and incentives from the Chinese government (Altenburg et al., 2008). Thus, we introduce a dummy variable¹ to control for the potential difference regarding indigenous innovation between this dominant sector and other sectors. We define the value of this variable as '1' if a firm is in the 'Electric equipment and machinery' sector, otherwise the value is '0'.

¹ We also used two alternative strategies to control for the industrial sectors. First, we used 22 dummy variables to control for different industrial divisions, represented by the first two digits of the CIC code. However, due to the relatively small number in our sample, adding 22 dummy variables in the models did not allow sufficient convergence of variables in the data. Second, we used five dummy variables to control for five major industrial divisions in our data plus an additional category of 'other industries.' Consequently, no significant difference in the results was found other than that shown in this paper.

At the licensing-agreement level, we determine whether a licensing agreement is exclusive or non-exclusive. The former transfers all indicia of ownership to the licensee, who gets a promise from the patent owner that the patent will not be licensed to anyone else in a stipulated field of use, while the latter means that the patent owner essentially promises not to sue the licensee for the use of the patent. One might expect that the licensee of an exclusively licensed technology is more likely to augment the monopolistic ownership over a patent (and is thus more reluctant to innovate further), while the licensee of a non-exclusively licensed technology is motivated to innovate further based on such a technology before other licensees succeed in doing so. However, a counterargument also seems to make sense. Therefore, we need to control for *licensing exclusiveness (LE)*, which is operationalized as the number of licensees that have license agreements with the same patent from a licensor within three years after the year of licensing (Dodgson, 1991). While '1' indicates an exclusive licensing agreement, a higher value of this variable reflects the extent to which a patent is utilized competitively by multiple licensees. Next, old or new technologies have their advantages and disadvantages as a knowledge input for further innovation (Nerkar, 2003; Heeley and Jacobson, 2008). Thus, we need to control for the *technology age (TA)* of the patents that are included in a licensing agreement. This variable is measured as the number of years between the year when a patent was filed at the SIPO and the year when the patent was in-licensed by a Chinese firm (Almeida and Kogut, 1997). If a licensing agreement included more than one patent, then we calculate the average for the value of this variable. This variable is also lagged for one year to avoid potential endogeneity problems.

Furthermore, we control for a number of variables that count for the external environment. First, *Province patent stock (PPS)* refers to the accumulative number of Chinese patent applications within the five years prior to licensing-in in the province where the licensee

resides (Singh, 2008). This variable controls for the differences in technological development across provinces in China. This information was collected from the publicly available patent application data at the SIPO. Finally, we also added four *year dummy variables* (*Year2001*, *Year2002*, *Year2003*, and *Year2004*) to control for any other unobservable variances pertained to a particular year. Year 2000 is omitted as the reference year.

3.3. Estimation specification

In this study, the dependent variable is operationalized by two different measures in order to probe the in-depth implications of the results. The first is a count variable, which can qualitatively indicate *whether* and quantitatively indicate *to what extent* a licensee firm subsequently filed international patent applications. Models for count data have been prominent in economics and management (Cameron and Trivedi, 2005). The foundational building block in this modeling framework is the Poisson regression model, which is estimated by using maximum likelihood estimation techniques (Greene, 2003). However, there is an implicit restriction on the distribution of observed counts in a Poisson model: the variance of the random variable is constrained to equal the mean. In studies using patent statistics, this condition is seldom met because of overdispersion in the data, i.e., the variance largely exceeds the mean. Due to overdispersion in our data (e.g., the standard deviation of absorptive capacity is nearly 18 times its mean), we resort to negative binomial regression models instead, which add a parameter α to the model, controlling for unobserved heterogeneity and thus correcting for overdispersion in the data (Cameron and Trivedi, 2005; Greene, 2003).

In addition to the problem of overdispersion, the first measure of the dependent variable also suffers from an excessive amount of zero values relative to the amount of actual observed cases in which a firm filed an international patent application. The value of the dependent

variable can be zero when a firm *decided* not to apply for an international patent, and it can also be zero when a firm was *not capable* of filing an international patent application. Unlike in the first situation, the zero value of the dependent variable in the second situation was unrelated to a firm's decision making, but both situations resulted in the same outcome. A Vuong test was used to compare the standard negative binomial to the zero-inflated negative binomial (ZINB) (Vuong, 1989). The ZINB deals with the existence of two (latent) groups within the population: an *always-zero* group, which has strictly zero counts (with a probability of 1) and a *not-always-zero* group, in which both zeros and positive counts can be observed (with a non-zero probability that the count is different than zero) (Lawal, 2012). In our case, the always-zero group is the one that was not capable of further innovating, while the not-always-zero group was capable of further innovating but might have decided not to do so. Correspondingly, the estimation process of ZINB encompasses two parts. The first part contains a logit regression of the predictor variables on the likelihood that there is no decision at all regarding international patent applications. The second part includes a negative binomial regression on the probability of each count for the group, which has a non-zero probability that the count is not zero. This means that the ZINB distribution is a mixture distribution that assigns a mass of p to 'excessive' zeros and a mass of $(1-p)$ to a negative binomial distribution (Lawal, 2012), where $0 \leq p \leq 1$. Specifically, the model mainly used in this study is represented as:

$$E(Y_i) = \exp\{\alpha + \beta_1 * RIL + \beta_2 * AC + \beta_3 * LicScale + \beta_4 * PPS + \beta_5 * TA + \beta_6 * LE + \beta_7 * AGE + \beta_8 * SIZE + \beta_9 * SECTOR + \beta_{10} * Year2001 + \beta_{11} * Year2002 + \beta_{12} * Year2003 + \beta_{13} * Year2004 + \epsilon\}$$

Where Y_i is the dependent variable and other independent variables have been defined previously, α is the constant term, ϵ is an error term (which is assumed to be

uncorrelated with the independent variables), and β_i are the regression coefficients to be estimated.

The second measure is a ratio of the number of US, European, and Japanese patent applications to the total number of patent application of a firm within the five years after the licensing date. Due to the ‘home advantage’ effect (Criscuolo, 2005), firms in a specific country usually tend to file more domestic patents than international ones. Therefore, there is no cases in our sample in which all the patent applications of a Chinese firm are international ones. Thus, this measure becomes a continuous variable with a limited range of value between 0 and 1, including 0 but excluding 1. Therefore, a Tobit model is employed for estimation (Greene, 2003).

1. Results

The descriptive statistics and correlations between the variables are presented in Table 1. The independent variable is not highly correlated with the control variables. The only exception is the correlation between *technology age* and the *ratio of foreign license* (0.6497), which is high enough to suspect there could be a multicollinearity problem. However, robustness tests indicate that the results are consistent and unaffected by these correlations among the variables, because the maximum estimated variance inflation factors is 2.79, which is below the recommended level of 10 (Chatterjee and Price, 1991).

 Insert table 1 here

Table 2 presents the results of all estimated models. First of all, given that the first measure of our dependent variable is a count variable, a Vuong test indicates a high probability that a

two-group modeling process could be run using a ZINB regression ($p < 0.01$) rather than conventional negative binomial models. Models 1 and 2 report the results by using a ZINB model. To be more specific, Model 1 is the part of a logit regression and Model 2 is the part of a negative binomial regression. The coefficient for the ratio of foreign licenses in Model 1 is positive but non-significant ($\beta = 0.846$, $p > 0.10$), indicating that the extent to which a Chinese firm in-licensed international technology did not influence the likelihood of *whether* a licensee firm will make subsequent international patent applications. However, the coefficient for the ratio of foreign licenses in Model 2 is positive and significant ($\beta = 2.150$, $p < 0.01$), which supports our prediction that the extent to which a Chinese firm in-licensed international technology is positively associated with the likelihood that a licensee firm will make *more* subsequent international patent applications. Taking Models 1 and 2 together, we interpret the results of the ZINB model as follows. The positive association between in-licensing international technologies by a Chinese firm and the likelihood of making subsequent international patent applications is buffered by a firm's decision making. In other words, the extent to which a Chinese firm in-licensed international technology does not necessarily lead to a decision to file new international patents; however, for those firms that have decided to do so, there is a positive association between international patent in-licensing and subsequent new international patent applications.

The dependent variable in Model 3 is a continuous variable with limited value, indicating the percentage of international patents among all the patent applications filed by a licensee firm after licensing in technologies. The coefficient for the ratio of foreign licenses in Model 3 is positive and significant ($\beta = 0.718$, $p < 0.01$). Thus, the results in Model 3 confirm that there is a positive relationship between in-licensing foreign technologies and filing new international patents by Chinese firms at either the US, Europe, or Japanese patent office. Such a

surprisingly satisfactory result indicates that the positive effect of the independent variable does not seem to be diluted by the alleged ‘home advantage’ effect when the dependent variable is measured as the ratio of international patent applications to the total number of new patent applications. In other words, even though we count for the fact that Chinese firms in general tend to apply for relatively more domestic patents than international ones, the significant positive relationship between in-licensing foreign technologies and filing new patents at the USPTO, EPO or JPO still holds.

Moreover, the high correlation between *technology age* and the *ratio of foreign licenses* (0.6497) indicates that Chinese firms have still been licensing in relatively mature technologies during the last decade. We also find that firm sector has a significantly positive effect on the dependent variable (a count variable) in the ZINB models (Models 1 and 2), while it shows no significant effect on the dependent variable (a continuous variable with limited value) in the Tobit model (Model 3). This finding suggests that the Chinese firms in the ‘Electric equipment and machinery’ industry, compared to firms in other industries in our data, had a higher likelihood of generating more subsequent indigenous innovations. However, if we take the ‘home advantage’ effect into account, then such a significantly positive effect is outnumbered by an even larger number of domestic new patent applications in this industry. Similarly, this logic might hold true for *firm age*, *firm size*, and *license scale* as well, since they present the same patterns of effects on the dependent variables, i.e., patent count in Model 2 and patent ratio in Model 3. In contrast, we find that the positive effects of absorptive capacity remain consistently significant on both the number and the extent of international patent applications. It seems that absorptive capacity in particular plays a key role in firms’ indigenous innovation performance. Moreover, the effect of the squared term of *license scale* shows a significant negative sign on the number of patent applications in Model 2, which

might suggest that there is a curvilinear (inverted U-shaped) relationship between inward technology licensing and subsequent international patent applications.

Insert table 2 here

2. Discussion and Conclusion

This paper, to our knowledge, is one of the pioneering studies that investigate the relative contribution of international technology in-licensing compared to domestic licensing to the ‘indigenous innovation’ outputs of Chinese firms. Using patent data, we found an appropriate proxy for ‘indigenous innovation’ of Chinese firms by measuring their new patent applications at the USPTO, EPO, or JPO. The results have shown that international technology in-licensing contributed more significantly than domestic licensing to Chinese firms’ new international patent applications. That is, international licenses were associated with better performance with regard to ‘indigenous innovation,’ even though the national strategic innovation policy encourages Chinese firms to reduce their dependence on foreign technologies and acquire technologies from foreign sources only if they are significantly important and advanced. It is worthwhile to note that merely in-licensing more international patents does not necessarily increase the possibility that a Chinese licensee firm will generate high-quality indigenous innovations, because some capable firms might decide not to do so. However, there is a positive relationship between the amount of in-licensing of international patents and the possibility that a Chinese licensee firm will have more high-quality indigenous innovations if it is capable and decides to do so. This positive relationship holds true even when we take the ‘home advantage’ effect into account. In summary, the results of our

analysis suggest a significantly greater contribution of international patent in-licensing, compared to those from domestic origins, to subsequent indigenous innovations made by Chinese licensee firms during the last decade.

Although the findings in this study seemingly suggest that international technology in-licensing has been a crucial source of Chinese firms' indigenous innovation, they are not at all at odds with the importance of internal R&D. Sun and Du (2010) have found that firms' internal R&D is the primary source of indigenous innovation, as measured by the number of patents and new products. In fact, China's R&D expenditure increased from 1.1% in 2002 to 1.5% of GDP in 2010. Its share of the world's total R&D expenditure grew from 5.0% in 2002 to 12.3% in 2010, placing it second only to the United States (Gupta and Wang, 2011). However, an increase in R&D expenditure alone does not necessarily lead to stronger technological capabilities and more indigenous innovations. We argue that it is the *combination* of external learning of new technology and an increase in internal R&D that eventually enables indigenous innovation. In fact, Hu and colleagues have found that R&D significantly complements external technology transfer as measured by expenses (Hu et al., 2005). Not surprisingly, technologies from international sources provide crucial knowledge that is not available in the domestic market to Chinese firms. Chinese firms that acquire technologies from international sources have more opportunities to explore novel configurations of knowledge elements. To summarize, the findings in this study suggest that Chinese firms during the last decade have gradually developed their indigenous innovation capabilities through a significant increase in R&D expenditure and acquiring key and reliable technologies from foreign sources.

Further deliberation based on these findings can be illustrated by recognizing a discrepancy between the policy orientation and the real practice of Chinese firms towards 'indigenous

innovation.’ On the one hand, the national innovation policy orients towards ‘indigenous innovation’ through large internal R&D investment and a dynamic technology transfer system, with a reduced reliance on foreign technologies. However, on the other hand, the reality is that Chinese firms in this sample relied more heavily on international than domestic technology sources. This discrepancy has strategic implications not only for Chinese firms, but also for foreign firms in developed countries and innovation policy makers. First, the successful development of some Chinese large firms reinforces our findings and helps to confirm a learning trajectory of these firms (Li, 2010). For instance, Haier, Huawei, and Lenovo have all followed a learning process that started with importing foreign technologies to quickly fill gaps in technological competence; they then exploited the technological knowledge in the Chinese local market and finally became international players with determined international expansion strategies and many international patents as their strategic assets.

Second, the strategically important implications for firms in developed countries are relevant with respect to how to compete and/or collaborate with firms in emerging economies, particularly, in China. From the perspective of firms in developed countries, such a fast pace of Chinese firms’ learning trajectory may impose threats in both Chinese and international markets, where the then-licensor (foreign) firms face strong competitive pressure from the then-licensees (Chinese firms), which turn out to be capable of developing new (and perhaps competing) technology. The reactive technology strategy is dependent on their business models. We suggest that for fully integrated firms (e.g., Apple), core technologies are central to their entire value chain system and crucial for their core competences. A good strategy is thus to license out non-core technology to prevent potential direct competition from Chinese licensees while still commercially benefiting from technology out-licensing. Meanwhile, for

non-fully integrated firms (i.e., firms that are specialized in R&D but do not internalize manufacturing), licensing out core technology will be of less concern because Chinese licensees mostly function at the downstream stages of the value chain. Direct competition is less likely or takes time to occur. A clear understanding of Chinese national innovation policy, and the real practice of Chinese innovating firms, is necessary for foreign firms to decide on their technology development strategy with regard to capturing the value of technology through tightening their protection of core competences or the fast diffusion of technologies.

This paper also has some important implications for innovation policy makers in China. ‘Indigenous innovation’ in China can only be achieved by strengthening Chinese firms’ internal R&D capabilities in order to build sufficient absorptive capacity for innovation and actively acquiring external technologies through an open system of innovation. On the one hand, it is strategically important to guide the Chinese economy gradually towards technological independence from the developed Western world and enhance China’s competitiveness in the global market. On the other hand, policy makers should not rush ‘indigenous innovation’ by merely focusing on increasing Chinese firms’ R&D expenditures and forcing them to either rely on domestic technologies (which are of less use) or acquire advanced foreign technologies (which are out of reach). Moreover, policy makers should clearly identify the antecedents of – and specify measurable outputs for – ‘indigenous innovation.’

Our study also has limitations, which could be the challenge for future research. Many other factors may affect the trajectory and pace of Chinese firms’ learning processes, but we could not include them all in our analysis. For instance, we do not have information on what kinds of inter-firm relationships the technology in-licensing were based on. As a result, we could not control for whether technology in-licensing was based on ad hoc licensing contracts or

included as part of an agreement of joint ventures, minority holdings, alliances, or other kinds of inter-firm collaborative relationships. Furthermore, we were unaware of a firm's strategic market orientation, which could influence its preference towards international or domestic patent applications. We believe these two factors may play important roles in better understanding the influences of technology in-licensing by Chinese firms on their technological capability building. Future research should include these two variables to improve the explanatory power of the analysis. Finally, R&D expenditure is usually used in the literature as an indicator of firms' absorptive capacity, which is crucial for firms to acquire and assimilate external knowledge and further generate new knowledge. Our findings did not confirm the importance of absorptive capacity, measured as the accumulative number of Chinese patent applications within the five years prior to the in-licensing, due to the limitation of our dataset. We expect that the results might be different if we could measure absorptive capacity by calculating the R&D expenditure of the sample firms. It would be a great challenge for future research to collect firm-level data on the R&D expenditure of Chinese firms, since they are usually either not accessible or not reliable.

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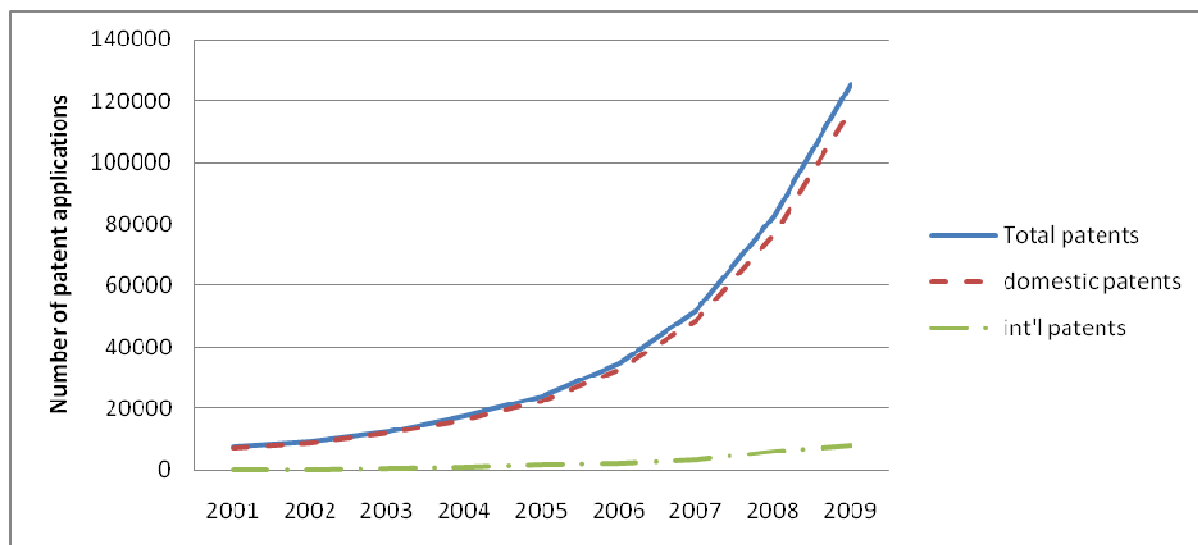
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Exhibit 1: An overview of new patent applications by Chinese licensee firms during 2001 till 2009

* International patents here only include those filed at the USPTO, EPO or JPO.

Table 1: Descriptive statistics

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
1. Ratio of Int'l license	0.55	0.49	-									
2. Absorptive capacity	18.09	122.56	0.1129	-								
3. License scale	2.73	4.02	0.1384	0.0418	-							
4. Province patent stock	4.38	0.411	0.4277	-0.0037	0.0688	-						
5. Technology age	5.77	3.50	0.6497	0.0219	0.1519	0.3642	-					
6. Licensing exclusiveness	14.78	18.74	0.5979	0.0068	-0.0178	0.4955	0.4831	-				
7. Firm age	9.71	10.58	0.0674	0.0776	-0.0881	-0.1413	-0.0225	0.0926	-			
8. Int'l patent count (Y_i)	28.66	178.05	0.0268	0.5072	-0.0072	0.1894	-0.0197	0.0128	0.0390	-		
9. Int'l patent ratio (Y_r)	0.26	0.41	-0.0216	-0.1268	-0.0468	0.0786	0.0044	-0.0180	-0.2208	-0.0613	-	
10. Firm size	3.08	0.67	-0.0097	-0.0365	-0.0400	-0.1767	-0.0002	-0.0457	0.0931	0.0426	0.0277	-
11. Firm Sector	0.53	0.50	0.0155	0.0844	0.0079	0.0695	-0.0188	-0.0168	0.0746	0.0884	0.0683	0.0680

a. Firm number=178, observations=196.

b. Dummy control variable (Year) were not shown in this table.

Table 2: Analysis results

	Model 1	Model 2	Model 3
	Patent count (Y _i)	Patent count (Y _i)	Patent ratio (Y _r)
	Logit part	Negative binomial part	
Constant	-8.764 (6.012)	-13.84*** (2.712)	-1.715* (1.010)
Firm age	-0.0736 (0.0494)	2.127*** (0.514)	-0.0015 (0.0061)
Province patent stock	1.320 (1.415)	0.108 (0.0803)	0.163 (0.214)
Technology age	0.262 (0.212)	-0.0092*** (0.0006)	-0.0320 (0.0269)
Absorptive capacity	0.0070** (0.0030)	0.133*** (0.0218)	0.0005* (0.0003)
License scale	-0.101 (0.0899)	1.043*** (0.220)	0.0088 (0.0111)
License scale squared	-0.0324 (0.0429)	-0.1131* (0.0661)	-0.0012 (0.0021)
Firm size	0.311 (0.530)	0.069*** (0.013)	0.0907 (0.0989)
Licensing exclusiveness	-0.0310 (0.0296)	-1.529*** (0.348)	-0.0140*** (0.0051)
Firm sector	3.682*** (0.924)	3.843*** (0.631)	-0.0269 (0.136)
Ratio of Int'l license	0.846 (1.334)	2.150*** (0.552)	0.718*** (0.238)
Log likelihood	-114.00	-114.00	-52.61
LR χ^2	46.69	46.69	14.99* (Wald ch2)

- Standard errors in brackets
- significant at 10%; ** significant at 5%; *** significant at 1%
- Observations=196
- Dummy control variable (Year) were included but not shown in this table.