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The effects of licensing-in on innovative performance in different technological regimes

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ABSTRACT

Technology licensing has become an important way to adopt external technology in the growing markets for technology. This study examines the effect of licensing-in on innovative performance and identifies the boundary conditions when this effect is greater in terms of technological regime. We employ the propensity score matching approach and compare the innovative performance between firms that engage in licensing-in and firms that do not to control for the endogeneity issue. Based on the empirical results from the Korean Innovation Survey, this study finds evidence that adopting external technology through licensing-in does not always enhance innovative performance. Additionally, the results show that the effectiveness of licensing-in varies with technological regimes. Adopting licensing-in practices improves innovative performance in industries with relatively (1) high levels of technological opportunities, (2) low levels of cumulativeness, and (3) high levels of appropriability. We also discuss the implications of these findings for research on the market for technology and licensing strategies.

1. Introduction

The emergence of the market for technology has a considerable influence on firms' innovation process through the division of innovative labor and technology transactions in this market (Arora et al., 2001a, 2001b). Traditional perspectives on innovation have regarded the innovation process from idea generation to commercialization as being wholly conducted within the boundary of a firm. However, the growing market for technology implies that firms can profit from licensing their technologies and that formal licensing-in becomes a window of access to external technologies (Arora et al., 2013; Laursen et al., 2010).

Recently, the literature on the market for technology has mainly focused on the supply side of the market. The demand side of the market also deserves scholarly attention to elucidate the nature of the market for technology (e.g., Arora and Gambardella, 2010; Laursen et al., 2010). From the licensee's perspective, previous studies suggested several reasons for firms adopting external technologies through licensing-in. By engaging in licensing-in, firms can reduce the risks and costs associated with the innovation process, keep up with technological advances, and facilitate technological learning (Atuahene-Gima, 1993; Johnson, 2002; Lowe and Taylor, 1998). Additionally, firms sometimes enter into a licensing-in agreement to acquire industry standards or freedom-to-manufacture (Grindley and Teece, 1997; Lowe and Crawford, 1984). Prior studies examined how licensing-in affects various outcomes, such as financial performance, innovation, and the speed of invention (Laursen et al., 2010; Leone and Reichstein, 2012; Tsai and Wang, 2007; Wang and Li-Ying, 2014; Wang et al., 2013a).

Despite the considerable body of literature, we ensured that value exists in highlighting whether adopting external technology through licensing-in is always beneficial for innovative performance and when does this effect become stronger according to the technological environment. First, in response to the academic need for a better understanding of the demand side of the market for technology, this study examined the treatment effect of licensing-in on innovative performance (Arora and Gambardella, 2010; Kani and Motohashi, 2012). Furthermore, this study attempted to contribute to the literature on the market for technology by identifying the boundaries or environmental contingency factors for licensing-in practices that are advantageous to firms' innovative performance (e.g., Lichtenthaler, 2011; Natalicchio et al., 2014). A technological regime reflects a significant environment that affects firms' innovative activities and performance (Nelson and Winter, 1982). Technological regimes are characterized by three dimensions: technological opportunity, cumulativeness, and appropriability conditions (Malerba and Orsenigo, 1993). These

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three dimensions influence firms' innovative activities and the benefit from participating in the market for technology. The effects of licensing-in may vary with the technological regimes under which firms operate.

Overall, this paper attempts to answer the question of whether engaging in licensing-in is always beneficial to firms' innovative performance and when the effects of licensing-in on innovative performance are more fruitful in terms of the technological regime. The findings of this study show that adopting an external technology through licensing-in does not always have positive effects on innovative performance. Additionally, our results show that technology regimes are significant boundary conditions for licensing-in effects. Firms that engage in licensing-in perform better than firms that do not in industries characterized by relatively high levels of technological opportunity, low levels of cumulativeness, and high levels of appropriability.

The remainder of this paper is organized as follows. The next section discusses theoretical perspectives and hypotheses development. The data and the empirical methods are subsequently described. We then report our results and findings, and the final section concludes and provides limitations of this study.

2. Theory and hypotheses

2.1. Implication of the market for technology on firm innovation process

The firm innovation process entails a resource-intensive search to discover valuable new combinations of knowledge (Fleming and Sorenson, 2004; Hargadon and Sutton, 1997; Stuart and Podolny, 1996). Thus, firms need to collaborate with and exchange knowledge from various actors beyond their organizational boundaries (Katila, 2002; Laursen and Salter, 2006; Shan et al., 1994). As a way to achieve their innovation goals, firms are increasingly participating in *markets for technology* (Arora et al., 2001a), in which "transactions for the use, diffusion and creation of technology" (Arora et al., 2001a: 423) are occurring, such as those involving technology packages (patents and know-how), patent licensing, and non-patentable knowledge (e.g., design, software).

Among mechanisms that facilitate inter-firm technology transactions in the market for technology, *licensing* is an ordinary and significant method for technology transfer between firms (Anand and Khanna, 2000; Arora and Fosfuri, 2003). Previous studies on this research domain largely focused on the supply side of the market (e.g., Arora and Fosfuri, 2003; Arora et al., 2013; Gambardella and Giarratana, 2013). For example, on the supply side of licensing transactions, a licensor usually encounters a "licensing dilemma" (Fosfuri, 2006) resulting from the conflict between two licensing effects: the revenue effect and the rent dissipation effect. Recently, the demand side of the licensing phenomenon has also attracted scholarly attention from management and innovation researchers who seek to understand the nature of the market for technology (Arora and Gambardella, 2010; Kani and Motohashi, 2012). In this paper, we attempt to contribute to this research trend by providing valuable insights into the research on the market for technology from the licensee's perspective.

Previous studies argued that sellers' and buyers' incentives to participate in technology transactions are conditioned by various factors (Conti et al., 2013; Jensen et al., 2015). The literature rooted in organizational and management theory investigated the influence of a firm's capability on their likelihood of engaging in technology transactions, which is known as absorptive capacity (Cohen and Levinthal, 1990). For example, Arora and Gambardella (1994: p. 93) distinguished between two dimensions of this capability, which are the "ability to evaluate" and the "ability to utilize" technological information. They showed that firms with a greater "ability to utilize" seek more external technologies. In other words, they are more likely to license-in technologies. Firms with greater "ability to evaluate" seek fewer external technologies (i.e., less likely to license-in technologies), although the technologies they pursue are more valuable. In contrast, researchers who are closely related to economic tradition are interested in the institutional factors that increase actors' incentives to engage in technology transactions, such as intellectual property rights (Gans et al., 2002), contract effectiveness (Arora, 1996), and industry structures (Anton and Yao, 1994; Fosfuri, 2006). In summary, firms' incentives for licensing-in technologies in the market for technology are affected by the environmental factors and internal capabilities.

From the point of view of licensee firms' innovation strategy, numerous reasons exist for why firms decide to acquire external technologies through licensing-in. First, licensing-in allows a firm to reduce the costs and uncertainties related to expensive and risky innovations. From the traditional view of innovation, a firm ought to conduct an entire R&D process by itself to produce novel innovations. However, the existence of a market for technology, in particular for licensing-in, enables a firm to save considerable investments in internal R&D (Wang et al., 2013a). Firms are able to utilize already developed solutions that enable them to make up for what their technology lacks through licensing-in (Lowe and Taylor, 1998). Second, firms could catch up with state-of-the-art technological advances through licensing-in. Licensing-in enables firms to access ready-made and proven technologies (Atuahene-Gima, 1993). Acquiring external technology in a well-developed market for technology could reduce transaction costs and assist firms in remaining at the technological frontier in a given industry. Third, licensing-in facilitates technological learning (Johnson, 2002). Technology transfers may provide opportunities for technical learning (Lin, 2003). With respect to organizational search, licensing-in external technologies could foster exploring and adopting external knowledge, leading to an expansion of firms' technological search space (Laursen et al., 2010). Fourth, firms choose to license-in external technologies to facilitate entry into new markets (Lieberman and Montgomery, 1988) or to unlock existing technologies (Lowe and Crawford, 1984). Lastly, firms license-in technologies to acquire industry standards (Lowe and Crawford, 1984) and sometimes they need to engage in cross-licensing arrangements to ensure "design-freedom" or "freedom-to-manufacture" (Grindley and Teece, 1997).

Based on these motivations to engage in licensing-in practices, prior studies examined various outcomes of adopting external technologies through licensing-in. For example, Tsai and Wang (2007) tested that inward technology licensing enhances the financial aspect of firm performance measured as value added. Other studies used various measures to investigate whether adopting licensing-in has a positive effect on Chinese firms' innovative performance. They examined the effect of licensing-in on the number of patents applied, new product introductions, and new product development performance (Wang and Li-Ying, 2014; Wang et al., 2013a). Additionally, Laursen et al. (2010) suggested that licensing-in could moderate the relationship between absorptive capacity and explorative innovation such that licensing-in reinforces the positive relationship between assimilation/monitoring absorptive capacity and exploration. Leone and Reichstein (2012) focused on the speed of innovation and showed that licensing-in can shorten the time taken to innovate.

Although previous studies examined that licensing-in could affect the various aspects of financial and innovative outcomes, questions remain as to whether adopting licensing-in always has a positive effect on innovative performance, and how the effect of licensing-in differs across surrounding environments. Because the effectiveness and efficiency of firms' internal innovations and

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the acquisition of external innovations can differ depending on technological environments, we expect that the characteristics of *technological regimes* within a certain industry may act as boundary conditions for the effect of licensing-in on firm innovation performance.

2.2. The influence of technological regimes on the performance effect of licensing-in

A technological regime defines a technological environment, which represents the framework conditions in which firms implement innovation (Nelson and Winter, 1982; Winter, 1984). Technological regimes consist of at least three dimensions (Malerba and Orsenigo, 1993): technological opportunity, technological cumulativeness, and appropriability. The technological opportunity dimension refers to "the ease of innovating for given amount of money invested in search" (Malerba and Orsenigo, 1993: 48). Technological cumulativeness indicates that "today innovations and innovative activities form the base and the building blocks of tomorrow innovations and that today innovative firms are more likely to innovate in the future in specific technologies and along specific trajectories than non-innovative firms" (Malerba and Orsenigo, 1993: 48). The appropriability condition reflects "the possibilities of protecting innovations from imitation and of extracting profits from innovative activities" (Malerba and Orsenigo, 1993: 48). These three dimensions characterize learning environments in which firms develop and implement their innovative activities. In other words, the extent to which firms' internal innovations (or the acquisition of external innovations) are valuable to them may differ across industries because industries differ with respect to the properties of technological regimes (Park and Lee, 2006; Song et al., 2014b). Thus, the effectiveness of firms' licensing-in strategy also varies depending on the technological regime in which they operate because firms' internal innovations are more important than the acquisition of external innovations under certain technological environments. Hence, we suggest that the effect of licensing-in on innovative performance is altered by technological regimes under which the firm operates.

2.2.1. Technological opportunity

Technological opportunity refers to firms' access to technological inputs from different sources such as suppliers, customers, and other organizations (Breschi et al., 2000). Thus, a high level of technological opportunity reflects that firms reach greater fruition after any given amount of R&D investment because, from relatively abundant possibilities, they can choose for their own innovations the most effective ones with the lowest costs (Song et al., 2014a).

Based on this definition of technological opportunity, we posit that firms that engage in licensing-in bear more fruits in industries with abundant technological opportunities for several reasons. First, in such industries, it is important for firms to gain a window onto new technologies to keep up with technological progress (Breschi et al., 2000). Higher levels of technological opportunity indicate that numerous fruitful technological advances exist in the external environment of firms, thus favoring an open approach to innovation and enabling firms to rely heavily on external ideas and knowledge (Zeng et al., 2010). The information gained through licensing-in can play a significant role in searching for external technological advances. Previous studies suggested that adopting licensing-in enables firms to access technological advances and provides proven technologies (Atuahene-Gima, 1993; Leone and Reichstein, 2012). Therefore, by adopting licensing-in, firms can access state-of-the-art technological advances and achieve rapid innovation, allowing them to improve innovative performance in industries with significant technological opportunities.

Second, firms can foster radical search and knowledge recombination by adopting licensing-in practices in industries with greater technological opportunities. Knowledge recombination is one of the most important sources of innovation (Fleming, 2001). High levels of technological opportunity indicate that numerous possibilities exist for knowledge recombination in either internal or external knowledge. Radical search, namely exploration, is more critical to increasing the possibilities for knowledge recombination in industries with better technological opportunities. Licensing-in helps firms search more distantly and expand the search space (Laursen et al., 2010). Thus, firms can exploit better opportunities for novel combinations between internal and external knowledge by engaging in licensing-in activities than in the case of only in-house investments.

For these reasons, we suggest the hypothesis that licensing-in brings better innovative performance in industries with significant technological opportunities, as follows.

Hypothesis 1. In industries with higher levels of technological opportunity, firms that engage in licensing-in exhibit higher innovative performance than firms who that do not engage in licensing-in.

2.2.2. Technological cumulativeness

Technological cumulativeness refers to the fact that today's technological innovation activities build the foundation for tomorrow's innovations. An innovation generates a stream of subsequent innovations that are gradually developed upon the original one or it creates new knowledge that is employed for other innovations in relevant technological domains (Breschi et al., 2000; Malerba and Orsenigo, 1993). Although increasing multidisciplinarity of inventive activities and rising product complexity also lead firms to use external technologies (Granstrand et al., 1997; Pavitt, 1991), we expect that the cumulativeness condition as a dimension of the technological regime can significantly affect the performance of firms engaging in licensing-in practices as well as their incentives toward such practices. By considering the technological regime in terms of cumulativeness of technical knowledge, we argue that firms engaging in licensing-in agreements exhibit higher innovative performance than firms that do not adopt those agreements when the degree of technological cumulativeness is relatively low.

First, firms' access to external knowledge through licensing-in agreements is particularly beneficial to their innovative activities in the lower cumulativeness regime because the internal innovations previously implemented become less important in that regime. Firms often engage in licensing-in practices as a tactical reaction to a technological shortfall (Lowe and Taylor, 1998). To complement these technological shortfalls, firms have to either develop necessary technologies by themselves or acquire them from external technology markets. Because prior innovations developed internally are less required for firms to create new innovations in a relatively low cumulativeness environment, acquiring necessary technologies from outside, rather than developing them internally, is a more efficient way for firms to introduce new innovations in a timely manner. In fact, regardless of the level of technological cumulativeness, introducing innovations to a market in a proper time is one of the critical factors for firms to achieve a competitive advantage (Markman et al., 2005). However, we expect that acquiring external technologies through licensing-in practices is a more time efficient way for firms to release their innovations in the low cumulativeness regime because they don't need to invest substantial time and resources to gain all technologies necessary to generate new innovations in such regime. Specifically, firms' acquisition of external technologies through licensing-in agreements can accelerate their innovation processes by allowing them to save time during technological developments by averting possible mistakes (Gomory, 1989) and to reduce the number of tasks required for developing new technologies (Leone and Reichstein, 2012). In turn, this reduction dampens the risks involved with innovative activities and shortens innovation time (Markman et al., 2005). Additionally, lower cumulativeness conditions can be favorable for firms that want to stay at the technological frontier in an industry, a main objective of firms engaging in licensing-in activities. Because firms can accelerate their own innovation processes by obtaining ready-made and proven external knowledge through licensing-in agreements (Atuahene-Gima, 1993), firms engaging in licensing-in practices can not only keep up with state-of-the-art technological advances but also hold other competitors at bay in a relatively low cumulativeness environment.

In contrast, when technological knowledge is highly cumulative, firms often engage in licensing-in or cross-licensing agreements to ensure "design freedom" or "freedom-to-manufacture" (Grindley and Teece, 1997). Because overlaps are more likely among newly introduced products from different firms in the regime of high cumulativeness, firms tend to enter licensing agreements to avert the risk of infringing other firms' patents (Grindley and Teece, 1997; Scotchmer, 1991). Indeed, their ultimate purpose of engaging licensing-in agreements is to promote the development and commercialization of their innovations, such as licensing essential patents (e.g., communication standards or image compression technologies) to develop new electronic devices in the mobile phone industry. Yet, in a relatively high cumulativeness regime, firms engaging in licensing-in agreements are often situated at a disadvantaged position in terms of bargaining those contracts with licensors, which have essential technologies to develop products in the industry. In other words, transaction costs for licensee firms can be higher in the regime of high cumulativeness. Therefore, we infer that it is limited for firms engaging in licensing-in agreements to add value in the development and commercialization of their innovations in the high cumulativeness condition. In summary, from the perspective of enhancing firm innovation, the contributions of these licensing-in agreements are somewhat limited in a relatively high cumulativeness regime because the reason for engaging in licensing-in in these settings is to reduce the patent enforcement costs or to secure the freedom of operations rather than to add value for firm innovation.

Thus, we expect that firms that engage in licensing-in agreements show higher innovative performance than firms that do not engage in those agreements in a relatively low cumulativeness regime.

Hypothesis 2. In industries with lower levels of cumulativeness, firms that engage in licensing-in exhibit higher innovative performance than firms that do not engage in licensing-in.

2.2.3. *Appropriability*

The appropriability condition indicates how well innovations are protected from imitation and firms can derive profits from innovations. We expect that the benefits of licensing-in exist in industries with high levels of appropriability, all other factors being equal. At first, how firms benefit from licensing-in largely depends on how well the technologies are transferred. Technology licensing entails not only the transaction of codified knowledge such as patent, blueprints, and specifications, but also the transfer of tacit knowledge and know-how around the licensed technology. However, effective technology transfers through licensing are highly vulnerable to the risk of opportunistic behavior because licensing agreements are inherently arm's length and incomplete contracts (Arrow, 1962). For example, the possibility exists that licensors may neglect their duties to provide their best engineers or scientists to licensees, as well technical services after the licensing fee has been paid (Arora et al., 2001b). Opportunism is one of the main determinants of the transaction costs involved in market transactions, and uncertainty about opportunistic behavior cannot be resolved ex ante (Williamson, 1985). Regarding mitigating opportunistic behavior, several studies suggest that a strong appropriability regime can make licensors behave less opportunistically because a high level of appropriability reduces imitation risk, uncertainty, and transaction costs involving enforcement and monitoring costs (Han and Lee, 2013; Kim, 2009). For instance, Arora (1995) showed that licensors do not need to behave opportunistically in a strong appropriability regime because they can withdraw the licensing of the patent if licensees' behavior is not satisfied. Therefore, a high level of appropriability reduces double-sided opportunistic behavior between licensors and licensees, which allows for more effective transfer of tacit knowledge and know-how on the licensed technology (Arora, 1995; Teece, 1998).

Furthermore, as an indirect effect, a strong appropriability regime can reduce the problems caused by information asymmetry such as the "market for lemon," referring that inferior products and services are mostly placed on the market (Akerlof, 1970). When licensees consider acquiring external technologies through licensing, one of their fears is that technologies on the market may not be superior enough to be exploited and commercialized in-house (Pisano, 1997, 2006). In the case of the market for technology, information asymmetry can exist because licensors have more information on the scope and value of technology, and licensees may be at risk of adverse selection. However, a strong appropriability regime reduces the uncertainty of the scope and value of technology, which results in fewer problems due to information asymmetry and adverse selection (Gans et al., 2008). Also, if the appropriability condition is high enough, licensors could put more of their valuable technologies on the market because of less concern over imitation and knowledge expropriation (Arora and Fosfuri, 2003; Gans et al., 2002). Thus, we could expect that, in industries with high levels of appropriability, the value of technologies in the market is relatively high in general (Katz and Shapiro, 1987; Rockett, 1990). In well-functioning markets for technology, licensees can identify and acquire the ready-made technology that they need, which allows them to enhance their innovative performance.

In contrast, in industries with lower appropriability, effective technology transfer through licensing might be hindered by licensors' increased opportunistic behavior. Additionally, potential licensors might hesitate to put useful technologies on the market due to information asymmetry and fear of imitation in weak appropriability conditions. From the licensees' perspective, in a weak appropriability regime, licensees are at higher risk of involuntary infringement of third parties' technologies or engaging in patent litigations. This increased risk will reduce incentives to develop new technologies based on the licensed technology which is not helpful for innovative performance. For these reasons, acquiring external technologies through licensing-in might not be as helpful as expected for innovation if appropriability is not high enough.

Given that acquiring external technologies through licensing-in has some benefits to firms' innovative performance, we suggest that in industries with a strong appropriability regime, it would be better for firms to engage in licensing-in than in non-licensing.

Hypothesis 3. In industries with higher levels of appropriability, firms that engage in licensing-in exhibit higher innovative performance than firms that do not engage in licensing-in.

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3. Methods

3.1. Data and sample

This study utilizes the Korean Innovation Survey (2008) from the Science and Technology Policy Institute (STEPI), one of the surveys approved by the Korean National Statistical Office as a designated statistic. The survey provides information on the innovative activities of manufacturing firms in Korea for the period 2005–2007. The survey is based on the Community Innovation Survey (CIS) and the methodology and questionnaires follow the OECD Oslo manual. The Community Innovation Survey has been widely used in studies on economics, strategic management, and innovation (e.g., Cassiman and Veugelers, 2006; Klingebiel and Rammer, 2014; Laursen and Salter, 2006; Laursen and Salter, 2014; Love et al., 2014).

The advantages of using the Korean Innovation Survey are that it captures firms' licensing activities that might be confidential and that it allows a comparison of the inter-industry heterogeneity of innovative activities. Initially, because the disclosure of licensing activities is not an obligation, firms may not reveal information on licensing activities. However, the Korean Innovation Survey includes firms' activities on licensing because the Korean National Statistical Office ensures the survey's confidentiality. Additionally, we are able to compare the differences in the effects of licensing-in among industries because the survey is large-scale and contains all manufacturing areas.

The Korean Innovation Survey includes information on 3081 firms in 22 industries. The sample covers manufacturing firms with more than 10 employees. For the analysis, we restricted our attention to firms that reported that they had conducted product innovation during the observation period. Some industries are excluded because they lacked a licensee, which makes a probit estimation for the licensing-in decision impossible. The final sample contains 776 firms with non-missing variables. Among the 776 firms, 57 firms reported that they had experience with licensing-in activities during last three years. We assume a partial lag between the independent variables and the dependent variable by relating innovative performance in 2007 to the explanatory variables measured for the period 2005–2007. Although some limitations of a cross-sectional nature exist in the data when interpreting the results, this assumption is in accordance with prior CIS studies (e.g., Klingebiel and Rammer, 2014; Laursen and Salter, 2006).

3.2. Measurement

3.2.1. Dependent variable

Innovative performance is measured as the proportion of turnover attributable to product innovations that were new to the market or new to the firm during the previous three years. This variable indicates firms' ability to introduce innovative products to the market as well as short-term commercial success (Love et al., 2014). This indicator reflects the impact of product innovations on firms' overall turnover and degree of innovativeness (OECD/Eurostat, 2005).[1] In prior studies, this variable is widely used as one of the most appropriate measures of innovation output (Laursen and Salter, 2006; Leiponen and Helfat, 2010; Love et al., 2014).

3.2.2. Independent variable

The Korean Innovation Survey includes information on firms' licensing activities, such as licensing-buy, licensing-sell, licensing-in, licensing-out, and cross-licensing. We define *licensing-in* as a binary variable that takes the value of 1 if firms adopt external technology through licensing-in during three years, and 0 otherwise. This variable does not include licensing-buy or cross-licensing.

This study includes three characteristics of technological regimes: *technological opportunity, cumulativeness*, and *appropriability*. *Technological opportunity* is defined as "the ease of innovating for any given amount of money invested in search" (Malerba and Orsenigo, 1993: 48). Higher levels of technological opportunity reflect a powerful incentive to conduct innovative activities. Thus, this variable indicates the efforts and resources invested in innovative activities. Previous studies generally used R&D investment in innovation activities as a proxy for *technological opportunity* (Castellacci and Zheng, 2010; Peneder, 2010). This study measures *technological opportunity* at the industry level based on the OECD industry classification (Czarnitzki and Thorwarth, 2012). OECD classifies manufacturing industries into high, medium-high, medium-low, and low technology categories based on R&D expenditures divided by value added and R&D expenditures divided by production (OECD, 2003). Industries are classified into these four categories after ranking them based on their average compared with aggregate OECD R&D intensities. *Technological opportunity* takes the value of 1 for industries with high or medium-high technology, and 0 for industries with medium-low or low technology.

Cumulativeness reflects the concept that past innovations and technological capabilities form the basis of current and future innovations (Breschi et al., 2000; Malerba and Orsenigo, 1993). According to Hölzl and Janger (2014), *cumulativeness* is measured as the ratio between (a) the sum of the scores of the importance of information sources from internal firms and affiliated firms, and (b) the sum of the scores of the importance of information sources from suppliers, customers, competitors, trade associations, consulting firms, universities, research institutes, conferences, and journals. Then, we aggregated this value at the two-digit KSIC industry level. The variable takes the value of 1 for industries with cumulativeness higher than the median value, and 0 for industries with cumulativeness lower than the median value.

Appropriability indicates the possibilities of protecting innovations from imitation and profiting from innovative activities (Malerba and Orsenigo, 1993). Several mechanisms are available to protect innovations, including patents, utility models, design rights, trademark rights, secrecy, complex designs, and lead time. We calculate the mean values of the effectiveness scores of appropriability mechanisms at the two-digit industry level (Levin et al., 1987). Then, the binary variable for *appropriability* takes the value of 1 for industries with an appropriability condition higher than the median value and 0 for industries with an appropriability condition lower than the median value.

3.2.3. Explanatory variables to predict the licensing-in decision

To calculate the propensity score for whether or not firms engage in licensing-in, we include various factors that may affect licensee firms' incentives toward such engagement. To control for size effects, we measure *firm size* as the logarithm of the average number of employees within three years. *Profitability* is defined as the average value of operating income divided by the total sales during three years. To control for export orientation, we measure *export intensity* as the average value of export sales divided by total sales within three years. *R&D intensity* is measured as the

[1] The Oslo manual mentioned that there are some interpretation problems when researchers use this type of operationalization. First, this indicator might be affected by the length of the product life cycle. Firms with products that have short life cycles are expected to experience more frequent product innovation, and they may have higher shares of sales from product innovations. Additionally, the possibility exists that younger firms might have a higher share of sales from product innovations than older firms because younger firms generally have a smaller product portfolio. Lastly, if firms' objective of innovation is to replace products being phased out, these firms might have a higher share of sales from product innovations than do firms that want to extend their product range.

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Table 1
Description of variables.

Variable	Description
Innovative performance	The proportion of turnover due to product innovations that were new to the market or new the firm during the previous three years
Licensing-in	Dummy indicating whether firms adopt external technology through licensing-in during three years
Technological opportunity	Dummy that takes the value of 1 if industries are high or medium-high technology industries based on OECD classification
Cumulativeness	Dummy that takes the value of 1 if industries with higher cumulativeness than the median value at industry level based on the ratio between the importance of internal knowledge sources and the importance of external knowledge sources
Appropriability	Dummy that takes the value of 1 if industries with higher appropriability condition than the median value at industry level based on the effectiveness of appropriability mechanisms
Firm size	Logarithm of the average number of employees
Profitability	Operating income divided by total sales
Export intensity	Export sales divided by total sales
R&D intensity	R&D expenditure divided by total sales
Search breadth	The number of external knowledge sources that contribute to innovation
Collaboration	The number of types of partners that contribute to innovation
Patent stock	Logarithm of the number of total patents granted

average amount of total R&D expenditures divided by the total sales during three years. We also include several factors related to firms' technological activities, such as *search breadth, collaboration*, and *patent stock*. We expect that if firms search more broadly for knowledge, they are more likely to engage in licensing-in. The Korean Innovation Survey includes sources of knowledge that contribute to innovation, such as affiliated firms, suppliers, customers, competitors, trade associations, new employees, consulting firms, universities, research institutes, conferences, and journals. Following Laursen and Salter (2006), each source is coded as a binary variable that takes the value of 1 for use of the given knowledge source, and 0 for no use. Then, the sources of knowledge are added up to indicate *search breadth*, which reflects firms using more sources of knowledge search more broadly. Similarly, several types of potential collaboration partners exist, such as affiliated firms, suppliers, customers, competitors, consulting firms, universities, and research institutes. These variables are assigned the value of 1 if firms reported that they actually collaborated with each of the potential partners, and 0 if they did not. Subsequently, *collaboration* is measured as the total number of types of partners for innovation. We expect that the more frequently firms engage in collaboration with various types of innovation partners, the more likely firms adopt external technologies through licensing-in. We define *patent stock* as the logarithm of the total number of patents granted. Lastly, industry dummies are included as two-digit KSIC codes to control for industry effects. Table 1 summarizes the definitions of the variables used in this study.

3.3. *Empirical approaches: propensity score matching method*

The significant challenge to evaluating the effects of licensing-in on innovative performance is that a decision to engage in licensing-in is endogenous and self-selective (Shaver, 1998). The possibility exists that some unobserved characteristics might simultaneously influence firms' decisions to engage in licensing-in and innovative performance. In other words, inherently more innovative firms might choose to engage in licensing-in activities. Thus, we cannot precisely assess the effect of licensing-in on innovative performance through a simple comparison of licensee and non-licensee. Although comparing the innovative performance of participating in licensing-in and not participating in licensing-in within the same firm might be ideal, this type of randomized experiment is impossible. To overcome this issue, this study employs propensity score matching (Arnold and Javorcik, 2009; Imbens and Wooldridge, 2009; Rosenbaum and Rubin, 1983), which compares the counterfactual outcomes available.

We chose the propensity score matching method for the following reasons. First, the method allows us to estimate the effect of a treatment on an outcome by reconstructing original observational data in a quasi-experiment setting (Li, 2013; Titus, 2007). Although the experiment is considered the gold standard for estimating the causal effect (Antonakis et al., 2010), social scientists generally depend on observational data for various reasons, such as an ethical problem. By adjusting covariates between the treatment and the control groups, the propensity score matching method allows us to reconstruct counterfactuals by using observational data. In other words, this method can approximate *randomization* by balancing "observable" characteristics and identifying the appropriate control group (Becker and Ichino, 2002). Furthermore, researchers can more precisely estimate the treatment effect through the propensity score matching method because doing so can eliminate outliers by ensuring that the sole data on variables relevant to a person in both treatment and control groups is used (Titus, 2007). Although the propensity score matching method is limited in that unobserved factors that can affect both the treatment and the outcome are not accounted for, this method is known to produce the unbiased causal effect under the assumption of ignorability (Rosenbaum and Rubin, 1983; Wooldridge, 2002).

In propensity score matching, the central challenge is constructing the treatment group and the control group. The treatment and the control groups are constructed on the basis of similarity calculated from the propensity score. The propensity score is calculated as the predicted probability of a treatment that results in the decision to engage in licensing-in. At first, we use a probit model to estimate the predicted probability of firms' decisions to engage in licensing-in on the basis of various characteristics, such as firm size, profitability, R&D intensity, export intensity, search breadth, collaboration, patent stock, and industry. Propensity score matching assumes that the treatment is randomized and exogenous in terms of the propensity scores derived from observable firm characteristics. We then match firms with licensing-in to firms without licensing-in based on their predicted propensity scores for engaging in licensing-in activities. Thus, in this study, the treatment group consists of firms engaged in licensing-in and the control group consists of firms that are not engaged in licensing-in, and they have similar propensity scores for predicting the probability of the decision to engage in licensing-in. To determine the degree to which propensity score matching makes a comparable sample of the treatment and the control groups, we conduct a hotelling test to ensure that the two groups are not significantly different.

Subsequently, to compare the innovative performance difference between the treatment and the control groups, we calculated

Table 2
Descriptive statistics and correlations.

Variables	Mean	s.d.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1. Innovative Performance	33.41	27.06	0	100	1.00											
2. Licensing-in	0.07	0.26	0	1	0.04	1.00										
3. Technological Opportunity	0.64	0.48	0	1	0.07*	0.07	1.00									
4. Cumulativeness	0.42	0.49	0	1	−0.05	−0.03	−0.29*	1.00								
5. Appropriability	0.33	0.47	0	1	0.01	0.02	−0.65*	−0.06	1.00							
6. Firm Size	4.79	1.56	2.12	9.79	−0.13*	0.15*	−−0.01	0.25*	0.01	1.00						
7. Profitability	0.06	0.11	−1.38	0.99	0.02	0.00	0.04	−0.06	−0.01	−0.04	1.00					
8. Export Intensity	0.19	0.27	0	1	−0.01	0.05	0.09*	0.08*	−0.05	0.30*	−0.00	1.00				
9. R&D Intensity	0.03	0.06	0	0.74	0.14*	0.00	0.13*	−0.14*	−0.04	−0.27*	−0.10*	−0.06*	1.00			
10. Search Breadth	6.91	3.77	0	11	−0.05	0.15*	0.14*	0.04	−0.06	0.39*	0.06	0.18*	−0.05	1.00		
11. Collaboration	1.17	1.90	0	7	−0.02	0.20*	0.09*	0.01	−0.04	0.26*	−0.00	0.10*	0.00	0.35*	1.00	
12. Patent Stock	1.84	1.65	0	9.39	−0.02	0.24*	0.15*	0.02	−0.12*	0.56*	0.02	0.19*	0.00	0.28*	0.23*	1.00

N = 776.
* $p < 0.05$.

the average treatment effect from the treatment (ATT) using the following formula:

$$ATT = \frac{1}{n}\sum\left(Innovative\ performance^{Treated} - Innovative\ performance^{Control}\right)$$

The standard errors calculated confirmed that the differences in innovative performance between the two groups are statically significant. The ATT reflects the difference in the counterfactual performance between firms that engaged in licensing-in and that firms did not. This process occurs through the "teffects psmatch" command in the STATA 13 statistical package. To test the hypotheses that the effects of licensing-in differ according to the technological regime, we construct subsamples that are high or low in technological opportunity, cumulativeness, and appropriability. We then compare the average treatment effects on the treatment in each subsample (See Appendix A for more detail information of industry classification).

4. Results

4.1. Descriptive statistics and results of propensity score matching method

Table 2 provides the descriptive statistics and pairwise correlations of the variables included in the probit analysis of the licensing-in decision.

Table 3 displays the probit regression for a firm's decision to adopt licensing-in practices using the entire sample in our study. The extent to which a firm utilizes various sources of knowledge, i.e., search breadth, has a positive relationship with its adoption of licensing-in practices ($r = 0.05$, $p < 0.05$). This finding suggests that the more broadly the firm searches for knowledge for its innovation, the more likely it adopts the licensing-in practice. The degree of collaboration with outside actors also has a positive relationship with the adoption of licensing-in practices ($r = 0.10$, $p < 0.01$), indicating that the more a firm works with actors beyond its boundary, such as suppliers, customers, and research institutions, the more likely it adopts the licensing-in practice. Additionally, the number of patents held by a firm has a strong positive relationship with its adoption of licensing-in practices ($r = 0.22$, $p < 0.01$).

Table 3
Probit model of licensing-in decision.

Dependent variable: Licensing-in	Whole sample
Firm Size	−0.02 (0.07)
Profitability	−0.40 (0.71)
Export Intensity	−0.12 (0.29)
R&D Intensity	0.31 (1.13)
Search Breadth	0.05** (0.02)
Collaboration	0.10*** (0.03)
Patent Stock	0.22*** (0.05)
Constant	−2.24*** (0.50)
Industry dummy	Yes
Pseudo R^2	0.17
Log likelihood	69.71***
Observations	776

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Using the result of the probit model in Table 3, we calculated the propensity scores of a firm's adoption of the licensing-in practice to compose the matched sample for a comparison of innovative performance after the adoption.

In Table 4, we display innovative performance for both the treatment (the firm adopting licensing-in practices) and the control (the firm not adopting licensing-in practices) groups. The average treatment effect on the treated (ATT) stands for the difference in the average outcome between the treatment group and the control group, i.e., the innovative performance gap between the treatment and the control groups. Additionally, we provide a summary of the results of the hotelling test to balance between these groups for each model (See Appendix B for more detailed information on the matching result of the entire sample).

In Model 1, our matching procedure generated 57 matches (N = 114) by adopting the licensing-in practice for the entire sample. The ATT of adopting the licensing-in practice for innovative performance is 4.68 percentage points, but is not statistically significant. This result is somewhat interesting because previous studies showed that firms that adopt the licensing-in practice outperform comparable firms that do not adopt this practice (Leone and Reichstein, 2012; Wang and Li-Ying, 2014; Wang et al., 2013b). As is subsequently discussed, this result has implications for the empirical results for three hypotheses.

We obtained an indication of the performance effect of licensing-in on firms' innovation and further investigated whether such a performance improvement depends on technological regimes, such as technological opportunity, technological cumulativeness, and the appropriability condition, as in Hypotheses 1–3.

For technological opportunity, we classified firms into high and low technological opportunity subgroups using our measurement and repeated the same matching procedure on these subgroups, respectively. Model 2 of Table 4 shows that the ATT of adopting the licensing-in practice on the high technological opportunity subgroup in innovative performance is 8.12 percentage points, and is statistically significant at the 10 percent level. The results also show that the ATT of adopting the licensing-in practice on the low technological opportunity subgroup in innovative performance is −10.15 percentage points, and is not statistically significant. Thus, this result is consistent with Hypothesis 1, thereby suggesting that

Table 4
Innovative performance of firms of adopting licensing-in practices vs. firms of not adopting licensing-in practices.

	Model 1	Model 2		Model 3		Model 4	
	Whole sample	Technological opportunity		Technological cumulativeness		Appropriability	
		High	Low	High	Low	High	Low
Treatment group (licensing-in)	38.02	42.68	29.40	32.09	41.48	42.61	35.34
Control group (no licensing-in)	33.34	34.56	39.55	33.44	27.13	28.80	36.46
ATT	4.68	8.12*	−10.15	−1.35	14.34**	13.80**	−1.11
S.E.	5.82	4.80	8.15	7.85	5.94	5.73	8.25
N	114	74	40	42	72	42	72
Hotelling test							
F	0.59	0.66	0.33	0.45	0.38	0.31	0.38
p-value	0.75	0.69	0.93	0.86	0.90	0.94	0.90

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

firms that engage in the licensing-in practice benefit more from it than firms that do not engage in the practice in environments with higher levels of technological opportunity.

Similarly, we implemented the matching procedure on high and low technological cumulativeness subgroups, respectively. Model 3 of Table 4 shows that the ATT of adopting the licensing-in practice on the high technological cumulativeness subgroup in innovative performance is −1.35 percentage points, but is not significant. The ATT of adopting the licensing-in practice on the low technological cumulativeness subgroup in innovative performance is estimated at 14.34 percentage points, and is statistically significant at the 5 percent level, thus providing support for Hypothesis 2. From this result, we can infer that firms that adopt licensing-in practices outperform those that do not adopt these practices under the condition of lower levels of technological cumulativeness.

Model 4 of Table 4 shows that the ATT of adopting the licensing-in practice on the high technological appropriability subgroup in innovative performance is 13.80 percentage points, and is significant at the 5 percent level. The model also shows that the ATT of adopting the licensing-in practice on the low technological appropriability subgroup in innovative performance is −1.11 percentage points, and is not significant. This result provides support for Hypothesis 3. Thus, the level of the appropriability conditions appears to be an important contingency factor for the effect of licensing-in on firms' innovative performance.

4.2. Additional analysis

In Table 5, As is subsequently discussed, this result has implications for the empirical results for three hypotheses. appropriability mechanisms into two different types.[2]

In terms of technological opportunity, the number of patents at the industry level might capture the level of technological opportunities of that industry. We divided industries according to whether their level of technological opportunity was high or low based on the median value of the number of patents applied for within the last three years at each two-digit KSIC industry. In Model 5, the results also support hypothesis 1, which states that adopting licensing-in increases innovative performance in industries with high technological opportunity (ATT = 13.67, $p < 0.01$), but not in industries with low technological opportunity.

Additionally, we distinguished several appropriability mechanisms into formal and informal mechanisms. Formal appropriability mechanisms include patents, utility models, design rights, and trademark rights, whereas informal appropriability mechanisms cover secrecy, complex designs, and lead time (Castellacci, 2007). In Model 6 of Table 5, the ATT of adopting licensing-in in the highly formal appropriability subgroup for innovative performance is 11.48 percentage points, and is significant at the 1 percent level. The ATT of adopting licensing-in has no significant effect on innovative performance in industries with low formal appropriability. Similarly, in Model 7, the results show that firms engaging in licensing-in also exhibit higher innovative performance in industries with high informal appropriability (ATT = 9.81, $p < 0.05$), but there is no significant effect in industries with low informal appropriability. The results confirm that adopting licensing-in is beneficial for innovative performance in industries industries with high levels of both formal and informal appropriability regardless of the type of appropriability mechanism.

5. Conclusion and discussion

5.1. Conclusion

This paper evaluated the treatment effect of licensing-in on innovative performance and found some situations in which firms that engage in licensing-in practices exhibit a higher innovation performance than those that do not. Our results show that the adoption of licensing-in practices is not always beneficial to firms' innovative performance. Our study also revealed that technological regimes are important contingency factors for the performance effect of licensing-in on firm innovation. We detected improvements in the innovation performance of firms that engage in licensing-in practices when they operate in higher technological opportunities, lower technological cumulativeness, and higher appropriability. In summary, our results suggest that the enhanced innovation performance from licensing-in practices depends on the properties of technological regimes under which firms operate.

5.2. Theoretical and managerial implications

This study offers several contributions to research on the firm innovation process and the market for technology. First, this study contributes to the research on the demand side of the market for technology. As previously mentioned, recently, management and innovation researchers have paid attention to the demand side of licensing arrangements (Arora and Gambardella, 2010; Kani and Motohashi, 2012). In line with this scholarly attention, we examined the effect of licensing-in on firms' innovation performance and the conditions under which that effect changes from the licensee firms' perspective. For the empirical analysis, we employed the propensity score matching method to control the endogenous

[2] We thank the anonymous reviewers for their helpful comments on this additional analysis.

Table 5
(Additional analyses) Innovative performance of firms of adopting licensing-in practices vs. firms of not adopting licensing-in practices.

	Model 5		Model 6		Model 7	
	Technological opportunity (measured by patents)		Formal Appropriability		Informal Appropriability	
	High	Low	High	Low	High	Low
Treatment group (licensing-in)	37.29	38.68	37.92	38.10	43.81	34.65
Control group (no licensing-in)	23.62	30	26.44	35.65	34.00	30.89
ATT	13.67**	8.68	11.48***	2.45	9.81**	3.76
S.E.	6.51	8.00	3.47	5.82	3.27	4.74
N	54	60	50	64	42	72
Hotelling test						
F	0.68	0.15	0.73	0.39	0.14	0.66
p-value	0.68	0.99	0.64	0.90	0.99	0.70

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

nature of a firm's licensing-in decision. In particular, contrary to the results of previous studies (e.g., Leone and Reichstein, 2012; Wang and Li-Ying, 2014; Wang et al., 2013b), our results showed that firms that engage in licensing-in practices do not always improve their innovative performance. Rather, their innovative performance is enhanced when they operate under specific technological regimes. Thus, this paper also contributes to the existing research on the effect of licensing-in on firm innovation performance.

In addition, we found several boundary conditions of the treatment effect of licensing-in on innovative performance. Prior studies pointed out the theoretical importance of identifying conditions under which licensing-in technologies are beneficial to firm performance (e.g., Lichtenthaler, 2011; Natalicchio et al., 2014). In this paper, we introduced the technological regime, which is one of the most important situational factors for firm innovation, to determine the boundary conditions of the performance effect of licensing-in. Our results showed that the performance effect of licensing-in is contingent on three technological regimes: technological opportunity, technological cumulativeness, and appropriability. Thus, our study provides important implications for research on the market for technology because we shed light on conditions under which the performance effect of licensing-in is significant.

Our study also provides managerial implications for understanding the performance effect of licensing-in practices. The results revealed that the adoption of licensing-in practices is not always beneficial to firms that engage in these practices. Recently, many firms attempted to improve their innovation competitiveness by adopting various methods to internalize external knowledge in the market for technology, such as formal licensing-in agreements. However, our empirical results imply that firm managers need to be more cautious when considering whether to engage in licensing-in agreements because the effects of licensing-in depend on other contingency factors. In this connection, our research indicates that favorable situations exist in which firms can improve their innovative performance by engaging in licensing-in practices. Our paper examined conditions under which the effect of licensing-in on firm innovation performance is realized. Based on our results, firm managers need to adopt licensing-in practices after they carefully consider their surrounding environments in terms of technological regime characteristics.

5.3. Limitations and future research directions

Although this research provides several implications for managers as well as extant studies, it also has some limitations. First, the cross-sectional nature of our dataset constrained our empirical approach. Although some scholars used the same type of cross-sectional dataset for their research (e.g., Garriga et al., 2013; Laursen and Salter, 2014; Robin and Schubert, 2013), we cannot investigate more dynamic aspects of the licensing-in practice's influence on firm innovation using this type of dataset. As previously explained, our dataset was constructed from a survey that gathered information on firms only from 2005 to 2007 (the Korean Innovation Survey is not provided as a panel dataset). Thus, we could not include a firm's previous experience of adopting licensing-in practices, i.e., whether a firm engaged in licensing-in practices before 2005, when we calculated the propensity scores for firms to engage in licensing-in practices. To verify the hypotheses, we attempted to ensure robust results by employing the propensity score matching method, which can mitigate the endogeneity issue related to firms' licensing-in decisions. However, our results do not allow us to make a strong claim of causality because we rely on the cross-sectional dataset. If using a panel dataset is possible, future research might investigate the effect of licensing-in on innovative performance more precisely.

Second, the generalizability of our findings may be limited. Although almost all manufacturing industries were included in our study, our results were derived from a dataset of only one country. Because the level of economic development and cultural characteristics differ across countries, firms in each country may also have an idiosyncratic nature of innovative activities. Additionally, because our dataset only pertains to the period from 2005 to 2007, repeating the same research for different periods may be required.

Third, contingency factors, besides technological regimes, that significantly influence the effect of licensing-in on firm innovation performance may exist. For example, the performance effect of licensing-in might vary with firm size because firms have different incentives to innovate given their sizes and, thus, hold distinctive characteristics of innovative activities (Ettlie and Rubenstein, 1987; Hansen, 1992; Lee and Sung, 2005; Shefer and Frenkel, 2005). The extent to which the external technologies obtained through licensing-in agreements overlap with the extant patent stock of a firm may also influence the effect of licensing-in practices on a firm's innovative performance (e.g., Mowery et al., 1998; Sears and Hoetker, 2014). Unfortunately, for confidentiality reasons, the dataset we used in this study does not provide detailed information on a firm's patent stock or acquired external technologies through licensing-in agreements. However, it will be a fruitful research avenue to considers detailed information on technology stocks when analyzing the effect of licensing-in agreements on a firm's innovativeness. Another limitation of this study on contingency factors is that we did not consider the bargaining power in the market for technology. The decision to participate in licensing or the effect of licensing are largely influenced by bilateral contracts, negotiations and bargaining power. In turn, this bargaining power is determined by the relative size, the licensing experience, the relative number of sellers and buyers in the market for technology and generality of technology. Future studies can consider bargaining power in the market for technology as a contingency factor in the effectiveness of licensing-in. In summary, a future study should determine the various contingency factors that influence the effect of licensing-in on firm innovation. Uncovering additional boundary conditions of the performance effect of licensing-in can provide significant implications for firm managers considering the adoption of such practices.

Finally, we measured innovative performance as the proportion of turnover attributable to innovations of products that were new to the market or to the firm. Although this measure has been widely used in previous studies (e.g., Laursen and Salter, 2006; Love et al., 2014; OECD/Eurostat, 2005), it may not fully capture firms' innovative performance. For instance, if a firm introduces new products, the sales of its existing products can be influenced by the product innovations. In other words, this measurement would not reflect a cannibalization of extant products or a firm's strategic decision to replace prior products. However, employing data including sales by product within a firm might be needed to circumvent these limitations. Future research could measure a firm's innovative performance more elaborately by using detailed information about the change in each product's sales caused by the introduction of new products within firms. Also, in terms of measuring innovative performance, future research can use other variables such as the quality of innovation measured by weighted forward citation of patents, new product introduction, and innovation efficiency measured by production frontier methodologies (Chen et al., 2015).

In summary, our study revealed several situations in which firms that engage in licensing-in practices can outperform firms that do not. We hope that numerous researchers expand the research on the market for technology by discovering the implications of licensing-in practices for firm innovation.

Appendix A. Distribution of firm size and technological regimes by industry classification.

KSIC	Industry	Number of firms				Technological opportunity	Cumulativeness	Appropriability
		No. of firms	49 employeess or less	50–299 employees	300 employees or more			
15	Food Products and Beverages	48	9	10	29	Low	High	High
17	Textiles, Except Apparel	31	15	9	7	Low	Low	High
19	Tanning and Dressing of Leather, Manufacture of Luggage and Footwear	22	10	8	4	Low	High	Low
20	Wood Products of Wood and Cork; Except Furniture	11	6	4	1	Low	High	Low
24	chemicals and chemical products	87	23	29	35	High	Low	Low
25	Rubber and Plastic Products	51	21	15	15	Low	Low	High
26	Other Non-metallic Mineral Products	47	12	21	14	Low	High	High
27	Basic Metal Products	42	10	20	12	Low	High	Low
28	Fabricated Metal Products, Except Machinery and Furniture	29	16	8	5	Low	Low	High
29	Manufacture of Other Machinery and Equipment	85	44	21	20	High	Low	Low
30	Computer and Office Equipment	31	19	9	3	High	Low	High
31	Electrical equipment	61	32	15	14	High	Low	Low
32	Electronic Components, Radio, Television and Communication Equipment and Apparatuses	80	13	25	42	High	High	Low
33	Medical, Precision and Optical Instruments, Watches and Clocks	60	33	21	6	High	High	Low
34	Motor Vehicles, Trailers and Semitrailers	73	7	23	43	High	Low	Low
35	Other Transport Equipment	18	4	6	8	High	Low	High

Notes: Four industries were dropped from the original sample because they do not included firms engaging in licensing-in, which are KSCI 18 (wearing apparel and fur articles), 21 (pulp, paper and paper products), 22 (printing and reproduction of recorded media), and 23 (coke and refined petroleum products).

Appendix B. Balancing tests for the whole sample.

Variables	*t*-test on the mean of each variable.			
	Treatment	Control	t-stat	p-value
Firm Size	5.68	5.83	0.46	0.64
Profitability	0.06	0.04	−1.14	0.25
Export Intensity	0.24	0.27	0.43	0.67
R&D Intensity	0.03	0.02	−1.27	0.20
Search Breadth	9.01	9.32	0.53	0.59
Collaboration	2.52	2.80	0.55	0.58
Patent Stock	3.25	3.11	−0.38	0.70
Hotelling test	**T^2**	**F-stat**	**p > F**	**N**
	4.42	0.59	0.75	114

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