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Can the Property Rights Theory Explain Cross-border Vertical Integration of Multinational Firms? Firm-level Evidence in Korea

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Abstract

We empirically test the property rights theory for multinational firms' decision on cross-border vertical integration. To examine its unique predictions that alternative theories, such as the transaction cost economics, do not imply, we investigate not only the impact of the importance of producers' relationship-specific investment on vertical integration decision but also that of suppliers' relationship-specific investment. Using data on Korean multinational firms in the producing industries and their foreign affiliates in the supplying industries, we find that cross-border backward vertical integration is positively related to the R&D intensity of domestic producing industries, and negatively related to that of foreign supplying industries. In the growing literature on the boundaries of multinational firms, we provide novel test results that the property rights theory can explain multinational firms' decision on cross-border vertical integration.

JEL Classification: D23, F14, L22, O14

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1. Introduction

There are two forms of cross-border vertical integration. Forward vertical integration refers to the case where multinational supplying firms own final good producing firms in foreign countries (or operate foreign regional headquarters to produce final products), whereas backward vertical integration is the one where multinational producing firms own input supplying firms in foreign countries (or establish foreign affiliates to produce intermediate goods). For an example of forward integration, Hyundai Motor, a multinational car company in Korea, has had one of its regional headquarters in California, U.S. since 1985.[1] In contrast, Samsung Electronics, a multinational smartphone maker in Korea, recently established a foreign affiliate in Xi'an, China that supplies semiconductor chips (Yang, 2012).

To understand the motivation behind the two different forms of vertical integration, we need a theory that discerns the determinants of backward and forward integrations. In fact, Grossman and Hart (1986), Hart and Moore (1990), and Hart (1995) (hereafter GHM) developed such a theory, which is now known as the property rights theory (hereafter PRT). They focused on firms' ex-ante incentives for relationship-specific investment. Given that ownership efficiently determines ex-post bargaining outcome between producing and supplying firms in incomplete contracts, they showed that a firm whose relationship-specific investment is more important in relationship production should own the other firm as this ownership structure provides optimal (i.e., welfare maximizing) incentives for relationship-specific investment. Thus, the PRT predicts that backward (forward) vertical integration is positively (negatively) associated with the importance of producers' relationship-specific investment and negatively (positively) related to that of suppliers' relationship-specific investment.

There is another well-known theory of vertical integration, which is based on transaction cost economics (hereafter TCE) developed by Williamson (1971, 1975). He also considered relationship-specific investment. However, he argued that ex-post bargaining between producers and suppliers

[1] The regional headquarter is not a small office that connects to Korea-based headquarters. It has an independent role for R&D, design, testing and marketing in the U.S. More information about the Hyundai U.S. headquarters can be retrieved from http://www.hyundaiusa.com.

generates transaction costs due to the specificity of investment and that vertical integration can eliminate these costs regardless of whether it is backward or forward. Thus, the TCE predicts that any forms of vertical integration are "positively" associated with relationship-specific investment by any parties. Note that, unlike the PRT, it does not distinguish between backward and forward vertical integrations.

In this paper, we empirically examine multinational firms' decision on vertical integration in the international context. Our paper has several features that deserve attention, compared to the previous studies that we will summarize later. First, we examine the predictions of the PRT by GHM that are distinguishable from those of the TCE. Starting from Antras (2003), there has been a few studies that claim to test the PRT by GHM. This literature demonstrated a positive association between backward vertical integration (measured by intra-firm imports) and the importance of multinational producers' specific investment. However, as explained above, the TCE can also generate this positive association. Regarding this identification issue, Antras and Yeaple (2014) pointed out that "The literature has generally interpreted this finding as an empirical validation of the property-rights model…, but one should be cautious in interpreting those results since these patterns are not necessarily inconsistent with alternative theories of firm boundaries, such as the transaction-cost model…" (p.122). To improve upon empirical identification for the PRT, we investigate the importance of relationship-specific investment not only by producers but also by suppliers. Only the PRT considers this "relative" importance of relationship-specific investment and generates opposite predictions between the importance of producers' and suppliers' investments on vertical integration.

Second, we explicitly consider the fixed costs of foreign direct investment in applying the PRT to the cross-border context. The literature on firm heterogeneity and foreign direct investment has shown that the additional fixed costs have played a critical role for firms' decision on various forms of foreign direct investments against domestic investments (Helpman, Melitz, and Yeaple, 2004, and Grossman, Helpman and Szeidl, 2006). With these fixed costs, cross-border vertical integration becomes a viable option against other alternatives only if transactions between producers and suppliers are significant. Thus, as the predictions of PRT can be weakened or disappeared if these transactions are small, we take into account this possibility in our empirical specification.

Third, we focus on the choice of cross-border vertical integration *per se*, rather than the share of intra-firm trades that the previous studies of the PRT do. In testing the PRT, using the share of intra-firm trades as a proxy for vertical integration may suffer from a problem of sample selection because, as pointed out above, only the firms that have significant transactions with their foreign counterparties would be willing to pay such high fixed costs and engage in intra-firm trades. Furthermore, intra-firm trades are the outcome of two decisions: extensive margin of vertical integration and intensive margin of trade volume. As the PRT considers only the former decision, the usage of intra-firm trades as a proxy for vertical integration may bias the test results.

In this paper, we use the firm-level data for Korean multinational firms during 2006-2010. The literature on cross-border vertical integration has focused on backward integration as most of vertical integration by multinational firms in advanced countries is backward. Following the literature, we also analyze backward integration as Korean multinational firms' vertical integration is likely to be backward. Nevertheless, we note that Korean multinational firms also engage in forward integration as suggested, for instance, by the Hyundai Motor case introduced earlier. Thus, it is important to identify carefully whether observed cross-border vertical integration is backward or not. For this, we apply the methodology developed by Acemoglu *et al*. (2010) who used the input-output table to identify domestic backward vertical integration in U.K.

For the variable that measures the importance of relationship-specific investment, we use the R&D intensities at the industry level in Korea and foreign counterpart countries in which foreign affiliates of Korean multinational firms are located. Two things are noteworthy. First, we focus on R&D intensity because other variables used in the previous literature such as skilled workers, physical capital and specialized equipment are not readily available for the counterpart countries at the industry level. Second, as the counterpart countries, we focus on the Asian countries since foreign affiliates of

Korean multinational firms are highly concentrated in a few countries in Asia.[2] This may be an advantage of analyzing Korean multinational firms. The collection of relationship-specific investment data for multinational firms in advanced countries such as U.S. is very difficult as they have so many counterpart countries in which supplying affiliates are located.

Our main results confirm the original predictions of PRT in a context of international economy. Korean multinational firms tend to choose more cross-border backward vertical integration as the R&D intensities of domestic producing industries increase and the R&D intensities of foreign supplying industries decrease. These relations are more pervasive for the firms whose share of input costs accounted for by their foreign affiliates are large. These results are quite robust to endogeneity, sample selection, alternative measures of vertical integration, and a potential influence from parent firms' decision. Our finding may have an economic significance as well because the activities of multinational firms originated from emerging economies have grown to explain more than one-third of foreign direct investments in global markets as of 2013. Our finding also suggests that, like multinational firms in advanced countries, newly emerged multinational firms behave in a way that the PRT predicts.

The PRT has been tested in the international trade context. Antras (2003), Yeaple (2006), and Nunn and Trefler (2013) used various proxies for the importance of multinational producers' investments such as headquarters' R&D intensity, skill intensity, physical capital intensity and specialized equipment intensity, and found the positive relationship between intra-firm trade and these intensities of headquarters. In addition to the fact that we use a direct observation of vertical integration rather than a proxy for it, our paper differs from these papers as we examine the negative relationship between backward vertical integration and the R&D intensities of foreign supplying industries. It allows us to interpret that our results conform to the predictions of the PRT that the TCE does not imply. Recently, Antras and Chor (2013) confirmed the validity of the PRT for multinational

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[2] Korean multinational firms imported 88 billion dollars of manufacturing goods from their foreign affiliates in 2012. Among the 88 billion dollars, almost 90% are imported from Asia regions, according to the *Business Analysis of Foreign Direct Investment* reported by the Export-Import Bank of Korea.

firms not only from the producers' side but also from the suppliers' side as we do. However, they examine the predictions of the PRT made by Antras and Helpman (2008) who modified GHM's incomplete contract model by introducing partial contractibility. Accordingly, instead of the relative importance of "non-contractible" investment, they examine the relative degree of contractibility between producers and suppliers, and its impact on intra-firm trades.[3]

The rest of our paper is organized as follows. Section 2 introduces activities of Korean multinational firms and summarizes the relationship between relationship-specific investments and the cross-border backward vertical integration. Section 3 explains our testing hypothesis and empirical specification. Section 4 presents the results. Section 5 concludes our paper.

2. Cross-Border Backward Vertical Integration and Technology Intensity

In this section, we show the relationship between cross-border backward vertical integration and technology intensity as a measure of relationship-specific investments. For this purpose, first we explain how we construct the two variables and then elaborate their overall relationship.

2.1 Measure of Cross-border Backward Vertical Integration

We define a measure of cross-border backward vertical integration for a Korean manufacturing firm that is equal to 1 if the parent firm in the producing industry owns a firm in the supplying industry in a foreign country; otherwise zero. We obtain pairs of parent firm and its foreign affiliates from the *Survey of Business Structure and Activities* (SBSA) collected by Statistics Korea in the period of 2006–2010.[4] To implement the definition for the measure of cross-border backward vertical

[3] Antras and Helpman's contractibility indicates how the party's transactions are contractible. Accordingly, Antra and Chor's contractibility measure is not related to the importance of relation-specific investment. In particular, their contractibility measure was originally developed by Nunn (2007), who adopted the methodology of Rauch (1999) that classifies trades according to either organized exchanges or reference prices. The contractibility is measured as the trade share of organized exchanges, which is not related to the relative importance of relationship-specific investment.

[4] Since 2006, Statistics Korea has conducted annual survey for all business-sector firms incorporated with 50 workers or more. The survey is a highly representative of the Korean manufacturing sector as the total value-

integration, we take into account the following three criteria.

First, we define a parent firm as a firm that owns at least 50% of equity capital of its foreign affiliates.[5] This definition of a parent firm emphasizes a right of control over their foreign affiliates, which underlies the PRT. Moreover, Barefoot and Mataloni Jr. (2011) find that the intra-firm imports from majority-owned foreign affiliates accounts for more than 90% of the total intra-firm imports in the U.S. In this respect, our definition of foreign subsidiaries is also appropriate for defining subsidiaries in the supplying industry.

Second, to identify the producing-supplying-industry pairs, we define a supplying industry as an industry that supplies intermediate input of a producing industry, using the Input-Output table of Korea for 24 2-digit level manufacturing industries. Because international trade usually incurs higher transaction costs than domestic trade, a domestic parent firm might have little incentive to integrate a firm located in a foreign supplying industry if the parent firm in the producing industry purchases relatively small share of intermediate inputs from the supplying industry.[6] We thus use the producing-supplying industry pairs where supplying industry supplies at least 1% of the total intermediate input of a producing industry, which gives us 203 producing-supplying-industry pairs. Since our measure of the vertical relationship between parent firms and their affiliates is defined over the 2006–2010 period, we use the 2005 Input-Output table to avoid a possible reverse causality.[7]

Lastly, we define the backward vertical relationship by a flow from the supplying to producing industry accounting at least for 5% of the total intermediate input of the producing industry.[8] That is, cross-border backward vertical integration indicates a relation in which a final producer in Korean producing industry procures at least 5% of the total intermediate input from its affiliate in the

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added of firms in the 2007 SBSA, for instance, accounts for approximately 70% of the value-added of the Korean manufacturing sector.

[5] The survey includes firms who own at least 20% of foreign affiliates' equity capital, but the majority-owned affiliates account for more than 80% of the total number of vertically integrated foreign affiliates.

[6] As a robustness check, we examine all producing-supplying industry pairs with positive intermediate input flows, which increases the number of industry-pairs to 513. The results are shown in Section 4.2.

[7] We also used 2000 Input-Output table for a robustness check and found that results are qualitatively the same. The results are available upon request.

[8] We also considered 1% criterion for the vertical relationship and performed a robustness test. The results are qualitatively the same and are available upon request.

supplying industry.

In the previous studies of Tomiura (2007), Kohler and Smolka (2012), and Defever and Toubal (2013), intra-firm import shares of total imports are used as a proxy of cross-border sourcing behavior, which mixes both extensive and intensive margins.[9] Our measure of cross-border backward vertical integration is distinct from the previous literature since it includes only the extensive margin of vertical integration (not of sourcing behavior). Our measure is better for testing the PRT of vertical integration as the theory focuses solely on the choice of integration, not together with the volume of trade nor with a choice of sourcing behaviors.

2.2 Measure of Technology Intensity

The PRT shows that the importance of relationship-specific investment determines the choice of vertical integration. To capture this "importance" of specific investment, the literature, such as Antras (2003), Acemoglu *et al*. (2010) and others, suggests the "intensity" of technology or other investments as its measure. Furthermore, they focus on industry-level intensities because firm-level intensities would rather capture the amount of the firm's investment than its importance. Following them, we use industry-level R&D intensity measured by a ratio of R&D expenditures to value-added.

A main departure from them, however, is that we build up the measure by using various sources of datasets both from Korea and other host countries. For Korea, we obtain industry-level data on R&D expenditures from the 2005 *Survey of Research and Development* of Korea Institute of Science & Technology Evaluation and Planning. For China, we use OECD's ANBERD database where industry-level R&D data are available. For India, we obtain industry-level R&D data from *Science & Technology Indicators* published by National Science & Technology Management Information System, and for Indonesia, we use *Indikator Iptek Indonesia* by Indonesian Institute of Science. For the other Asian countries, R&D data are available only at the economy-level, but not at the industry-

[9] Corcos *et al*. (2013) is an exception; they decompose extensive and intensive margin of intra-firm trade. However, their main focus is on the choice of sourcing mode of a parent firm, while we examine a choice of vertical integration between producing firms in home and supplying firms located in foreign countries.

level. We thus estimate the other Asian countries' industry-level R&D multiplying their economy-level R&D by a common benchmark distribution of industry-level R&D. Since the economy-level R&D intensity for these countries is quite low and all of them are lower than 1%, we assume that the distribution of industry R&D is close to each other. We construct the benchmark distribution of industry R&D using industry-level R&D for countries with less than 1 % R&D intensity in the ANBERD dataset.[10] Data on industry-level value-added is obtained from OECD's STAN for Korea and China, and from UN's UNIDO for the other Asian countries. Because the sample period for vertical integration is 2006–2010, we use R&D expenditures in 2005 to avoid possible reverse effects.[11]

Our data construction is different from the existing literature (Antras, 2003; Nunn and Trefler, 2013), in which the technology intensity variable for the headquarter-located country is used. However, we measure not only R&D intensity in the *domestic* producing industry (Korea) but also R&D intensity in the *foreign* supplying industry. In the literature of cross-border vertical integration, it may be the first paper that distinguishes technology intensities in domestic producing and foreign supplying industry pairs using data on industry-level R&D for Korea and foreign countries both.

2.3 Relationship between Cross-border Backward Vertical Integration and R&D Intensity

For the relationship of the two measures, we focus on Asian markets since Korea's outbound foreign direct investment in manufacturing sectors is highly concentrated in Asia as shown in Figure 1, and both the relative share and the absolute amount of intra-firm trade in Asia is the largest compared to those in other regions.[12] The phenomenon of Asian concentration of intra-firm trade between Korean

[10] Because most foreign affiliates are located in some large Asian countries such as China, India, and Indonesia, omitting these countries with estimated industry R&D does not change our main results.
[11] The reverse effect may be not significant unless Korean affiliates have significant shares in the foreign supplying industries. Later we will instrument the R&D intensity of producing industries of Korea by Japan and US R&D intensity for robustness checks.
[12] While majority of sales by the foreign affiliates are local sales, the proportion of intra-firm trade is largest in Asia. According to the most recent report of 2012 *Business Analysis of Foreign Direct Investment*, the intra-firm trade share in Asia is 31.7%, while those in North America and Europe are only 2.6% and 3.5%, respectively.

firms and their affiliates is in contrast with multinational firms in advanced countries.[13] Figure 1 depicts the FDI trend from 1981 to 2010 depicted from the dataset of *Business Analysis of Foreign Direct Investment* provided by Export-Import Bank of Korea.

[Insert Figure 1]

Two things are noteworthy. First, the outward foreign direct investments took place intensively from 2006 on as Korean government finally abolished investment limits imposed on businesses and individuals in 2005.[14] While the annual average amount of the investments between 1991 and 2005 was 2.1 billion dollars, it became 6.4 billon dollars for 5 years from 2006 to 2010.[15] Second, Asia is the major market for foreign direct investment. Korean manufacturing firms invested on annual average 4.5 billion dollars in Asia during 2006–2010, which is about 70% of the total foreign direct investments for that period.

[Insert Table 1]

Now, we discuss the relationship between the cross-border backward vertical integration and the R&D intensity at industry level. Table 1 shows cross-industry distribution of vertically integrated foreign affiliates. Our sample of 6,102 Korean parent firms in manufacturing industries has 1,494

Furthermore, total intra-firm exports of the affiliates in Asia to Korean parent firms in 2012 are 120.2 billion dollars, which is 93% of the total intra-firm exports of all foreign affiliates. The high share of Asia in the intra-firm exports is also a noticeable fact during the period between 2006 and 2010.

[13] For instance, Barefoot and Maltaloni Jr. (2011) show that the intra-firm exports by U.S. owned foreign companies are relatively evenly distributed over the world. In particular, in 2009 the total intra-firm exports to U.S. were 266.9 billion dollars. Among them, the share of Asia was 51.3 billion dollars, Europe was 76.5 billion dollars and Latin America was 48.1 billion dollars.

[14] It is partly due to the fact that Korean government began mitigating the regulation of foreign direct investment in 1995 (Nicolas *et al*., 2013). See Nicolas *et al*. (2013) for this deregulation in details.

[15] There are two unusual FDI trends in 2001 and 2008 in the figure. First, the temporary surge of foreign direct investment in 2001 seems due to the large scale of investments by LG Electronics to Philips Electronics (LG Electronics Inc., 2002). Second, the investment in 2009 transitorily declined after the global economic crisis in 2008. The investment was recovered right after the event.

vertically backward integrated foreign affiliates.[16] A Korean firm has on average 0.245 number of foreign subsidiary in Asia that supplies inputs for production.[17] First, there are industrial variations. That is, more than 30% of firms in Motor Vehicles, Electronics, Electrical Equipment, Petroleum, and Apparel industries have supplying foreign subsidiaries, while less 10% of firms in Beverages, Tobacco, Wood, Paper, and Printing industries have supplying foreign subsidiaries. Second, approximately 70% of the vertically integrated foreign subsidiaries are agglomerated in China (1,046 out of 1,494) and the remaining 448 supplying subsidiaries are located in other Asian countries. In Table 1, Other Asia includes 12 Asian countries (Cambodia, Hong Kong, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, The Philippines, Sri Lanka, Thailand, Vietnam), however, almost 80% of backward vertically integrated affiliates in other Asian countries are located in Vietnam (169), Indonesia (94), and India (86). Notice that we consider other Asia as one region in column (4) of Table 1. This is because the country variations in other Asia region are mainly associated with the industrial variations within the region as a whole. For instance, the majority of foreign affiliates in India are concentrated in Motor Vehicle (44 out of 86). In Indonesia, Korean multinational firms have their affiliates mainly in Apparel, Textiles, Leather and Electronics (52 out of 94). In Vietnam, the main industries are Apparel, Textiles, Leather, Electronics, and Motor Vehicles (87 out of 169).

[Insert Table 2]

Next, Table 2 shows the R&D intensities of producing and supplying industries across countries. Columns (2) and (3) show R&D intensities in producing and supplying industries, respectively.[18] Columns (4) and (5) are R&D intensities of supplying industries in China and other Asia. As we will explain later in detail, the PRT suggests that the likelihood of backward vertical integration decision of producing firms becomes higher as the technology intensity gap between producing and supplying

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[16] Approximately 82% of all affiliates are backward vertically integrated with Korean parent firms.
[17] Because a firm has more than one foreign affiliate, the proportion of Korean firms that have at least one vertically backward integrated foreign affiliate is 0.229.
[18] If a producing industry has multiple supplying industries, the R&D intensities of the supplying industries are averaged.

firms is larger. However, note that in this paper we examine the decision for *cross-border* backward vertical integration. Hence, Korean producing firm will consider the decision by comparing technology intensities of domestic supplying industries and foreign counterpart supplying industries. That is, if a foreign supplying industry has lower technology intensity than the same domestic supplying industry, it is more likely for the domestic producing firm to decide *cross-border* vertical integration rather than domestic vertical integration.

For chemical industry in Table 2, the difference between R&D intensities of the producing industry (0.066) and its foreign supplying industry (0.042 for China) is substantial. However, the R&D intensity of domestic supplying industry for the chemical industry (0.035) is lower than that of China's supplying industry, which negatively affects the probability of cross-border vertical integration for firms in the producing industry. In contrast, the R&D difference between producing and China's supplying industries for rubber and plastic is small. However, a higher R&D intensity of domestic supplying industry for the rubber and plastic industry (0.045) than that of China's supplying industry (0.027) may increase the probability of cross-border vertical integration of firms in the producing industry. Consistently, probabilities of cross-border vertical integration in the two industries are not much different (see column (2)/(1) in Table 1 for chemical industry (0.257) and rubber and plastic industry (0.224)), although the difference in R&D intensities of domestic producing and foreign supplying industries is substantially larger in the chemical industry than in the rubber and plastic industry.

As we can observe in the last two columns in Table 2, the gap of R&D intensities between domestic and foreign supplying industries are mostly negative. The negative signs indicate an important implication for a choice of *cross-border* vertical integration as follows. This idea can be checked in Figure 2.

[Insert Figure 2]

First, panel A in Figure 2 shows a positive correlation between R&D intensity of domestic producing industries and industrial shares of cross-border vertical integration in both China and other Asia. Second, panel B reveals a negative correlation between R&D intensity of foreign supplying industries (relative to that of domestic supplying industry) and industrial shares of cross-border vertical integration in China and other Asia. These two facts tell us that, as the R&D intensity gap between domestic producing industry and foreign supplying industry gets larger, the Korean parent firms tend to have backward vertically integrated foreign suppliers. In Section 4, we will formally address regression estimations to test the predictions of the PRT for Korean multinational firms.

3. Empirical Specification and Data

3.1 Testable Hypothesis

Grossman and Hart (1986), Hart and Moore (1990), and Hart (1995) develop a theory of vertical integration, which is now known as PRT. It starts with the holdup problem associated with relationship-specific investment. Given that ex-post bargaining between producing and supplying firms is efficient (so there are no transaction costs) and that ownership (i.e., property rights) determines bargaining shares between them, the theory suggests that the proper allocation of ownership can solve the holdup problem and provide the firms with incentives for relationship-specific investment. In particular, it shows that it is optimal for the firm whose specific investment is more important in relationship production to own the other firm. That is, backward vertical integration is optimal if specific investment by a producing firm is more important and forward vertical integration is optimal otherwise. In our context, PRT predicts that the likelihood of backward vertical integration increases with the importance of relationship-specific investment of Korean producers and decreases with that of foreign suppliers, where the importance of investment is measured by the R&D intensity of corresponding industries.

In our empirical analysis, we focus on backward integration rather than forward integration. In the forward relationship, the downstream industry of the final manufacturing good supplier is the wholesale of retail trade industries. In this case, an important relationship-specific investment in the manufacturing suppliers is technology investment in R&D, whereas that in the trade industry is intangible assets such as marketing skills. In reality, it is very difficult to choose a single variable that measures the relative importance of relationship-specific investment in both manufacturing and trade industries. Despite examining the backward integration, our empirical model estimates the signs of relationship-specific investments in *both* the producing and supplying industries, which enable us so test the PRT hypothesis that distinguishes backward and forward integrations and non-integration.

Moreover, as we test the theory in the “cross-border” context, we will argue below (and formally show in Appendix) that this relationship manifests if the share of the producer’s input costs accounted for the supplier is large. For cross-border backward vertical integration, firms face additional costs of setting up plants in foreign countries. The presence of additional fixed costs of foreign direct investment has been widely accepted in the literature on multinational firms. The literature shows empirically that only high productive firms can afford foreign direct investment due to these fixed costs (Helpman, Melitz, and Yeaple, 2004). Given these fixed costs, cross-border backward vertical integration is thus a viable option for a multinational producer when the inputs provided by a foreign supplier are important for the producer so that the share of the inputs accounted for by the supplier is large. That is, if the input costs are too small, the PRT argument over cross-border vertical integration may become weakened or disappear. For this reason, we interact the share of the producer’s input costs accounted for by the supplier with R&D intensity measures in our regression model as shown below.

3.2 Empirical Specification and Data

To test the hypothesis on the likelihood of cross-border backward vertical integration of Korean manufacturing firms, we estimate the following equation:[19]

$$CBVI_{i,j,k,c} = \alpha + \left(\beta_P + \gamma_P SC_{j,k}\right) RD_j^P + \left(\beta_S + \gamma_S SC_{j,k}\right) RD_{k,c}^S + \delta SC_{j,k} + X_{i,j,k}'\Phi + D_c'\eta_c + \varepsilon_{i,j,k,c}$$

[19] Following the methodology of Acemoglu *et al*. (2010) and Lileeva and van Biesebroeck (2013), we build an empirical specification for testing whether the PRT holds for explaining CBVI.

where the dependent variable, $CBVI_{i,j,k,c}$, is a measure of cross-border backward vertical integration. It is equal to 1 if firm *i* in producing industry *j* of domestic country owns a firm in supplying industry *k* of foreign country *c*. With this definition of the cross-border vertical integration, we would like to emphasize the extensive margin of a multinational producing firm integrating with a foreign supplier. When it is zero for firm *i*, the choice of zero may imply many different options for the firm; cross-border outsourcing, domestic vertical integration, and domestic outsourcing. In particular, when a firm chooses a domestic vertical integration, our measure of $CBVI_{i,j,k,c}$ assigns zero for the following reason. If the R&D intensity of a producing industry in Korea is larger than foreign R&D intensity of its supplying industry, the PRT predicts that cross-border backward vertical integration is likely to occur. However, we argue that this would happen only when the domestic counterpart supplying industry has a higher R&D intensity than that of the foreign supplying industry.[20] Otherwise, the domestic producing firm may decide to integrate with the domestic supplier. As $CBVI_{i,j,k,c}$ = 0 includes domestic backward vertical integration, the measure of $CBVI_{i,j,k,c}$=1 captures the firm's *extensive* margin of cross-border backward vertical integration.

Our main explanatory variables in the above specification are the two R&D intensities. RD_j^P is R&D intensity in the producing industry *j* of domestic country, and $RD_{k,c}^S$ is R&D intensity in the supplying industry *k* in country *c*. If the PRT can explain the vertical integration, we expect a positive effect for RD_j^P and a negative effect for $RD_{k,c}^S$ on the likelihood on the cross-border vertical integration. However, as we explained above, the opposite effects of R&D intensities of the producer and the supplier would become clearer as the input share of the supplier in the total cost of the producer is high. Thus we introduce the cost share variable $SC_{j,k}$, which is the share of inputs from supplying industry *k* in the total cost of the producing industry *j*. We interact the R&D intensity variables with the cost share variable, and evaluate R&D effects at the sample mean of cost shares and

[20] For the same reason, we showed that in Panel B in Figure 2 the relationship between CBVI and the R&D intensity of the foreign supplying industry relative to that of the domestic supplying industry.

the standard errors of the R&D effects will be calculated using the delta method.

Second, in addition to an interaction term, we use $SC_{j,k}$ as an independent explanatory variable. All other things being equal, the incentive for a final good producer to integrate its input supplier would increase with the input costs. Acemoglu *et al*. (2010) predicts that a greater share of the costs would increase the extent to which producers are likely to be held up by suppliers. Hence, we expect the estimated coefficient to be positive.

Finally, $X_{i,j,k}$ is a vector of firm-level characteristics including firm size and total factor productivity (TFP), and D_c is a vector of country dummies.[21] The measure of firm size is a log value of tangible fixed asset of firm *i*. The TFP of firm *i* is defined as real value-added over income share weighted average of labor and capital inputs. Nominal value-added is defined as total sales revenue minus intermediate input costs. Nominal intermediate input is calculated by the sum of costs of goods sold and selling, general, and administrative expenses minus the sum of labor expense and depreciation. To deflate nominal value-added, we use the KSIC 2-digit industry-level value-added deflator published by the Bank of Korea. Labor input is measured by the number of employees. Real capital stock is the value of tangible fixed assets deflated by the 2-digit industry-level investment deflator obtained from the Korea Industrial Productivity (KIP) database. The labor income share is assumed to be two-thirds and the capital income share is one minus the labor income share.[22]

We expect both positive effects from the size and TFP of firms. Korean multinational firms have usually large scales of production for global markets and their sales are larger than those of domestically oriented firms. In addition, the productivity of the firms has been known as an important factor for foreign direct investment in the literature (e.g., Helpman, Melitz, and Yeaple, 2004). Lastly, two country dummies for China and other Asia are used. The interpretation for the dummy variables is that all other things being equal, the dummies reflect unobserved country characteristics related to

[21] Inclusion of country-specific control variables such as GDP for market size and wage rate for labor costs rather than including country dummies generates qualitatively similar results.

[22] The labor income share in the National Accounts for Korea and the U.S is close to each other, which suggests that this share seems reasonable. To allow industry-level variation in labor income share, we use the 2-digit-level labor income share. However, results are qualitatively the same.

different costs of foreign direct investment. By controlling the country-specific effects we can find out more clearly marginal effects of R&D intensities on the choice of vertical integration across different regions.

Table 3 reports descriptive statistics for the variables used in regressions. We collapse five-year data into a single cross-section because changes in firms' organization rarely happen over the short period. After omitting firms without information about firm-specific variables such as TFP, we have 5,981 manufacturing firms. There are 203-industry pairs where inter-industry transaction based on the 2005 Input-Output table occurs. Each observation represents a firm *i* in the producing industry *j* (in Korea) that uses input form supplying industry *k* in country *c* (Korea, China, and Other Asia).[23] We have 145,827 firm-industry-country pair level observations.

[Insert Table 3]

Table 3 shows that the mean and standard deviation of our dependent variable is 0.01 and 0.099 respectively. This implies that the choice variable, CBVI, has an enough variation around the mean value. Furthermore, the mean and standard deviation values for firm-specific variables, firm size and TFP, also imply that firm-level heterogeneity matters for the choice of cross-border backward vertical integration. Table 3 summarizes our main variables of R&D intensity in producing and supplying industries. The mean value of the R&D intensity in domestic producing industry is 0.077 and the mean of the R&D intensity in foreign supplying industry is 0.028. Since we used the R&D intensity for supplying industries from Asian countries, the mean value of supplying industry is smaller than that of producing industry in Korea.

The regressions of our empirical specification are conducted at the firm-industry-country pair level, while some explanatory variables including cost shares and R&D intensities are at the

[23] When firm *i* has more than two foreign affiliates in different industries or locations, we treat them as different observations. In a section of robustness check, we control the multi-plant firms and single plant firms by considering large versus small and medium-sized firm samples. We find that there are not qualitatively different results from the two subsamples.

producing-supplying industry level. We thus use standard errors adjusted for clustering at the level of 203 supplying-producing-industry pairs.[24] The results are summarized in Section 4.

4. Empirical Results

4.1 Main Results

The first column presents results for our main hypothesis about the relationship between the cross-border backward vertical integration and R&D intensities in domestic producing and foreign supplying industries. We calculate the R&D effect in the producing industry as, $\hat{\beta}_P + \hat{\gamma}_P \overline{SC}_{j,k} = -0.051 + 1.226 \times 0.079$, where $\overline{SC}_{j,k}$ the sample mean of input cost share. The estimated R&D effect in the producing industry is 0.046 and is also statistically significant at the 1% level. The result shows a positive relationship between the technology intensity in the domestic producing industry and cross-border backward vertical integration. The R&D effect in the foreign supplying industry on vertical integration is –0.062, suggesting a negative relationship. The results for the opposite effects of technology intensity in domestic producing and foreign supplying industries confirm that the PRT can be applicable to cross-border backward vertical integration.

[Insert Table 4]

In addition, in order to confirm whether the results are more pervasive for the case of a high share of input costs, we further evaluate the opposite R&D effects of producers and suppliers when the share of input costs is above and below the sample mean with the result from column (1). For firms with the share of input costs that is higher than the mean, the R&D effect of producers is 0.266 and that of suppliers is –0.314, which are all statistically significant at 1% level. The results show stronger opposite effects for the case of a high share of inputs costs. However, when the share is lower

[24] Since the R&D intensity variable in the supplying industry is at the industry-country level, we also use standard errors adjusted for clustering at the producing-supplying-industry-country level. This generates qualitatively the same results.

than the mean, the R&D effect of producers is –0.020 and that of suppliers is not statistically different from zero. The results imply that the PRT prediction for the R&D effects on cross-border backward vertical integration holds only when the share of input costs is large enough for firms to cover large costs in setting up their foreign plants. The existence of large set-sup costs for cross-border vertical integration differentiates our PRT test in the international context from domestic one tested in Acemoglu *et al*. (2010).

As for the firm-specific variables, coefficient estimates of firm size and firm-level TFP variables in column (1) are all positive and highly significant. In particular, the result with TFP variable is consistent to the existing literature (Corcos *et al*. (2013) for French firms' sourcing choice) that firms with high productivity can cover the fixed costs associated with foreign entry.

The share of input costs of producing industry *j* from supplying industry *k* has a positive effect on the choice of backward vertical integration. That is, if a firm purchases a significant share of inputs it may be likely to be held up by its suppliers. To reduce the holdup problem, the firm may choose to integrate with suppliers. Our result confirms this tendency for the case of cross-border backward vertical integration.

The estimated coefficient for China dummy in column (1) is 0.018 and is also statistically significant at the 1% level, whereas Other Asia dummy is 0.004 and is insignificant. The results are consistent with a higher ratio of CBVI in China than in other Asian countries shown in Table 1. To address heterogeneity in firms' location choice between China and other Asian countries, we run regressions over two samples; China and other Asia in columns (2) and (3), respectively. The opposite effects hold for the two samples of China and Other Asia. In columns (4) and (5), we further split the sample of other Asia into two groups according to their R&D intensity. Nonetheless, we find out qualitatively similar results about the R&D effects of producers and suppliers in the two groups of other Asian countries.

4.2 Robustness Checks

To assess the robustness of our findings about the relationship between technology intensity and cross-border backward vertical integration, we examine various issues related to endogeneity, sample selection, alternative measures of cross-border backward vertical integration and a potential influence from another parent firms. The wide range of robustness checks produces qualitatively similar results as shown from Table 5 to Table 8.

Instrument Variable Estimation

To test the PRT, we examined the opposite effects of R&D intensity in domestic producing and foreign supplying industries on firms' decision on cross-border backward vertical integration. However, the vertical integration may also affect R&D investments, which results in a possible endogeneity problem.[25] To avoid this problem, we use two instrumental variables (IV) for R&D intensity in the domestic producing industry: R&D intensities of Japan and the U.S. Thus, the use of Japan's or U.S.'s R&D as an instrument can remove factors associated with reverse causality in the Korea's R&D variable. In particular, the Japan's R&D variable is a strongly relevant instrument because of a high similarity in industrial structure of technology for the two countries. However, Japan's FDI destination is also similar to Korea's in a sense that Japanese multinational firms have heavily invested to set up production network in Asia (Baldwin and Okubo, 2014). So, we also consider U.S.'s R&D intensity variable as an alternative instrumental variable since U.S.'s FDI destination is more diverse than Korea's FDI and the R&D intensity of U.S.'s producing industry is not related to Korean multinational firms' choice of vertical integration. Using the two instrumental variables, we run regressions for the whole sample, China, and Other Asia and show the results in Table 5.

[Insert Table 5]

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[25] To address this issue in Table 4, we used the R&D intensity variable in 2005 pre-dating the period of vertical integration activities in 2006–2010. The predating R&D intensity in the foreign supplying industry is not likely to be affected by the entry of Korean firms. In robustness checks, we thus focus on the endogeneity problem in R&D intensity in the domestic supplying industry.

Panel A in Table 5 shows the results with Japan's R&D intensity as an instrument for R&D intensity in the Korean producing industry. Two variables are instrumented: R&D intensity in the producing industry and its interaction term with the share of costs. In the first stage regression for column (1) of Panel A, *F*-statistics for the two instrumented variables show that the instrument variable of Japan's R&D passes a standard weak instrument test, which indicates a strong correlation between the Japan's and Korea's R&D. As shown in Table 5, all results are quite robust with the use of instrument variable. The R&D effect in the producing industry is positive and the effect in the supplying industry is negative in all columns of Panel A. Panel B presents results with US's R&D intensity as an alternative instrumental variable. Panel B presents that endogeneity tests report IV estimation results significantly different from those in Table 4. However, the signs of R&D opposite effects in the producing and supplying industries remain unchanged and the magnitudes of the effects also change little. Overall, this implies that results with the US R&D intensity are qualitatively similar to our main results.

Large versus Small and Medium-sized Firms

Usually, large companies own multi-plants in the producing industry, while small and medium-sized firms operate single plants. So, unlike the small and medium-sized firms, large firms may have a within-firm variation in deciding their vertical integrations. Acemoglu *et al*. (2010) and Lileeva and van Biesebroeck (2013) directly considered a sub-sample of multi-plant firms to see whether the presence of within-firm variation affects their results. Similarly, we can also test the role of within-firm variation of large firms by conducting a robustness test for two samples of large versus small and medium-sized firms. Furthermore, large Korean firms are quite dominant in terms of international activities such as foreign direct investments. Thus the similar results for the subsamples of large and small and medium-sized firms also confirms that our findings are not driven by many small firms that have relatively small economic significance in terms of the FDI amount.

In fact, to control the size-related effects, we included firm size by tangible assets and total factor productivity in our main test. However, this does not completely control the size effect mentioned above. In order to check whether our results are affected by within-firm variations, we divide our sample into two groups: Large firms versus small and medium-sized firms. We define large firms as firms with 250 or more employees and small-and-medium firms as with less than 250 employees. The total number of large firms in our sample is 863 and that of small-and-medium firms is 5,055. The main test results are summarized in Table 6.

[Insert Table 6]

As we expect, when the subsample consists of small and medium-sized firms only, the R&D effects are weaker than when our sample contains large firms only. However, the main results qualitatively remained unchanged; the R&D intensity in producing industry has a positive impact on the vertical integration decision while the R&D intensity in supplying industry has a negative impact.

Industry-Pairs with Positive Input Flows

Since the cross-border vertical integration incurs a substantial size of set-up costs, we thus examine producing-supplying-industry pairs that have more than 1% of the total intermediate input of the producing industry. To relax this, we include all producing-supplying-industry pairs that have at least positive input flows from supplying to producing industries. The number of industry pairs increases from 203 to 513. Table 7 shows that the inclusion of all industry-pairs with positive input flows does not qualitatively change our main results. For all Asia, China and other Asia cases, the R&D intensity effects in the producing industry are positive and statistically significant, and the R&D intensity effects in the supplying industry are statistically significant and negative.

[Insert Table 7]

Alternative Measure of Vertical Integration

Throughout the paper, we define the backward vertical relationship by a flow from the supplying to producing industry accounting at least for 5% of the total intermediate input of the producing industry. However, some intermediate inputs are crucial for the producing industry even though its share in the producing industry is relatively small. To address this issue, we use a more relaxed criterion for defining vertical integration, i.e., the flow from the supplying industry accounting for at least 1% of the total intermediate input of the producing industry. We apply this new criterion for both the sample with two sets of producing-supplying-industry pairs used in Tables 4 and 7. The relaxed criterion for vertical integration generates qualitatively the similar results.[26]

Excluding Firms Owned by Another Parent Firms

When a firm chooses a cross-border backward vertical integration, a firm is supposed to do so as an independent firm. However, if the domestic firm in the producing industry is owned by a foreign firm, the firm's FDI decision could be influenced by her foreign parent firm. The choice of the vertical integration may not be associated with the characteristics of the investing firm itself. Thus, the inclusion of foreign-owned firms in the sample may result in a bias in testing the PRT predictions. To address this issue, we exclude the foreign-owned firms in the sample. We define a firm as foreign-owned one if a more than 50% of its capital equity is owned by a foreign firm. Furthermore, we also extend the idea to cases where a firm is owned by a domestic parent firm as well. Even if it is owned by a domestic parent firm, the decision of the cross-border vertical integration may be contaminated by the parent firm. So, we further exclude firms owned by any parent firms.

[Insert Table 8]

Panel A of Table 8 presents the results when we exclude 431 foreign-owned firms in the producing industry and panel B is when we exclude 1,091 firms with either domestic or foreign parent firms. As observed in the table, the results qualitatively remain unchanged. As R&D intensity in the

[26] Results are available upon request.

domestic producing industry is higher and that in the foreign supplying industry is lower, the likelihood of cross-border backward vertical integration is higher. This result supporting the PRT predictions is observed in all Asia, China and other Asia cases.

5. Conclusion

In this paper, we tested the hypothesis of property rights theory of Grossman and Hart (1986) to the case of cross-border vertical integration and showed the opposite relationship-specific investment decision of producing and supplying firms using Korean firm level data. Our results imply that cross-border backward vertical integration is positively related to R&D intensity of producing industries in Korea, and negatively related to R&D intensity of foreign supplying industries.

Two contributions are noteworthy. First, this is the first empirical evidence directly showing opposite effect of the investment intensities of domestic producing and foreign supplying firms on their vertical integration decision. The existing literature has so far tested partial contractibility of supplying and producing industries, rather than investment intensities of them. Second, our result is the first evidence to reveal the property right theory for multinational firms from emerging countries. Due to the different nature of global production network of emerging countries, we could not simply apply the existing empirical strategy in the literature. A necessary step for the study on FDI from emerging countries was to identify cross-border backward vertical integrations from forward ones.

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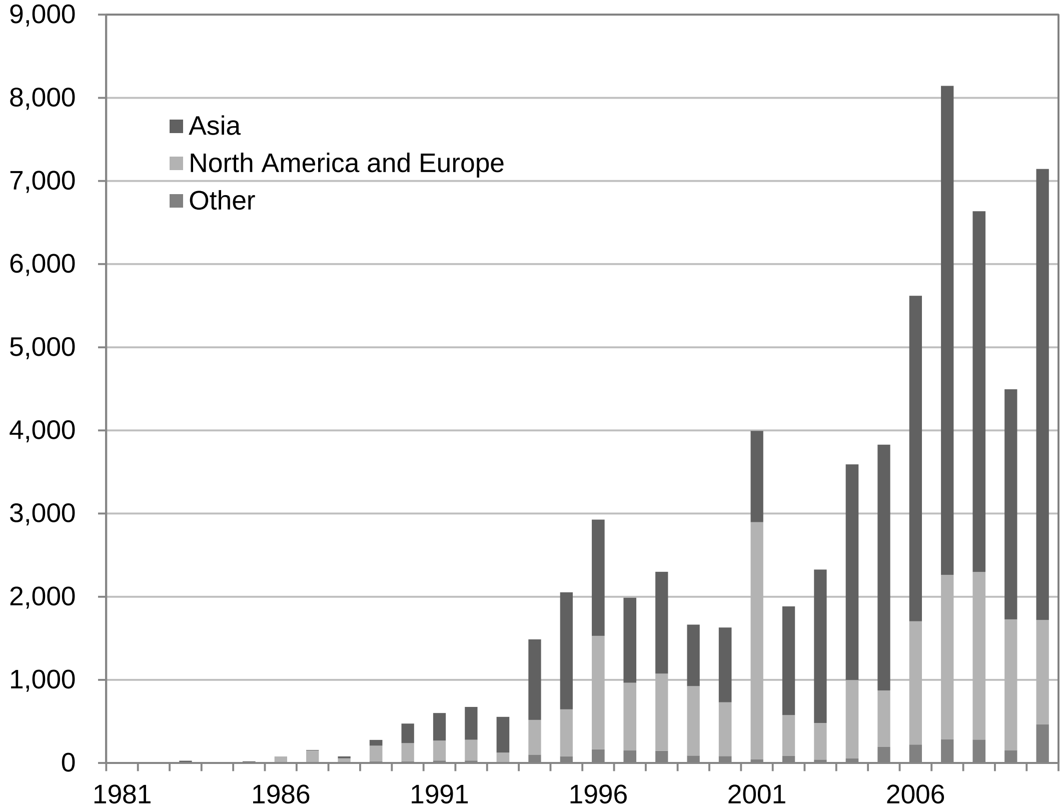
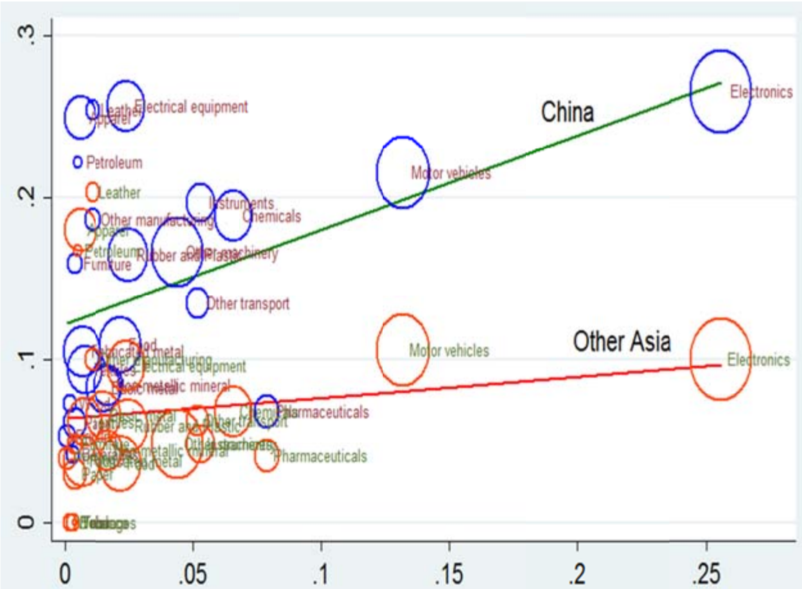
Figure 1. Outward FDI of Korean Firms in Manufacturing Sectors, 1981-2010
(Unit: in millions USD)



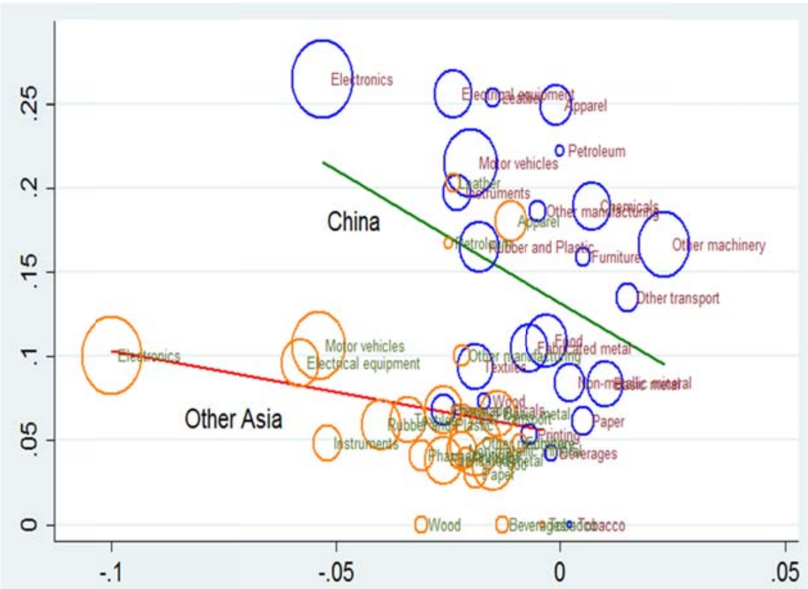
Notes: The data is obtained from webpage of the Export-Import Bank of Korea. The bar in each year indicates annual amount of FDI outflows of Korean firms in manufacturing sectors. Asia is all Asia countries in Asian regions except for Middle East Asian countries, which are included in the category of Other. Other includes Middle East Asia, Oceania, and Africa.

Figure 2. Cross-border Backward Vertical Integration and R&D intensity

Panel A. CBVI and R&D intensity in the producing-industry



Panel B. CBVI and R&D intensity in the supplying-industry



Notes: The vertical axis is the two measures of cross-border backward vertical integration for China (in blue) from column (3) divided by (1) in Table 1 and Other Asia (in red) from column (4) divided by (1) in Table 1. The horizontal axis of Panel A is R&D intensity of the producing industry from column (2) in Table 2 that is the same for both China and Other Asia. The horizontal axis of Panel B is R&D intensity of supplying industry for China from column (4) minus (3) in Table 2 and for Other Asia from column (5) minus (3)fin Table 2. The size of bubble represents the total number of parent firms in an industry. Each panel has two predicted lines from separate linear regressions for China and Other Asia samples.

Table 1. Backward Vertically Integrated Foreign Affiliates of Korean Manufacturing Firms

KSIC Code	Industry name	(1) Number of firms	(2) No. of VI foreign affiliates	(3) No. of VI FA in China	(4) No. of VI FA in Other Asia	(2)/(1)	(3)/(1)	(4)/(1)
10	Food	414	60	45	15	0.145	0.109	0.036
11	Beverages	48	2	2	0	0.042	0.042	0.000
12	Tobacco	6	0	0	0	0.000	0.000	0.000
13	Textiles	308	48	29	19	0.156	0.094	0.062
14	Apparel	245	105	61	44	0.429	0.249	0.180
15	Leather	59	27	15	12	0.458	0.254	0.203
16	Wood	41	3	3	0	0.073	0.073	0.000
17	Paper	132	12	8	4	0.091	0.061	0.030
18	Printing	76	7	4	3	0.092	0.053	0.039
19	Petroleum	18	7	4	3	0.389	0.222	0.167
20	Chemicals	338	87	64	23	0.257	0.189	0.068
21	Pharmaceuticals	148	16	10	6	0.108	0.068	0.041
22	Rubber and Plastic	393	88	65	23	0.224	0.165	0.059
23	Non-metallic mineral	227	29	19	10	0.128	0.084	0.044
24	Basic metal	302	45	25	20	0.149	0.083	0.066
25	Fabricated metal	344	49	36	13	0.142	0.105	0.038
26	Electronics	922	336	244	92	0.364	0.265	0.100
27	Instruments	188	46	37	9	0.245	0.197	0.048
28	Electrical equipment	344	121	88	33	0.352	0.256	0.096
29	Other machinery	620	133	103	30	0.215	0.166	0.048
30	Motor vehicles	670	215	144	71	0.321	0.215	0.106
31	Other transport	126	25	17	8	0.198	0.135	0.063
32	Furniture	63	13	10	3	0.206	0.159	0.048
33	Other manufacturing	70	20	13	7	0.286	0.186	0.100
	Total or Average	6,102	1,494	1,046	448	0.211	0.143	0.068

Note: Since we identify the backward vertical integration in Asia only, the number in column (2) is the sum of those in China in column (3) and Other Asia in column (4).

Table 2. R&D Intensity in Producing and Supplying Manufacturing Industries

KSIC Code	Industry name	(1) Number of firms	(2) R&D intensity in producing industry	(3) R&D intensity in supplying industry: Domestic	(4) China	(5) Other Asia	(4) – (3)	(5) – (3)
10	Food	414	0.022	0.017	0.014	0.002	-0.003	-0.015
11	Beverages	48	0.003	0.015	0.013	0.002	-0.002	-0.013
12	Tobacco	6	0.004	0.005	0.007	0.001	0.002	-0.004
13	Textiles	308	0.008	0.037	0.018	0.003	-0.019	-0.034
14	Apparel	245	0.006	0.013	0.012	0.002	-0.001	-0.011
15	Leather	59	0.011	0.027	0.012	0.003	-0.015	-0.024
16	Wood	41	0.002	0.034	0.017	0.003	-0.017	-0.031
17	Paper	132	0.004	0.025	0.030	0.006	0.005	-0.019
18	Printing	76	0.001	0.024	0.017	0.003	-0.007	-0.021
19	Petroleum	18	0.005	0.031	0.031	0.006	0.000	-0.025
20	Chemicals	338	0.066	0.035	0.042	0.009	0.007	-0.026
21	Pharmaceuticals	148	0.079	0.041	0.015	0.010	-0.026	-0.031
22	Rubber and Plastic	393	0.025	0.045	0.027	0.005	-0.018	-0.04
23	Non-metallic mineral	227	0.017	0.029	0.031	0.007	0.002	-0.022
24	Basic metal	302	0.015	0.015	0.025	0.001	0.010	-0.014
25	Fabricated metal	344	0.007	0.029	0.022	0.003	-0.007	-0.026
26	Electronics	922	0.256	0.115	0.062	0.015	-0.053	-0.100
27	Instruments	188	0.053	0.064	0.041	0.012	-0.023	-0.052
28	Electrical equipment	344	0.024	0.066	0.042	0.008	-0.024	-0.058
29	Other machinery	620	0.044	0.023	0.046	0.004	0.023	-0.019
30	Motor vehicles	670	0.132	0.058	0.038	0.004	-0.020	-0.054
31	Other transport	126	0.052	0.033	0.048	0.011	0.015	-0.022
32	Furniture	63	0.004	0.010	0.015	0.001	0.005	-0.009
33	Other manufacturing	70	0.011	0.025	0.020	0.003	-0.005	-0.022
	Total or Average	6,102	0.035	0.034	0.027	0.005	-0.007	-0.029

Notes: R&D intensity in the producing industry in column (2) is the domestic R&D intensity for each producing industry. Columns (3), (4) and (5) show R&D intensity in the domestic, Chinese, and other Asian supplying industries, respectively.

Table 3. Descriptive Statistics

	Mean	Median	Standard deviation	Q1	Q3
VI(*ijk*)	0.010	0.000	0.099	0.000	0.000
Firm size	8.757	8.661	1.503	7.964	9.552
Firm TFP	2.544	2.565	0.671	2.226	2.905
Share of costs (*jk*)	0.079	0.027	0.126	0.015	0.067
R&D intensity in producing industry (*j*)	0.077	0.044	0.086	0.017	0.132
R&D intensity in supplying industry (*k*)	0.028	0.015	0.041	0.006	0.032

Notes: A firm-level measure of cross-border backward vertical integration, VI(*ijk*), is a dummy variable that takes 1 if a Korean manufacturing firm in producing industry owns a foreign affiliate (a manufacturing firm located in Asia (excluding Japan, Singapore, and Taiwan) at any time during the 2006–2010 period) in supplying industry; 0 otherwise. An industry *k* is defined as supplying industry for producing industry *j* if the share of intermediate inputs from industry *k* to industry *j* is higher than 5% of total intermediate input of producing industry *j*. Firm size is measured by tangible fixed asset in 2005 millions KRW. Firm size and TFP are logarithmic values. The share of cost is defined as intermediate inputs from supplying industry *k* to producing industry *j* divided by total costs of producing industry *j* that is calculated from 2005 Input-Output Table in Korea. R&D intensity is the ratio of R&D expenditures to value-added. The sample includes 145,827 observations on 5,918 firms.

Table 4. Main Results

	(1) All	(2) China	(3) Other Asia	(4) Other Asia (Medium R&D)	(5) Other Asia (Low R&D)
R&D intensity in producing industry (*j*)	-0.051***	-0.072***	-0.030***	-0.017***	-0.016***
	(0.010)	(0.012)	(0.007)	(0.004)	(0.004)
R&D intensity in supplying industry (*k*)	0.049**	0.097***	0.049***	0.028***	0.029***
	(0.021)	(0.023)	(0.013)	(0.009)	(0.007)
R&D intensity in producing industry (*j*)	1.226***	1.979***	0.791***	0.579***	0.312***
x share of costs (*jk*)	(0.164)	(0.273)	(0.161)	(0.141)	(0.039)
R&D intensity in supplying industry (*k*)	-1.407***	-2.340***	-1.056***	-0.661***	-0.527***
x share of costs (*jk*)	(0.214)	(0.347)	(0.213)	(0.164)	(0.073)
Share of costs (*jk*)	0.110***	0.134***	0.052***	0.016***	0.041***
	(0.022)	(0.027)	(0.008)	(0.004)	(0.006)
ln Firm size (*i*)	0.003***	0.003***	0.002***	0.001***	0.001***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
ln Firm TFP (*i*)	0.024**	0.018**	0.017**	0.006**	0.013**
	(0.010)	(0.009)	(0.007)	(0.003)	(0.005)
China (*c*)	0.018***	0.016***			
	(0.004)	(0.004)			
Other Asia (*c*)	0.004		0.006***		
	(0.003)		(0.001)		
Other Asia (medium R&D) (*c*)				0.002***	
				(0.000)	
Other Asia (low R&D) (*c*)					0.005***
					(0.001)
R-squared	0.066	0.089	0.040	0.026	0.021
Observations	145,827	97,218	97,218	97,218	97,218
R&D intensity effect in producing industry	0.046***	0.085***	0.032***	0.028***	0.009*
R&D intensity effect in supplying industry	-0.063*	-0.088**	-0.034**	-0.024**	-0.012**

Notes: Dependent variable is a dummy variable of backward vertical integration, for whether a Korean manufacturing firm (in a producing industry) owns a foreign affiliate in a supplying industry in destination countries for any year in 2006–2010. Using 2005 input-output table, a manufacturing industry is defined as the supplying industry if more than 5% of total cost (labor, capital, and intermediate inputs) of a producing industry is purchased from that industry. The sample includes 5,918 Korean manufacturing firms with 50 employees or more. In columns (2) and (3), the sample includes 145,827 firm-industry-country observations for two destination countries (China or other Asian countries). In columns (2)–(5), the sample includes 97,218 firm-industry-country observations for a single foreign destination country. Destination country is China for column (2); other Asian countries for column (3); countries with medium R&D intensity (0.5–1%) among other Asian countries for column (4); and countries with low R&D intensity (0–0.5%) among other Asian countries for column (5). Other Asian countries consist of countries with medium R&D intensity (India, Malaysia, Hong Kong, Pakistan) and countries with low R&D intensity (Laos, Vietnam, Cambodia, Indonesia, Philippines, Nepal, Sri Lanka, Thailand). Numbers in parentheses are clustered standard errors at the level of 203 producing-supplying-industry pairs with 1% or higher intermediate input share. R&D intensity effects in the last two rows are evaluated at a sample mean of cost share (0.079).
* Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level

Table 5. Robustness: Instrument Variable Estimation

Panel A. IV: R&D intensity in Japan

	(1) All	(2) China	(3) Other Asia
R&D intensity in producing industry (*j*)	-0.039***	-0.058***	-0.023***
	(0.012)	(0.015)	(0.007)
R&D intensity in supplying industry (*k*)	0.047**	0.097***	0.048***
	(0.022)	(0.023)	(0.011)
R&D intensity in producing industry (*j*)	1.161***	1.993***	0.642***
x share of costs (*jk*)	(0.206)	(0.313)	(0.076)
R&D intensity in supplying industry (*k*)	-1.370***	-2.381***	-0.942***
x share of costs (*jk*)	(0.246)	(0.325)	(0.096)
R-squared	0.066	0.089	0.039
Observations	145,827	97,218	97,218
R&D intensity effect in producing industry	0.053***	0.100***	0.028***
R&D intensity effect in supplying industry	-0.061*	-0.091**	-0.027***
Endogeneity test (F-statistics)	0.79	0.90	1.73
Weak IV test (R&D intensity in producing industry)	32.08***	31.73***	32.03***
Weak IV test (R&D intensity in producing industry x share of costs)	10.87***	10.17***	10.73***

Panel B. IV: R&D intensity in the U.S.

	(1) All	(2) China	(3) Other Asia
R&D intensity in producing industry (*j*)	-0.073***	-0.099***	-0.042***
	(0.016)	(0.020)	(0.011)
R&D intensity in supplying industry (*k*)	0.054**	0.107***	0.051***
	(0.024)	(0.026)	(0.014)
R&D intensity in producing industry (*j*)	1.504***	2.353***	0.940***
x share of costs (*jk*)	(0.287)	(0.458)	(0.259)
R&D intensity in supplying industry (*k*)	-1.611***	-2.639***	-1.160***
x share of costs (*jk*)	(0.226)	(0.445)	(0.291)
R-squared	0.066	0.088	0.039
Observations	145,827	97,218	97,218
R&D intensity effect in producing industry	0.046**	0.087***	0.032**
R&D intensity effect in supplying industry	-0.074**	-0.101**	-0.040**
Endogeneity test (F-statistics)	9.95***	7.95***	6.94***
Weak IV test (R&D intensity in producing industry)	29.36***	28.15***	29.24***
Weak IV test (R&D intensity in producing industry x share of costs)	14.23***	13.66***	14.63***

Notes: Dependent variable is a dummy variable of backward vertical integration. All columns include logarithm of both firm size and firm TFP, and country dummies. Both R&D intensity in producing industry and its interaction with share of costs are instrumented with R&D intensity in Japan for Panel A, R&D intensity in the U.S. for Panel B, and their interactions with share of costs. To allow clustered standard errors, regression-based endogeneity test is performed. Weak IV tests report *F*-statistics in the first-stage regressions. Numbers in parentheses are clustered standard errors at the level of 203 producing-supplying-industry pairs with 1% or higher intermediate input share. R&D intensity effects in the last two rows are evaluated at a sample mean of cost share.
* Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level

Table 6. Robustness: Large versus Small and Medium-sized Firms

Panel A. Large firms

	(1) All	(2) China	(3) Other Asia
R&D intensity in producing industry (*j*)	-0.087***	-0.130***	-0.053***
	(0.023)	(0.030)	(0.019)
R&D intensity in supplying industry (*k*)	0.094*	0.159***	0.128***
	(0.050)	(0.046)	(0.035)
R&D intensity in producing industry (*j*)	2.030***	3.447***	1.515***
x share of costs (*jk*)	(0.478)	(0.698)	(0.555)
R&D intensity in supplying industry (*k*)	-3.069***	-4.569***	-2.545***
x share of costs (*jk*)	(0.387)	(0.693)	(0.772)
R-squared	0.154	0.190	0.107
Observations	21,657	14,438	14,438
R&D intensity effect in producing industry	0.074**	0.142***	0.067**
R&D intensity effect in supplying industry	-0.149***	-0.202***	-0.073*

Panel B. Small and medium-sized firms

	(1) All	(2) China	(3) Other Asia
R&D intensity in producing industry (*j*)	-0.039***	-0.056***	-0.022***
	(0.007)	(0.009)	(0.004)
R&D intensity in supplying industry (*k*)	0.036**	0.080***	0.032***
	(0.018)	(0.019)	(0.007)
R&D intensity in producing industry (*j*)	0.948***	1.570***	0.563***
x share of costs (*jk*)	(0.141)	(0.236)	(0.061)
R&D intensity in supplying industry (*k*)	-1.020***	-1.832***	-0.711***
x share of costs (*jk*)	(0.252)	(0.346)	(0.084)
R-squared	0.047	0.066	0.024
Observations	124,170	82,780	82,780
R&D intensity effect in producing industry	0.036***	0.068***	0.023***
R&D intensity effect in supplying industry	-0.044	-0.064*	-0.024***

Notes: Dependent variable is a dummy variable of backward vertical integration. The sample in Panel A includes 863 firms with 250 employees or more (large firms), and the sample in Panel B includes 5,055 firms with fewer than 250 employees (small and medium sized firms). All columns include logarithm of both firm size and firm TFP, and country dummies. Numbers in parentheses are clustered standard errors at the level of 203 producing-supplying-industry pairs with 1% or higher intermediate input share. R&D intensity effects in the last two rows are evaluated at a sample mean of cost share.

* Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level

Table 7. Robustness: All Industry-pairs with Positive Input Flows

	(1) All	(2) China	(3) Other Asia
R&D intensity in producing industry (*j*)	-0.023***	-0.033***	-0.014***
	(0.007)	(0.009)	(0.005)
R&D intensity in supplying industry (*k*)	0.024**	0.042***	0.022***
	(0.011)	(0.013)	(0.007)
R&D intensity in producing industry (*j*)	1.500***	2.433***	0.990***
x share of costs (*jk*)	(0.238)	(0.375)	(0.244)
R&D intensity in supplying industry (*k*)	-1.845***	-2.927***	-1.380***
x share of costs (*jk*)	(0.338)	(0.516)	(0.324)
R-squared	0.093	0.122	0.056
Observations	216,204	144,136	144,136
R&D intensity effect in producing industry	0.023***	0.042***	0.017**
R&D intensity effect in supplying industry	-0.033*	-0.048**	-0.020**

Notes: Dependent variable is a dummy variable of backward vertical integration. Using 2005 input-output table, a manufacturing industry is defined as the supplying industry if more than 5% of total cost (labor, capital, and intermediate inputs) of a producing industry is purchased from that industry. The sample consists of all industry-pair with positive flows (513 pairs) for 5,918 Korean manufacturing firms. In column (1), the sample includes 216,204 firm-industry-country observations for two destination countries (China or other Asian countries). In columns (2)–(3), the sample includes 144,136 firm-industry observations for a single destination country. Destination country is China for column (2); other Asian countries for column (3). All columns include logarithm of both firm size and firm TFP, and country dummies. Numbers in parentheses are clustered standard errors at the level of 513 producing-supplying-industry pairs with positive intermediate input flows. R&D intensity effects in the last two rows are evaluated at a sample mean of cost share.
* Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level

Table 8. Robustness: Excluding Firms Owned by Another Parent Firms

Panel A. Excluding firms owned by foreign parent firms

	(1) All	(2) China	(3) Other Asia
R&D intensity in producing industry (*j*)	-0.052***	-0.074***	-0.030***
	(0.010)	(0.012)	(0.006)
R&D intensity in supplying industry (*k*)	0.049**	0.099***	0.050***
	(0.022)	(0.023)	(0.012)
R&D intensity in producing industry (*j*)	1.270***	2.059***	0.797***
x share of costs (*jk*)	(0.154)	(0.259)	(0.139)
R&D intensity in supplying industry (*k*)	-1.462***	-2.431***	-1.068***
x share of costs (*jk*)	(0.213)	(0.339)	(0.188)
R-squared	0.069	0.093	0.041
Observations	135,336	90,224	90,224
R&D intensity effect in producing industry	0.048***	0.089***	0.033***
R&D intensity effect in supplying industry	-0.067*	-0.093**	-0.034***

Panel B. Excluding firms owned by either foreign or domestic parent firms

	(1) All	(2) China	(3) Other Asia
R&D intensity in producing industry (*j*)	-0.052***	-0.073***	-0.030***
	(0.010)	(0.012)	(0.007)
R&D intensity in supplying industry (*k*)	0.046**	0.096***	0.047***
	(0.021)	(0.023)	(0.012)
R&D intensity in producing industry (*j*)	1.237***	1.987***	0.791***
x share of costs (*jk*)	(0.166)	(0.274)	(0.166)
R&D intensity in supplying industry (*k*)	-1.392***	-2.329***	-1.037***
x share of costs (*jk*)	(0.207)	(0.337)	(0.216)
R-squared	0.066	0.089	0.039
Observations	129,420	86,280	86,280
R&D intensity effect in producing industry	0.046***	0.084***	0.032***
R&D intensity effect in supplying industry	-0.064*	-0.088**	-0.035***

Notes: Dependent variable is a dummy variable of backward vertical integration. Among 5,918 Korean manufacturing firms, the sample in Panel A excludes firms owned by foreign parent firms (431 firms) and the sample in Panel B excludes firm owned by either domestic or foreign parent firms (1,091 firms). In column (1), the sample includes 135,336 (Panel A) and 129,420 (Panel B) firm-industry-country observations for two destination countries (China or other Asian countries). In columns (2)-(3), the sample includes 90,224 (Panel A) and 86,280 (Panel B) firm-industry-country observations for a single foreign destination country. Destination country is China for column (2); other Asian countries for column (3). All columns include logarithm of both firm size and firm TFP, and country dummies. Numbers in parentheses are clustered standard errors at the level of 203 producing-supplying-industry pairs with 1% or higher intermediate input share. R&D intensity effects in the last two rows are evaluated at a sample mean of cost share.
* Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level

Appendix

A. The Derivation of Empirical Hypothesis

We extend the model of Acemoglu *et al*. (2010) into "cross-border" vertical integration by multinational firms in international economics. In particular, we focus on a multinational firm's decision on the organizational form of their input procurement: cross-border backward vertical integration vs. cross-border outsourcing. Compared to domestic firms that Acemoglu *et al*. (2010) consider, the literature on international economics (e.g., Yeaple, 2006) suggest that cross-bordering is associated with additional fixed costs but smaller variable costs regardless of whether it is backward vertical integration (FDI) or outsourcing. In addition, cross-border vertical integration requires another type of fixed costs such as setup costs. With these costs, the literature shows that only the most productive firms can engage in cross-border vertical integration. Thus, when comparing cross-border backward vertical integration and cross-border outsourcing, we need to introduce fixed costs for the former. This is the difference from Acemoglu *et al*. (2010) where no fixed costs are introduced in either vertical integration or outsourcing. Other than this, the model is the same as Acemoglu *et al*. (2010), so here we just briefly lay out its skeleton as follows (see Acemoglu *et al*. (2010) for the details).

Building on the PRT by GHM, the model considers the relationship between a producer (a multinational headquarter) and a supplier (a foreign firm) who delivers a customized input to the producer. They cannot make an ex-ante contract for this trade, but they engage in an efficient ex-post negotiation. The producer can procure the input through backward vertical integration or outsourcing. The production of the relationship is:

$$F(x_S, e_P, e_S) = \varphi x_S(pe_P + se_S) + (1-\varphi)pe_P,$$

where $\varphi \in (0,1)$ is the share of the producer's inputs accounted for by the supplier; $x_S \in \{0,1\}$ is the indicator whether the supplier provides a relationship-specific input; e_P and e_S are relationship-specific investment made by the producer and the supplier, respectively; p and s are the relative importance of the producer's and the supplier's investment, respectively. The cost of investment to the producer and the supplier are:

$$\Gamma_P(e_P) = \frac{1}{2}e_P^2 \ \text{ and } \ \Gamma_S(e_S) = \frac{1}{2}\varphi e_S^2.$$

In addition to this cost, the producer incurs a fixed cost of g if he procures the input through cross-border vertical integration. When ex-post negotiation breaks down, the producer and the supplier receive outside options, which depend on whether trade occurs under backward vertical integration or outsourcing. In the case of backward vertical integration, they are:

$$O_P^I(e_P, e_S) = F(x_S = 1, e_P, (1-\lambda)e_S) = \varphi x_S(pe_P + s(1-\lambda)e_S) + (1-\varphi)pe_P,$$

$$O_S^I(e_P, e_S) = 0,$$

where $\lambda \in [0,1)$ captures the loss of the supplier's investment due to the lack of his cooperation after breakup. In the case of outsourcing, the producer's and the supplier's outside options are:

$$O_P^O(e_P, e_S) = F(x_S = 0, e_P, e_S) = (1-\varphi)pe_P,$$

$$O_S^O(e_P, e_S) = \theta\varphi s e_S,$$

where $\theta \in [0,1)$ is an inverse measure of the supplier's loss when selling the input outside the relationship. The producer and the supplier engage in ex-post negotiation with symmetric Nash bargaining, so the output accruing to party $i \in \{P, S\}$ under organizational form $z \in \{I, O\}$ is:

$$y_i^z(e_P, e_S) = O_i^z(e_P, e_S) + \frac{1}{2}[F(x_S = 1, e_P, e_S) - O_P^z(e_P, e_S) - O_S^z(e_P, e_S)].$$

Each party simultaneously chooses its investment to maximize its payoff, which is the output accruing to it less the cost of investment. The solution to investment varies with organizational form in equilibrium. In the case of backward vertical integration, the equilibrium investment is:

$$e_P^I = p \ \text{ and } \ e_S^I = \frac{1}{2}\lambda s.$$

In the case of outsourcing, the equilibrium investment is:

$$e_P^O = \left(1 - \frac{1}{2}\varphi\right)p \ \text{ and } \ e_S^O = \frac{1}{2}(1+\theta)s.$$

With this equilibrium investment, the social surplus, which is calculated as the total production of the relationship minus investment and fixed costs, under cross-border backward vertical integration is:

$$S^I = \frac{1}{2}p^2 + \frac{1}{2}\varphi\lambda\left(1 - \frac{1}{4}\lambda\right)s^2 - g.$$

The social surplus under cross-border outsourcing is:

$$S^O = \left[1 - \frac{1}{2}\left(1 - \frac{1}{2}\varphi\right)\right]\left(1 - \frac{1}{2}\varphi\right)p^2 + \frac{1}{2}\varphi(1+\theta)\left[1 - \frac{1}{4}(1+\theta)\right]s^2.$$

Unlike cross-border outsourcing, the social surplus under cross-border backward vertical integration can be negative, which leads the following proposition.

PROPOSITION 1: For $g \in \left(\frac{1}{2}p^2, \frac{1}{2}p^2 + \frac{1}{2}\varphi\lambda\left(1 - \frac{1}{4}\lambda\right)s^2\right)$, there exists $\bar{\varphi} \in (0,1)$ such that cross-border backward vertical integration is always dominated (i.e., $S^I < 0$) for $\varphi < \bar{\varphi}$.

PROOF: Define $\bar{\varphi}$ such that $\frac{1}{2}p^2 + \frac{1}{2}\bar{\varphi}\lambda\left(1 - \frac{1}{4}\lambda\right)s^2 - g \equiv 0$. Given that $g \in \left(\frac{1}{2}p^2, \frac{1}{2}p^2 + \frac{1}{2}\varphi\lambda\left(1 - \frac{1}{4}\lambda\right)s^2\right)$, it must be the case that $\bar{\varphi} \in (0,1)$. As S^I increases with φ, $S^I < 0$ if and only if $\varphi < \bar{\varphi}$. ■

The proposition indicates that cross-border backward vertical integration is not a relevant choice of organization if the input share accounted for by the supplier is small, provided that it involves meaningful fixed costs. That is, if the supplier's input is not important as his share is small, the producer does not consider cross-border backward vertical integration to procure the input as the benefit of acquiring a small-share supplier is not enough to cover the fixed cost.

In contrast, if the input share accounted for by the supplier is large, cross-border backward vertical integration can be a relevant option, and the optimal organizational form maximizes the social surplus, generating the following results of the PRT of the firm.

PROPOSITION 2: Suppose that $\varphi > \bar{\varphi}$. For any given s, there exists $\bar{p}$ such that cross-border backward vertical integration is optimal (i.e., $S^I > S^O$) if and only if $p > \bar{p}$. Similarly, for any given p, there also exists $\bar{s}$ such that that cross-border backward vertical integration is optimal if and only if $s < \bar{s}$.

PROOF: Define $\Delta(p,s) \equiv S^I - S^O = \frac{1}{8}\varphi^2p^2 - \frac{1}{8}\varphi(1+\theta-\lambda)(3-\theta-\lambda)s^2 - g$. Define $\bar{p}$ such that $\Delta(\bar{p},s) \equiv 0$ and $\bar{s}$ such that $\Delta(p,\bar{s}) \equiv 0$. As $S^I > 0$ (because $\varphi > \bar{\varphi}$), $S^O > 0$, and $\Delta(p,s)$

is monotone with respect to p and s, it must be the case that $\bar{p} > 0$ and $\bar{s} > 0$. Since $\Delta(p, s)$ increases with p, $\Delta(p, s) > 0$ if and only if $p > \bar{p}$. Since $\Delta(p, s)$ decreases with s, $\Delta(p, s) > 0$ if and only if $s < \bar{s}$. ■

The proposition shows that cross-border backward vertical integration can be a relevant option when the input share accounted for by the supplier is large. In this case, cross-border backward vertical integration is optimal if the producer's investment becomes more important or if the supplier's investment becomes less important. These results are the straightforward replication of the PRT of the firm by GHM. However, a noticeable modification is that in an international context where "cross-border" integration is considered, the implication of the PRT is valid only when the input share accounted for by the supplier is large.

Financial Market Reaction and Prediction in Patent Litigations: A case study for South Korea

Junbyoung Oh

Financial Market Reaction and Prediction in Patent Litigations

- A case study for South Korea

Preliminary

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1. Introduction

- Increasing Number and Importance of Patent Litigation in Korea
- **Q: Effect of Litigation ?**
  Cutler and Summers(1988): Texaco-Pennzoil legal battle
  Lerner(1995) : Biotechnology firm, (-)
  Raghu et al.(2008) : IT industry, Plaintiff(+) Defendant(-)
  Marco(2006) : market reaction to patent litigation resolutions, (+)
  Bessen and Meurer(2007) : Plaintiff(-) Defendant(-)
- **Q: Is Stock Market Response consistent with the outcome of Litigation?**
  (Another important issue: Substantial Wealth Leakage during Litigation)

  Blose et al.(1996)
  Maloney and Mulherin(2003)
  → Price Discovery "the Space Shuttle Challenger"

  Griffin and Tversky(1992)

2

2. Korea's Patent Litigation System

1st Instance		2nd Instance		3rd Instance
Intellectual Property Tribunal	→	Patent Court	→	Supreme Court

(Patent Office)

Ex Parte Cases

Inter Parte Cases

- ***Invalidation Trial*** *of a Patent*
- ***Infringement Trial****(Trial to confirm the scope of a patent right)*
  - ***Positive Trial*** *to confirm the scope of a patent*
  (Patentee argues "target invention belongs to the scope of the patent)
  - ***Negative Trial*** *to confirm the scope of a patent*
  (Patentee argues "target invention does not belongs to the scope of the patent)

(Common Court)
Trial for Infringement and Damage Award

3. Data and Methodology(1)

3.1 Data

- Patent Litigation Data of South Korea(1987-2011)
- Stock Market Information
  -Korean Securities Dealers Automated Quotations(KOSDAQ)
  -Korea Composite Stock Price Index(KOSPI)
- Firm Information
  KIS-VALUE Data Base

Table 1. Summary Statistics for Litigated Firms

Litigant type	Sales (KRW)	Labor	Market share (%)	Firm number
Defendants	5.153e+12	9481	20.65	321
	(5.360e+11)	(903)	(1.43)	
Plaintiffs	2.878e+12	6850	15.62	30
	(1.190e+12)	(2560)	(4.58)	

3. Data and Methodology(2)

3.2 Methodology

- Event Study (Schwert, 1981; Brown and Warner, 1985)

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \quad \textbf{(1)}$$

R_{it} : the return to stock of firm i at day t
R_{mt} : the return to stock of market at day t

- The **abnormal return** is measured as the residual between the realized stock return and the expected stock return $\widehat{R_{it}}$ Fitted using the model.
- Set the day of litigation as day 0 and use day -270 to day -15 to calculate the expected return for each stock.
- The **cumulative abnormal returns(CARs)** over several days are calculated as the unweighted sum of the abnormal returns over those days.

4. Empirical Results

4.1 Market Reactions to Litigation (1)

Table 2. CARs for different types of litigants (values in %)

	$CAR_{day\ 0}$	$CAR_{day\ -1\ to\ 0}$	$CAR_{day\ -1\ to\ 2}$	$CAR_{day\ -1\ to\ 6}$	N
All litigants	-0.24*	-0.55**	-0.66**	-1.36***	351
	(0.14)	(0.21)	(0.33)	(0.45)	
Defendants	-0.28*	-0.52**	-0.64*	-1.49***	321
	(0.14)	(0.23)	(0.35)	(0.44)	
Defendants	-0.34*	-0.70***	-1.07**	-2.18***	241
(invalidation)	(0.18)	(0.26)	(0.42)	(0.48)	
Defendants	-0.12	0.02	0.68	0.62	80
(negative trials)	(0.22)	(0.43)	(0.64)	(0.96)	
Plaintiffs	0.19	-0.90	-0.95	-0.03	30
(positive trials)	(0.48)	(0.56)	(0.92)	(2.41)	

Standard errors are reported in parentheses.
We test whether the mean CARs are different from 0. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.1 Market Reactions to Litigation(2)

Table 3. CARs for "large" and "small" defendants (units in %)

	$CAR_{day\ 0}$	$CAR_{day\ -1\ to\ 0}$	$CAR_{day\ -1\ to\ 2}$	$CAR_{day\ -1\ to\ 6}$	N
No. of employees	-0.633***	-0.811**	-1.19**	-1.72**	160
(< median)	(0.232)	(0.327)	(0.519)	(0.698)	
No. of employees	0.0647	-0.224	-0.0903	-1.26**	161
(> median)	(0.169)	(0.313)	(0.473)	(0.528)	
Sales	-0.492**	-0.523*	-0.816	-1.10*	160
(< median)	(0.227)	(0.315)	(0.494)	(0.666)	
Sales	-0.0760	-0.510	-0.459	-1.87***	161
(> median)	(0.178)	(0.327)	(0.503)	(0.567)	
Market share	-0.593**	-0.785**	-1.10**	-1.59**	160
(< median)	(0.234)	(0.340)	(0.543)	(0.701)	
Market share	0.0241	-0.250	-0.177	-1.39***	161
(> median)	(0.167)	(0.300)	(0.448)	(0.524)	

Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.1 Market Reactions to Litigation(3)

Table 4. CARs for all litigants
after controlling for firm characteristics

	$CAR_{day\ 0}$	$CAR_{day\ -1\ to\ 0}$	$CAR_{day\ -1\ to\ 2}$	$CAR_{day\ -1\ to\ 6}$
CARs (%)	-0.394**	-0.681**	-0.991**	-1.67***
	(0.194)	(0.277)	(0.436)	(0.624)
sales	6.19e-16**	5.57e-16	1.10e-16	-1.32e-16
	(2.98e-16)	(3.90e-16)	(5.27e-16)	(7.02e-16)
labor	-1.40e-7	-2.22e-7	-8.23e-08	2.42e-7
	(1.98e-7)	(2.56e-7)	(3.48e-7)	(4.46e-7)
market _ share	-1.39e-5	2.78e-5	1.71e-4	6.47e-5
	(8.28e-5)	(1.44e-4)	(2.24e-4)	(2.61e-4)
N	349	349	349	349

Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.1 Market Reactions to Litigation(4)

Table 5. CARs for defendants
after controlling for firm characteristics

	$CAR_{day\ 0}$	$CAR_{day\ -1\ to\ 0}$	$CAR_{day\ -1\ to\ 2}$	$CAR_{day\ -1\ to\ 6}$
CARs (%)	-0.476**	-0.659**	-0.972**	-1.79***
	(0.203)	(0.298)	(0.468)	(0.600)
sales	7.80e-16***	7.69e-16**	2.07e-16	-3.03e-18
	(2.86e-16)	(3.55e-16)	(5.47e-16)	(7.43e-16)
labor	-2.31e-7	-3.30e-7	-5.22e-08	2.88e-7
	(2.00e-7)	(2.50e-7)	(3.60e-7)	(4.68e-7)
market_share	1.75e-6	2.53e-5	1.32e-4	1.26e-5
	(8.93e-5)	(1.55e-4)	(2.36e-4)	(2.68e-4)
N	320	320	320	320

Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.1 Market Reactions to Litigation(5)

Table 6. CARs for defendants in "patent invalidation" cases
after controlling for firm characteristics

	$CAR_{day\ 0}$	$CAR_{day\ -1\ to\ 0}$	$CAR_{day\ -1\ to\ 2}$	$CAR_{day\ -1\ to\ 6}$
CARs (%)	-0.461*	-0.829**	-1.36**	-2.42***
	(0.257)	(0.346)	(0.552)	(0.651)
sales	1.03e-15***	9.91e-16**	4.39e-16	7.67e-16
	(3.78e-16)	(4.77e-16)	(6.65e-16)	(9.64e-16)
labor	-2.77e-7	-3.07e-7	1.37e-7	2.96e-7
	(2.61e-7)	(3.19e-7)	(4.33e-7)	(6.17e-7)
market share_	-1.01e-4	-7.24e-5	-5.46e-5	-2.51e-4
	(1.08e-4)	(1.83e-4)	(2.82e-4)	(3.05e-4)
N	240	240	240	240

Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.2 The Predictive Power of Market Reactions to Litigation Outcomes (1)

Question 2 :

Is stock market response consistent with the final outcome of litigation?

4.2 The Predictive Power of Market Reactions to Litigation Outcomes (2)

Table 7. Litigation outcomes (criteria 1)

Litigant type	Rejected	Partly accepted partly rejected	Invalidation	Plaintiff withdrawal	Accepted	Subtotal
Defendants	win (90)	uncertain (13)	lost (4)	uncertain (71)	lost (143)	(321)
Plaintiffs	lost (15)	uncertain (1)	lost (0)	uncertain (5)	win (9)	(30)
Subtotal	(105)	(14)	(4)	(76)	(152)	(351)

The numbers in parenthesis give the number of cases for each cell.

$$outcome_i = \alpha + \beta \cdot CARs + \beta_1 \cdot Sales + \beta_2 \cdot Labor + \beta_3 \cdot Market\ \ share + D_{defendant} + \varepsilon_i$$

4.2 The Predictive Power of Market Reactions to Litigation Outcomes(3)

Table 8. Correlation between CARs and litigation outcomes (criteria 1)

	$CAR_{day\ 0}$	$CAR_{day\ -1\ to\ 0}$	$CAR_{day\ -1\ to\ 2}$	$CAR_{day\ -1\ to}$
CARs	-3.669**	-3.238***	-2.030***	-0.556
	(1.765)	(1.128)	(0.723)	(0.540)
defendants	-0.00832	0.0242	0.0189	0.00651
	(0.164)	(0.163)	(0.163)	(0.165)
sales	-4.78e-15	-5.32e-15	-6.89e-15	-7.15e-15
	(8.03e-15)	(7.93e-15)	(7.91e-15)	(7.99e-15)
market _ share	-5.16e-3	-5.03e-3	-4.77e-3	-5.08e-3
	(3.42e-3)	(3.41e-3)	(3.41e-3)	(3.44e-3)
labor	7.54e-6	7.36e-6	7.91e-6	8.20e-6
	(6.14e-6)	(6.10e-6)	(6.10e-6)	(6.16e-6)
_cons	-0.121	-0.158	-0.151	-0.129
	(0.159)	(0.158)	(0.158)	(0.160)
N	349	349	349	349

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

4.2 The Predictive Power of Market Reactions to Litigation Outcomes(4)

Table 9. Correlation between CARs and litigation outcomes for "large" and "small" firms

	$CAR_{day\ 0}$	$CAR_{day\ -1\ to\ 0}$	$CAR_{day\ -1\ to\ 2}$	$CAR_{day\ -1\ to\ 6}$	*N*
No. of employees	-4.549***	-5.016***	-2.908***	-0.503	173
(< median)	(2.087)	(1.488)	(1.102)	(0.740)	
No. of employees	-1.300	-1.548	-1.101	-0.600	176
(> median)	(2.671)	(1.590)	(1.023)	(0.951)	
Sales	-4.303**	-5.179***	-2.829**	-0.675	175
(< median)	(2.120)	(1.543)	(1.137)	(0.750)	
Sales	-2.174	-1.854	-1.381	-0.424	174
(> median)	(2.664)	(1.553)	(0.992)	(0.923)	
Market share	-3.590*	-4.407***	-2.028**	-0.176**	176
(< median)	(2.002)	(1.267)	(0.913)	(0.668)	
Market share	-3.289	-1.719	-1.953	-1.407	173
(> median)	(3.082)	(1.891)	(1.244)	(1.046)	

Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.2 The Predictive Power of Market Reactions to Litigation Outcomes(5)

- **Counterintuitive Results?**

The regression results suggest a negative correlation between the market reaction during the time of the announcement of the litigation and the final legal outcomes.

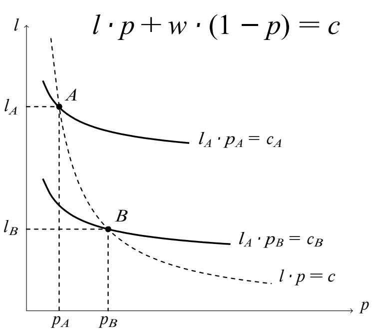
- The firms that suffer more from the market reaction end up more likely to win the litigation.

4.2 The Predictive Power of Market Reactions to Litigation Outcomes(6)

An explanation:
Psychological evidence of conservatism and representativeness heuristics
Kahneman and Tversky(1979), Griffin and Tversky(`992), Glaeser(2004)

Figure 1. Equal lines for loss and probability

- W=0
- Put more weight on the loss than the probability, the market reaction for firm A is greater than for firm B:
(Small firms > Large firms)
- But, firms go to court based upon $l*P$, firm A is less likely to lose the case compared to firm B.
- We observe **negative correlation** b/w market reaction and legal outcomes



4.3 Robustness Checks(1)

Table 10. Litigation outcomes (criteria 2)

Litigant type	Rejected	Partly accepted partly rejected	Invalidation	Plaintiff withdrawal	Accepted	Subtotal
Defendants	win (90)	win (13)	lost (4)	win (71)	lost (143)	(321)
Plaintiffs	lost (15)	lost (1)	lost (0)	lost (5)	win (9)	(30)
Subtotal	(105)	(14)	(4)	(76)	(152)	(351)

The numbers in parenthesis give the number of cases for each cell.

4.3 Robustness Checks(2)

Table 11. Correlation between CARs and litigation outcomes (criteria 2)

	day 0	day -1 to 0	day -1 to 2	day -1 to 6
CARs	-2.253**	-1.938***	-1.154***	-0.257
	(0.916)	(0.614)	(0.402)	(0.310)
defendants	0.226**	0.246***	0.243***	0.236**
	(0.0911)	(0.0909)	(0.0894)	(0.0916)
sales	-6.62e-15	-6.98e-15	-7.92e-15*	-8.07e-15*
	(4.71e-15)	(4.74e-15)	(4.65e-15)	(4.59e-15)
market _ share	-1.84e-3	-1.76e-3	-1.62e-3	-1.79e-3
	(2.07e-3)	(2.08e-3)	(2.05e-3)	(2.11e-3)
labor	6.26e-6*	6.16e-6*	6.50e-6*	6.65e-6*
	(3.51e-6)	(3.54e-6)	(3.52e-6)	(3.52e-6)
_cons	0.321***	0.298***	0.303***	0.316***
	(0.0873)	(0.0874)	(0.0858)	(0.0879)
N	349	349	349	349

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

6. Conclusion

We use the Korea Patent Litigation Data to study the CARs of the Plaintiffs and Defendants shortly around the filing of the litigation cases.

- **Findings:**

1) The combined CARs are negative when the litigation is announced.
2) The litigation usually hurts the defendants more than plaintiffs.
3) Smaller firms generally loss more after the announcement of the litigation.
4) Negative correlation between market reaction at the time of litigation and final legal outcomes.
5) The correlation is more significant for smaller firms.

- **Implications:**

1) The patent litigation system may have additional fringe costs and be detrimental to innovators.
2) Small innovators are likely to suffer from the bad market performance at the early stage of litigation.

Academic Advisors and their Ex-graduate Students: A Channel of Knowledge Diffusion

Kineung Choo

Academic Advisors and their Ex-graduate Students:

A Channel of Knowledge Diffusion

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2015 SJE International Symposium

This paper aims to …

- **provide empirical evidence for knowledge diffusion through the channel of the moving of the highly educated from academia to industries .**

- **and investigate the determinants of knowledge diffusion between universities and firms.**

To do this,

- **this paper focuses on actors who play roles in a diffusion process.**

Motivation

● The roles of universities are summarized as four functional aspects. (Hughes, 2006)

- to supply the educated to industries
- to increase knowledge stock by conducting research
- to provide solutions to issues firms confront
- to provide public goods by offering opportunities such as various informal contacts and formal meetings for acquisitions of new knowledge

● Knowledge transfer from academic advisors to students and the moving of the highly educated facilitate these functions.

● For the scientists, experiences of sharing the same laboratory life play important roles in leading their scientific life (Murray, 2004)

● The graduate students are incorporated and obtain kind of network capital through their degree courses.

Motivation

● There are various channels through which researchers in a firm acquire knowledge from the outside; fairs, exhibitions, professional conferences, scientific meetings, consulting, employment of the highly educated.

● The effects of newcomers from academia have been relatively under-explored and under-estimated in the literature.

●The better access to scientific networks in universities a firm has, the more benefits a firm draw from the various activities mentioned above.

Motivation

- Few studies have examined knowledge diffusion with the framework of university-industry linkage ***at the individual researcher level***.

- Existing literature has mainly addressed university-industry linkage ***at the organizational level.***

- or focuses on the moving of ***existing*** employees between organizations at the individual level (Breschi and Lissoni, 2009; Franco and Filson, 2000)

Motivation

- Employee mobility is well acknowledged as a key factor to knowledge diffusion.
- knowledge embodied in a mobile inventor goes across organizations with his move.
- Startups by ex-employees are founded based on the know-how and human networks built upon the ex-employees' former workplaces (Franco and Filson, 2000)
- Individuals' characteristics have larger influences on knowledge diffusion than those of the organization (D'Este and Patel, 2007)

- The moving of an advisee with a master's or (and) doctoral degree acts as a conduit for tacit knowledge flow.
- Relationships between academic advisor and their students are among non-market-based social ties, which are considered as contributors tacit knowledge diffusion (Breschi and Lissoni, 2009)

Motivation

- The moving of new researchers trained in universities implies the ***indirect*** or ***partial*** moving of their involved research networks.

- Informal contacts, which are often considered as the most interactions between university and industry, occur largely based on research networks.

- or reinforced by the research networks of inventors.

- Therefore, the moving of the highly educated play much more important roles in the diffusion process of knowledge (especially tacit knowledge) than we thought they would.

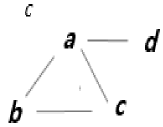
- However, firm's employment of new graduates with masters' or (and) doctoral degrees from academia lacks awareness in the studies about knowledge diffusion.

An imaginary situation of inventions by actors in a knowledge network

University A

Patent 1
- Professor(advisor) *a*
- Student *b*
- Collaborator *c*

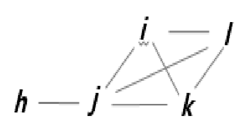
Patent 2
- Professor(advisor) *a*
- Collaborator d



Firm B

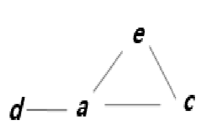
Patent 3
- Researcher worker *h*
- Researcher worker *j*

Patent 4
- Researcher worker *i*
- Researcher worker j
- Researcher worker *k*
- Researcher worker *l*



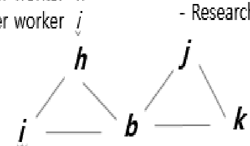
Patent 5
- Professor(advisor) *a*
- Collaborator d

Patent 6
- Collaborator *c*
- Professor(advisor) *a*
- Student *e*

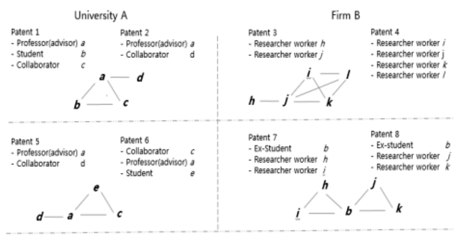


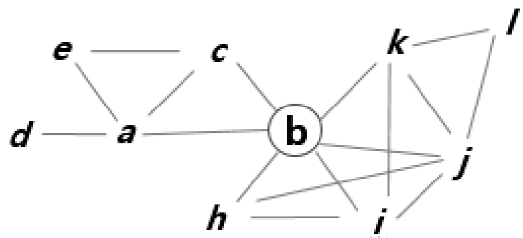
Patent 7
- Ex-Student *b*
- Researcher worker *h*
- Researcher worker *i*

Patent 8
- Ex-student *b*
- Researcher worker *j*
- Researcher worker *k*

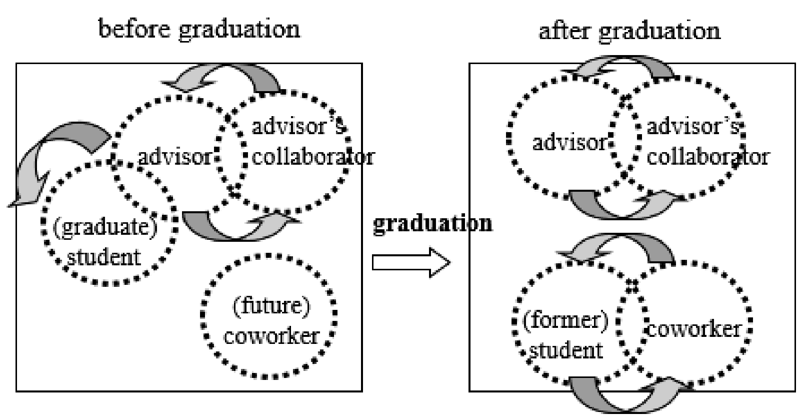


A knowledge network around ex-student b





Changes in a knowledge network after graduation



Collected Data

- Inventor data (1992~2005)
  source: KIPO
- Researcher data
  source: Korea Research Foundation
- Matched data of advisor-graduate
  source: Seoul National University
  ▷ data period: 1992-2008
  ▷ Birth year is the minimum information for solving the identification problem
  ▷ advisor-students pair with students' birth year enable us to recover birth date of students

- 485 inventor advisors were listed 4443 times as inventors
- 248 professors had experiences of co-invention with their students
- 1,151 student inventors put their name on the inventor lists with their advisors before graduation.
- 1,151 students were listed on inventor lists 8,073 times (5,013 without academic advisors)
- 4,249 students's collaborators

Technological proximities

- measuring proximities using cosine index as in Jaffe (1986) and others (e.g.)

$$P_{ij} = F_i^{'} F_j / [(F_i^{'} F_i)(F_j^{'} F_j)]^{1/2}$$

$$N_{ik}$$

represents the number of patents belonging to technology class *k* among patents by inventor *i*.

$$F_i^{'} = (N_{ii}, \ldots, N_{ik})$$

indicates technological profile of inventor *i* spread over 35 technological areas into which WIPO (2008) reclassified IPC codes.

$\beta_0 + \beta_1 + \beta_2 + \beta_3$

Methodology I

$$y_i = \beta_0 + \beta_1 treat_i + \beta_2 after_i + \beta_3 treat_i * after_i + e_i$$

y : proximity of a pair

- **Interpretation of coefficients in the 'difference in difference' model.**

	Treatment group	Control group	Difference
Before	$\beta_0 + \beta_1$	β_0	β_1
After	$\beta_0 + \beta_1 + \beta_2 + \beta_3$	$\beta_0 + \beta_2$	$\beta_1 + \beta_3$
Difference	$\beta_2 + \beta_3$	β_2	β_3

Methodology II

- Proximity = f (supervisor's characteristics,
  student's characteristics,
  collaborator's characteristics,
  and *other variables*
  (*+ network characteristics +*
  organizational characteristics)

Summary Statistics of proximity pairs

	student-student's coworker				adviser-student				adviser-student's coworker			
Variable	Mean	Min	Max	Obs	Mean	Min	Max	Obs	Mean	Min	Max	Obs
relatedness	0.395	0	1	72498	0.684	0	1	2096	0.392	0	1	10113
proximity year	2001.8	1991	2005	72498	2001.3	1991	2005	2096	2001.1	1991	2005	10113
mean_order	2.406	1	30	72319	2.910	1	16	2093	2.651	1	30	10089
research inst.(3)	0.073	0	1	72319					0.121	0	1	10089
university(3)	0.053	0	1	72319					0.079	0	1	10089
research inst._st.(1)	0.034	0	1	72383	0.063	0	1	2093				
university_st.(1)	0.277	0	1	72383	0.368	0	1	2093				
receive year of ms._st.(1)	1998.8	1993	2007	43169	1999.3	1993	2007	1317	1998.7	1993	2005	5340
receive year of dr._st.(1)	2001.4	1992	2008	47377	2002.1	1992	2008	1321	2001.0	1992	2008	6582
dr. dummy(1)	0.653	0	1	72498	0.630	0	1	2096	0.651	0	1	10113
both ms. and dr. from SNU(1)	0.249	0	1	72498	0.259	0	1	2096	0.179	0	1	10113
birth_year(2)	1950.7	1930	1970	72498	1952.5	1930	1970	2096	1951.7	1930	1969	10113
receive_year(2)	1982.0	1964	2001	69831	1984.3	1963	2000	1966	1983.6	1968	2000	9675
age at corresponding proximity(2)	51.1	26	74	72498	48.8	27	67	2096	49.4	27	67	10113
age when receiving deg.(2)	31.0	24	39	69831	31.4	23	42	1966	31.6	27	39	9675
deg. from univ in Korea.(3)	0.066	0	1	72498	0.094	0	1	2096	0.061	0	1	10113
deg. from univ in US.(3)	0.866	0	1	72498	0.779	0	1	2096	0.810	0	1	10113
deg. from univ in Japan.(3)	0.048	0	1	72498	0.040	0	1	2096	0.038	0	1	10113
time from ms.(1)	3.341	-12	12	43169	2.292	-12	12	1317	2.720	-14	12	5340

1st appl. dummy after ms._st.(1)	0.239	0	1	72498	0.260	0	1	2096	0.161	0	1	10113
1st appl. dummy after dr._st.(1)	0.173	0	1	72498	0.136	0	1	2096	0.173	0	1	10113
invention exp. before ms._st(1)	0.683	0	1	72498	0.626	0	1	2096				
invention exp. before dr._st.(1)	0.924	0	1	72498	0.913	0	1	2096				
invention exp. before ms.(3)	0.741	0	1	72498					0.767	0	1	10113
invention exp. before dr.(3)	0.839	0	1	72498					0.827	0	1	10113
time from 1st invention(3)	4.588	0	14	72366								
time from 1st invention_st.(1)	4.071	0	14	72496	2.376	0	14	2095				

Summary Statistics of proximity pairs (continued)

Summary Statistics of the control group

Variable	Mean	Min	Max	Obs
relatedness	0.706	0	1	3349
proximity year	2000.8	1991	2005	3996
research inst._st.(1)	0.072	0	1	2888
university_st.(1)	0.370	0	1	2888
birth_year(2)	1952.7	1930	1970	2896
receive_year(2)	1984.6	1963	2000	2744
receive year of ms._st.(1)	1999.5	1993	2007	1723
receive year of dr._st.(1)	2001.9	1992	2008	1859
dr. dummy(1)	0.642	0	1	2896
both ms. and dr. from SNU(1)	0.237	0	1	2896
age at corresponding proximity(2)	48.5	27	67	2896
age when receiving deg.(2)	31.6	23	42	2744
deg. from univ in Korea.(2)	0.115	0	1	2896
deg. from univ in US.(2)	0.732	0	1	2896
deg. from univ in Japan.(2)	0.050	0	1	2896
time from ms.(1)	2.204	−12	12	1723
time from dr.(1)	−0.924	−15	11	1859
invention exp. before ms._st(1)	0.647	0	1	2896
invention exp. before dr._st.(1)	0.895	0	1	2896

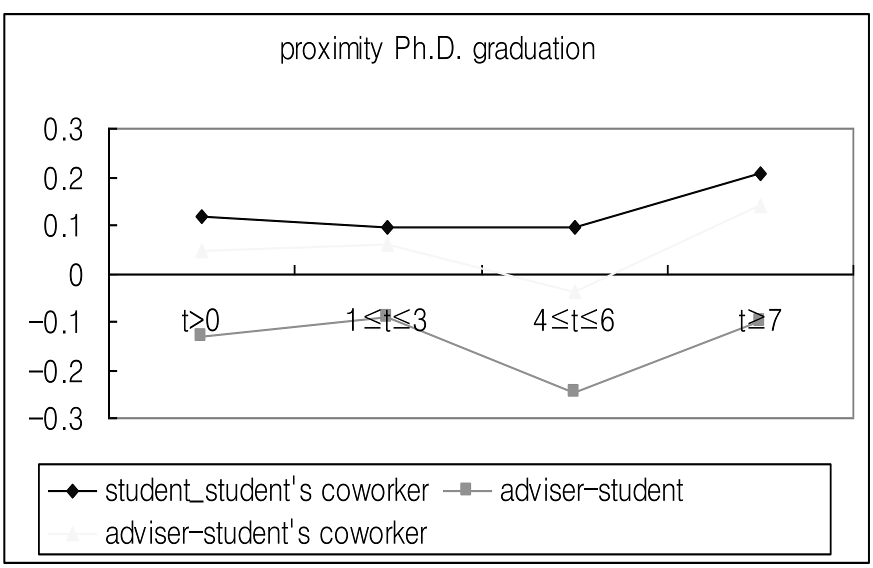
Changes in technological proximity after graduation with a doctoral degree

treatment group: t>0									
	student–student's coworker			adviser–student			adviser–student's coworker		
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.714	104.290	0.000	0.714	104.250	0.000	0.714	104.280	0.000
treat	−0.345	−48.340	0.000	0.001	0.070	0.945	−0.327	−38.160	0.000
after	−0.030	−1.710	0.087	−0.030	−1.710	0.087	−0.030	−1.710	0.087
treat*after	0.117	6.510	0.000	−0.131	−4.490	0.000	0.047	2.380	0.017
no. of obs.	71068			5151			12656		
R–sq.	0.029			0.014			0.107		
treatment group: 1≤t≤3									
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.714	104.290	0.000	0.714	104.250	0.000	0.714	104.270	0.000
treat	−0.345	−48.340	0.000	0.001	0.070	0.945	−0.327	−38.160	0.000
after	−0.025	−1.010	0.314	−0.025	−1.010	0.314	−0.025	−1.010	0.314
treat*after	0.095	3.750	0.000	−0.092	−2.470	0.014	0.062	2.260	0.024
no. of obs.	60273			4764			10982		
R–sq.	0.030			0.005			0.112		
treatment group: 4≤t≤6									
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.714	104.290	0.000	0.714	104.250	0.000	0.714	104.270	0.000
treat	−0.345	−48.340	0.000	0.001	0.070	0.945	−0.327	−38.160	0.000
after	0.001	0.030	0.980	0.001	0.030	0.980	0.001	0.030	0.980
treat*after	0.097	3.190	0.001	−0.247	−4.670	0.000	−0.038	−1.160	0.246
no. of obs.	55424			4532			10150		
R–sq.	0.033			0.010			0.125		
treatment group: t≥7									
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.714	104.290	0.000	0.714	104.250	0.000	0.714	104.270	0.000
treat	−0.345	−48.340	0.000	0.001	0.070	0.945	−0.327	−38.160	0.000
after	−0.085	−2.510	0.012	−0.085	−2.510	0.012	−0.085	−2.510	0.012
treat*after	0.205	5.910	0.000	−0.101	−1.440	0.150	0.138	3.540	0.000
no. of obs.	52447			4447			9694		

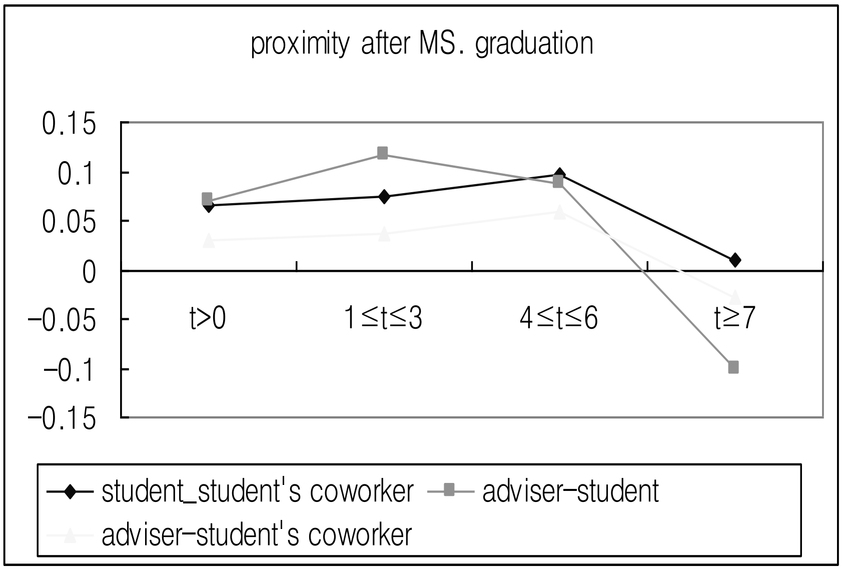
Changes in technological proximity after graduation with a master's degree

	student-student's coworker			adviser-student			adviser-student's coworker		
treatment group: t>0									
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.737	100.720	0.000	0.737	100.690	0.000	0.737	100.710	0.000
treat	−0.327	−42.420	0.000	−0.052	−3.780	0.000	−0.318	−34.650	0.000
after	−0.100	−6.870	0.000	−0.100	−6.860	0.000	−0.100	−6.870	0.000
treat*after	0.066	4.430	0.000	0.069	3.020	0.003	0.029	1.730	0.085
no. of obs.	71373			5045			12794		
R-sq.	0.023			0.012			0.113		
treatment group: 1≤t≤3									
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.737	100.720	0.000	0.737	100.680	0.000	0.737	100.710	0.000
treat	−0.327	−42.420	0.000	−0.052	−3.780	0.000	−0.318	−34.650	0.000
after	−0.082	−4.240	0.000	−0.082	−4.240	0.000	−0.082	−4.240	0.000
treat*after	0.075	3.760	0.000	0.117	4.130	0.000	0.037	1.630	0.104
no. of obs.	50421			4157			9972		
R-sq.	0.026			0.006			0.110		
treatment group: 4≤t≤6									
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.737	100.720	0.000	0.737	100.680	0.000	0.737	100.710	0.000
treat	−0.327	−42.420	0.000	−0.052	−3.780	0.000	−0.318	−34.650	0.000
after	−0.145	−6.520	0.000	−0.145	−6.520	0.000	−0.145	−6.520	0.000
treat*after	0.096	4.220	0.000	0.088	2.590	0.010	0.059	2.360	0.018
no. of obs.	49467			3965			9830		
R-sq.	0.029			0.016			0.117		
treatment group: t≥7									
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.737	100.720	0.000	0.737	100.670	0.000	0.737	100.700	0.000
treat	−0.327	−42.420	0.000	−0.052	−3.780	0.000	−0.318	−34.650	0.000
after	−0.061	−1.890	0.059	−0.061	−1.890	0.059	−0.061	−1.890	0.059
treat*after	0.010	0.290	0.770	−0.101	−2.010	0.045	−0.027	−0.770	0.443
no. of obs.	46025			3663			9314		

Changes in treatment effects over time



Changes in treatment effects over time



Findings from the DID analysis

1) Technological proximities between ex-student and her/his collaborator increase after graduation of the student.

2) Technological proximities between ex-student and her/his supervisor decrease after graduation of the student.

3) Technological proximities between supervisor and ex-student's current collaborator increase after graduation of the student.

Results from the regressions from determinant of technological proximity

	student-student's coworker						adviser-student						adviser-student's coworker					
	specification 1			specification 2			specification 1			specification 2			specification 1			specification 2		
Variables	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t	Coef.	t	P>t
cons.	0.395	44.92	0.000	1.081	21.29	0.000	0.635	16.52	0.000	0.468	2.80	0.005	0.390	25.86	0.000	0.445	4.61	0.000
university_st.(1)	-0.075	-8.76	0.000	-0.073	-8.50	0.000	0.120	6.14	0.000	0.117	5.67	0.000	-0.033	-1.91	0.056	-0.022	-1.27	0.204
research inst._st.(1)	-0.056	-7.37	0.000	-0.084	-10.52	0.000	-0.028	-0.71	0.478	-0.049	-1.12	0.262	-0.072	-4.59	0.000	-0.090	-5.35	0.000
mean_order	0.011	8.60	0.000	0.010	7.65	0.000	0.011	2.11	0.035	0.009	1.62	0.105	0.011	4.74	0.000	0.011	4.70	0.000
time from dr.(1)	0.008	9.82	0.000	0.011	14.61	0.000	-0.003	-0.67	0.501	-0.003	-0.63	0.531	0.001	0.44	0.659	0.004	2.49	0.013
1st appl. dummy after dr._st.(1)	-0.019	-3.79	0.000	-0.016	-3.20	0.001	0.047	1.69	0.092	0.048	1.63	0.102	-0.028	-2.25	0.025	-0.034	-2.65	0.008
invention exp. before dr._st(1)	0.011	1.50	0.135	0.064	8.77	0.000	0.059	1.54	0.123	0.083	2.09	0.037						
invention exp. before dr.(3)	0.005	0.78	0.434	-0.007	-0.96	0.338							0.064	3.71	0.000	0.061	3.46	0.001
time from 1st invention_st.(1)	0.006	7.40	0.000	0.006	8.28	0.000	-0.031	-7.15	0.000	-0.031	-7.04	0.000						
time from 1st invention(3)	-0.008	-12.92	0.000	-0.005	6.99	0.000							-0.006	-3.35	0.001	-0.004	-2.42	0.015
both ms. and dr. from SNU(1)	-0.023	-5.25	0.000	-0.012	-2.85	0.004				0.019	0.92	0.358	-0.035	-3.06	0.002	-0.024	-2.07	0.039
age at corresponding proximity(2)				-0.014	-37.24	0.000				-0.001	-0.64	0.524				-0.008	-8.96	0.000
age when receiving deg.(2)				0.001	0.47	0.638				0.006	1.36	0.174				0.006	2.14	0.032
deg. from univ. in U.S.(2)				-0.050	-5.45	0.000				-0.008	-0.23	0.817				0.175	8.80	0.000
deg. from univ. in Japan.(2)				0.096	7.74	0.000				0.100	1.53	0.127				0.223	5.88	0.000
deg. from univ. in other regions.(2)				0.198	8.72	0.000				-0.006	-0.12	0.902				0.194	7.18	0.000
no. of obs.	47249			45589			1318			1235			6562			6270		
R-sq.	0.019			0.051			0.121			0.132			0.011			0.024		

Concluding Remarks

- **test robustness of the results**
  e.g.) placebo control group

- **check whether there are any direct ties between actors before graduation**
- **and whether any direct ties are formed between actors after graduation**

- **draw policy implications from additional elaborate works**
  e.g.) - How do we boost proximities (knowledge diffusion) between actors
  - Is there any inherent characteristics to promote proximities (knowledge diffusion) ?
  - Is there any differences in the diffusion process across technological fields?

Innovation and Entrepreneurship: A First Look at Linkage Data of Japanese Patent and Enterprise Census

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Innovation and Entrepreneurship: A first look at linkage data of Japanese patent and enterprise census*

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Abstract

This paper presents the results of a comprehensive analysis of the innovative activities of the entire population of Japanese firms by using a linked dataset of Establishment and Enterprise Census and the IIP Patent Database (JPO patent application data). As of 2006, it was found that about 1.4% of about 4.5 million firms filed patents, and substantial patenting activities were found not only in the manufacturing field but also in a wide range of fields such as B2B services and financial sectors. In addition, a firm's survival and growth are regressed with patenting and open innovation (measured by joint patent application with other firms and universities), and it is shown that innovative activities measured by patenting are positively correlated with such firm performance. It is also found that the relationship between patents and the survival rate is stronger for larger firms, while that between patents and firm growth is stronger for smaller firms.

Keywords: enterprise census, patent database, entry and exit of firms.
JEL Classification: L25; O13

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1. Introduction

Productivity increase is an important factor for economic growth in developed nations, and it is found that 20%-40% of productivity in the OECD countries is attributable to high-growth-rate new startups (OECD, 2003). The importance of entrepreneurship for economic growth is stressed by Schumpeter, who defines "innovation" as a new combination, with five types of activities such as new product development and adaption of new process (Schumpeter, 1934). Schumpeter also argues that "creative destruction" is an essential fact about capitalism (Schumpeter, 1942). Creative destruction, i.e., firms that succeed in innovation increase their market share, firms with low productivity withdraw from the market, has been making a significant contribution to the economic expansion for long time (Baumol, 2010).

Along this line, the view that small and medium-sized enterprises (SMEs) are a source of innovation is shared in every country of the world. However, empirical research on firm dynamics and its contribution to economic development shows mixed results. First, it is found that survival rate of new firms is low. According to Bartelsman et. al. (2005), in 10 OECD countries 20%-40% of new companies disappear within two years of establishment. Furthermore, it is also understood that there is a positive correlation between entry and exit of firms that occurs together with macroeconomic fluctuations (Bartelsman et. al., 2005). As a result of the churning effect resulting from market fluctuations, generation and dissolution of small inefficient firms that have not reached a sufficient scale occurs simultaneously. This phenomenon can be viewed as firms simply moving through a revolving door (Santarelli and Vivarelli, 2010). Moreover, Schumpeter also provides two kinds of concepts on innovation, that is, the roles of SMEs are important with respect to creative destruction (Schumpeter Mark I) and circumstances where oligopolistic economic rents occur at large firms are also essential for economic dynamics (Schumpeter Mark II).

Innovation and entrepreneurship is an important topic for Japan, because Japan has a lower firm's turnover rate, compared to those in the OECD countries such as Europe and the United States. The share of entry and exit of enterprises is much lower than that of the United States, and Japan's ranking in the Global Entrepreneurship Monitor for entrepreneurial spirit is near the lowest in the world (GEM, 2010). It is difficult to cultivate startups in Japan, especially hi-tech startups with a technical background, due to labor market rigidity, underdevelopment of venture capital activities supplying risk money to start up projects, and other factors (Motohashi, 2010). In addition, a larger firm with substantial technological capability plays an important role in Japanese national innovation system, and in-house orientation of large firm's R&D may hinder entrepreneurship activities. For hi-tech startups to grow, it is expedient to tie up with a large firm, but generally, large Japanese firms are not very proactive in assimilating new technology using startups. However, growing competitive pressure from Korean and Chinese firms, Japanese large firms become increasingly difficult to follow through with in-house R&D style. It is becoming important for large firms to form alliances with universities and startups to accelerate its innovation speed; moreover, it is understood that the promotion of hi-tech startups is important for changing Japan's innovation system from large firm's in-house to a network-style one (Motohashi, 2005).

In this paper, we show the results of an analysis relating to innovation and company dynamics using data that links the enterprise census and a patent database. The objective of this research is to derive new implications relating to the issue of whether new firms are a source of economic growth (source of growth firms) or "revolving door" ones. In conclusion, it would seem apparent that both exist in combination, but in this study we take the position that the former (source of growth firms) are firms that are making some efforts toward patent application and/or open innovation. Patent applications can be seen as a variable that reflects that a firm has made some effort toward achieving technological innovation. We look at the size, age and industry distribution of patenting activities for entire population of Japanese firms, and its impact on firm's survival and growth. In addition, we investigate the impact of open innovation activities, such as collaborative R&D with other firms and universities, on firm's performance.

This paper is structured as follows. First, we introduce the data source in this study, i.e., the Enterprise and Establishment Census data and the JPO patent database, called IIP Patent Database (Goto and Motohashi, 2007). Next, we present the results of linking both these using company name and address information; the descriptive statistics resulting from the linked data are discussed. Then, we show the results of a quantitative analysis on the relationship between open innovation and patent applications (drawn from this linked data) and the survival rate and growth speed of firms. Finally, we summarize our findings and provide discussions and policy implications.

2. Description of enterprise census and patent database

2-1. Enterprise and Establishment Census

The Enterprise and Establishment Census encompasses all business establishments in

Japan. Along with providing base statistical data such as the number of establishments and employees, it is also used as the survey body information set for governmental statistical surveys. This survey has been conducted twice every five years, and was named the Establishment Census until July 1991. From the October 1996 survey onward, the name was changed to the Enterprise and Established Census. From the October 1996 survey, due to the addition of “address of head office” as a survey item, it became possible to group business establishments by company name. Currently, statistical data until October 2006 is publicly available. Moreover, this 2006 survey will be the last Enterprise and Establishment Census. In 2009, a similar survey are conducted under the name of “Economic Census Preparatory Survey,” and preparations are underway for a statistical survey based on a new survey framework to commence from 2012, called “The Economic Census.”

Table 1 shows the trend in business establishment and employee numbers from the Enterprise and Establishment Census. The number of business establishments decreased from 6,290,730 in 1981 to 5,722,559 in 2006. In contrast, the total employee numbers showed an increasing trend until 1991, and since then having been seesawing between 52 million and 55 million people. Therefore, the average employee number per business establishment (business establishment size) showed an increasing trend. Furthermore, the business establishments here included all business entities engaging in economic activities and unpaid family workers (family run businesses) were included in workers. In other words, there were many business establishments with zero employees (non-employee establishments), included in this sample.

(Table 1)

To make the panel data for the Enterprise and Establishment Census, company and business establishment numbers (identifying numbers) from past surveys are required at the time of conducting the research. In this survey, business establishments are the main statistical unit and it is possible to link panel data at a business establishment-level using establishment identification numbers. However, it is a bit tricky to compile enterprise level panel datasets. From 1996 survey onward, the name and address of enterprise headquarter are surveyed for all establishment, allowing up to aggregate establishment data into enterprise level. However, this enterprise data cannot be liked inter-temporally due to lack of enterprise identification system. Therefore, we have treated the firms with same establishments between two period are identical.

2-2. IIP Patent Database

The IIP Database is compiled based on the Consolidated Standardized Data, which is made public twice a month by the Japan Patent Office. The Consolidated Standardized Data includes patent information recorded as a text file with SGML and XML tags. In this study, these text files are converted to an SQL database to allow easier statistical processing of the data. Furthermore, information that is believed to be needed most by researchers is released as a CSV-format text file. At present, this includes information made public from January 1964 until October 2009 (15th public release of Consolidated Standardized Data, 2009).

The data released publicly in CSV-format as the IIP Patent File includes patent application data (application number, application date, examination request date, technological field, number of claims, etc.); patent registration data (registration number, rights expiration date, etc.); applicant data (applicant name, applicant type, country/prefecture code, etc.); rights holder data (rights holder name, etc.); citation information (citation/cited patent number, etc.); and inventor data (inventor name, address) (Goto and Motohashi, 2007). Figure 1 shows the database structure and number of data for each table. For example, this includes the data for 11,254,825 patent applications, and of those, 3,507,336 patents are registered. To each of these respectively, a table relating to applicant and rights holder is linked. Moreover, citation data includes data relating to examiner citations, that is, the past patent literature that the examiner cites as their reason for rejecting the patent application.

(Figure 1)

Based on raw data from the Consolidated Standardized Data by JPO, IIP-patent database has created with substantial efforts are made for ready-made usable data for researchers. The most important points of revision are concerning inconsistency in the recording method of applicant names in raw data. For example, while older data from the 1960’s had names displayed in katakana (Japanese own characters), more recent data has been recorded in kanji (Chinese characters). Thus, it is not possible to merge records under the same name using the original text information. In addition, due to company name and its notation methods (such as “incorporated” or “inc.”) changes, modifications are required to make sure that the same company under difference expressions should be recognized as the same ones.

This work begins with utilizing the Patent Office’s applicant ID codes. However, because this code underwent several changes before it became the present-day nine-digit code, we had to rectify this first. It should be noted that the Patent Office applicant ID code may be suffered from false negative errors (two different codes being assigned to the same person, where only one should have been assigned), but there were no false positive errors (the same code being assigned to two different records), since this code is assigned by patent examiner by hand.

First, we made classifications of applicant type (individual inventor, company, non profit organizations or universities), by using applicant name information. Then, we have extracted only company applicant names, and assigned our own ID numbers by assuming that companies that exist in the same municipality with the same company name were actually the same company (Thoma et. al, 2010). Moreover, there is a possibility of false negatives occurring in cases where company name standardization using this method is insufficient or in cases where the company had changed its name. There is also the possibility of false positives occurring in cases where two different companies with the same name exist in the same area. Linking this patent data with enterprise and establishment census data mitigates this problem, discussed more in the next section.

3. Data linkage of establishment census and patent database

3-1. Linkage method and results

Linkage between Enterprise and Establishment Census and the IIP Patent Database was conducted by using identical company name (standardized one) and location (municipality level). It is possible to obtain head office name and address from the Enterprise and Establishment Census on only three occasions: 2001, 2004, and 2006 surveys. In the other years, linking by using company name is impossible so that we decided to link panel data and the patent database for two surveys: 2001 and 2006 (2004 was a simplified survey year). In the Enterprise and Establishment Census, each establishment are categorized as one of 1. a single unit establishment firm, 2. the head office of multiple establishments firm, 3. a branch of multiple establishments firm The number of business establishments for the 2001 survey and the 2006 survey by type are as follows.

(Table 2)

Because patent applications are usually managed by a whole company, instead of an individual establishment, so that applicant information from patent data should be linked with a headquarter of multiple establishment firm or a single establishment firm. However, we know some cases where the address of the applicant is not the one at firm's head office. In addition, names and addresses information at patent data and/or enterprise and establishment census data are not complete. Therefore, we performed matching two datasets by using both branch and head office information. In the process of name cleaning of patent database, there is only one firm in each name and location (municipality level) set. However, there are some cases where one firm from patent data is liked with multiple firms in the enterprise and establishment census data. In this case the priorities were set as, head office > individual business establishment > branch office, to ensure one to one link. As a result, 1.33% of all firms in 2001 and 1.42% of all firms in 2006 have one or more patent applications. From the number of patent applied, out of roughly 10 million patent applications, about 60% of patents were matched with the enterprise and establishment census. Furthermore, when patent applicants from overseas and patents applied for by individual inventors are excluded, and when the application year is limited up until 2006, the total number of patents will be 8,801,613. Of these, 5,772,461 are matched from the 2006 data, which means that 65.3% of the patents are covered.

(Table 3)

Due to a variance in the spelling of company name and incomplete addresses, linkage cannot properly be made in some cases and, some companies that have submitted patent applications are treated as firms without patents. However, discontinued businesses that did not exist in 2006 were also included in the roughly 35% of unmatched patents. To conduct an assessment on this point, we made a firm-level analysis of patent data. First, the number of applicants, excluding individual inventors, who are located in Japan and have applied for at least one patent by 2006, is 167,430. As is shown in Table 3, the number of companies that we were able to link to the enterprise and establishment census data was 64,630, which was just under half of the total number of applicants. Figure 2 looks at the application status of the 167,430 applicants and illustrates cumulative number firms by last year of patent applications. For example, the number of applications corresponding to the year 2000 was 91,315. This shows the number of firms which applied patent in 2000 or before, but have not applied ever after 2000. It is not likely that firms that have not filed a patent application over a long period still existed in 2006. The number of firms that had not applied for a patent for more than ten years was roughly 70,000 (firms that last filed an application in 1996 and had not filed a new patent application until 2006), and the remaining number was roughly 97,000. When you consider that 64,000 of these were linked, you could say that a certain level of linkage performance has been achieved. The number of companies shown to be without patents in Table 3 is about 4.5 million, so that roughly 30,000 (97,000-64,000) of unidentified patents does not make a substantial bias.

(Figure 2)

3-2. Descriptive statistics on the distribution of patenting firms

Here, we use the above linkage data and conduct an analysis of how the ratio of companies applying for patents varies depending on company size, age and industry type. First of all, with respect to company size by the number of employees, the larger the company is, the higher is the ratio of companies applying for patents (Table 4).

(Table 4)

On the other hand, we are unable to see a clear trend relating to the company age and the ratio of patent applications. Table 5 shows the ratio of patent applications by establishment year of companies[1]. While there is a mildly higher ratio for firms that have been around for longer, this is not as great as the difference that we saw in the ratio by company scale. It is possible to assume that there is a positive correlation between the company scale and the company age. However, there are also many companies that are old but remain small in size. It is thought that these companies have a stable business in a niche market, and in many cases they are strangers to the kind of innovation activities seen in patents. Meanwhile, because innovation activities go hand in hand with risk, on the flip side of having the chance of becoming a large company with success, there is a strong possibility of failure, which will lead to the company being driven out of business. Therefore, the possibility for an innovative company to remain small in scale for a long time is assumed to be small.

(Table 5)

Tables 6 and 7 show the share of with patent firms by industry. Of the roughly 65,000 firms applying for patents, 27,000 belong to the manufacturing industry. We can see that

[1] In the Business Establishment and Company Statistics, there is only data for the establishment year of business establishments, so when a company is composed of multiple business establishments, we took the establishment year of the oldest business establishment to be that company's establishment year.

patent applications, which are the outcome of technological innovation, are typically seen in the manufacturing industry. However, we should also pay attention to the fact that there were many company patent applications in firms belonging to the wholesale and retail industries, the construction industry, and others such as the IT service industry. Furthermore, with respect to patent company application ratio, the IT industry exceeds the manufacturing industry. When we take a more detailed look at the manufacturing industry, the ratio of companies applying for patents in the chemicals industry is the highest. This reflects the fact that patent right can be enforced more strongly in chemical industry including pharmaceutical industry (Cohen et. al, 2002). In addition, the share of with patent firms is high in the precision machinery and electronics sectors, centering around electronics device technology.

(Table 6) (Table 7)

Table 8 looks at the share of with patent firms with respect to the entering, continuing (surviving), and exit of firms in/from the market between 2001 and 2006. When looking at firms as a whole, the firms that survived in the two periods of 2001 and 2006 have the highest ratio of patents. However, looking at the numbers in terms of company size shows that the smaller-sized category has a lower patent ratio among continuing companies. This could be seen as support for the hypothesis that innovation activities, such as patenting, go hand in hand with higher risk. On the other hand, for firms on a larger scale, the patent application ratio is higher for continuing companies because they are able to absorb substantial risks backed by its substantial in-house resources.

(Table 8)

Table 9 shows the share of with patent firms to indicate whether they are a new entrant, continuing, or a exit (from the market) company, categorized by the company establishment year. Looking at the number by new entrant, continuing, and exit, in general, companies with earlier establishment year had higher patent application ratio.

(Table 9)

Finally, Tables 10 and 11 represent the state of firm dynamics by industry. Table 10 is separated between industries that have a high ratio of company patent application for continuing firms when compared to new entrants and exit firms (manufacturing, IT, etc.), and industries that demonstrate the opposite pattern (forestry, real estate, medical welfare, etc.). The details of the manufacturing industry show that in most business categories, the ratio is largest for continuing firms, followed by new entrants and withdrawn firms.

(Table 10) (Table 11)

4. Econometric analysis of (open) innovation and firm survival and growth

Here, we use patents as an indicator of innovation to analyze its relationship with firm's survival and growth. In addition, we construct some indicators on open innovation, by using patent database. Concretely, we use whether a patent are applied jointly with other firms other firms (inter-firm linkages) and/or with university (industry-academia linkages). Furthermore, in order to track industry-academic linkages by patent database, we have used inventor information as well as applicant information, since industry-academia joint inventions had been usually patented solely by the firm until 2004, when national universities in Japan were incorporated and entitled to claim the patent right (Muramatsu and Motohashi, 2011).

Table 12 is a look at the ratio of open innovation firms with respect to company patent applications between 2001 and 2006 organized into new entrant, continuing, and exit firms. First, eixt firms, when compared to continuing firms, had a lower ratio of open innovation. On the other hand, new entrants also had a relatively lower index than continuing firms, but differences as large as that with exit firms were not seen. According to an empirical analysis of research conducted concerning firms' market entry, exit, and productivity, firms with a lower productivity had a higher chance of discontinuation in near future (Griliches and Regev, 1995; Baily et. al, 1992; Matsuura and Motohashi, 2005). The presence of open innovation may represent higher innovative capability of firms, particularly the case for joint research with universities, or open innovation also means sharing the risks associated with innovation activity with partners, particularly for the case of inter-firm collaborations, which raises firm's survival rate. In addition, when we take a look at continuing firms, both inter-firm cooperation and industry-academia cooperation are on the increase from 2001 to 2006, and this shows that open innovation is progressing.

(Table 12)

Table 13 is a look at the open innovation index by company size. The ratio of inter-company linkages increases along with size of the firm, and the ratio of industry-academia linkages shows a U-shaped distribution with higher value for large-scale and small-scale firms. This result for industry-academia linkages with respect to company size is consistent with the results based on the survey questionnaire on external R&D collaborations (Motohashi, 2008).

(Table 13)

Tables 14 and 15 take a look at the distribution by industry. Furthermore, to make a time series comparison possible, we will look at continuing firms only. Industries with a high number of patent applications are manufacturing and wholesale/retail, but the open innovation ratio is increasing in all industries. When we look at differences by business category, we see that the ratio of open innovation is increasing for service industries, such as IT as well as electricity/gas and other public utilities, and finance and insurance industry, although the number of firms is small for these sectors. Taking a granular look at the manufacturing industry, inter-company linkages are mostly increasing in the machine industry, while industry-academia linkages are increasing in the chemical industry and petro-chemistry.

(Table 14) (Table 15)

Table 16 estimates companies' survival function. We conduct a Probit estimate using independent variables such as company size and dummy variable for with patent application firm, as a dependent variable, which is 0 for continuing companies and 1 for exit companies in the period from 2001 to 2006. In addition to including dummy variables for industry, firm size and firm age, we use the scale valuable for size, age (taking logarithm of each) and a cross term of them as an independent variable in some specifications.

Model 1 looks at the relationship between patent dummy and continuation of companies, and from the fact that it is positive and statistically significant, we can see that companies applying for patents in 2001 have a high survival probability. Model 2 includes a cross term of logarithmic value of patent variable and a firm size as independent variables. A positive and statistically significant relationship can be seen with respect to a cross term implies that there is a positive relationship between patents and survival probability in large companies; however, for smaller companies, the inverse is true and there is a negative relationship (patent dummy's coefficient is minus). Model 3 looks at the relationship with firm age, and we found that older firms had a high probability of survival. Finally, Model 4 uses firm size, age and their cross term with patent variables. For the cross term with patents, we obtained a positive and statistically significant relationship for both firm scale and age, but the coefficients of cross terms of these two were negative. This shows that the relationship between patents and survival probability is positive when firm scale is large (firm age is larger), but that influence gets smaller as firm age increases (firm scale is large).

(Table 16)

Next, Table 17 used the same dependent variables to look at the relationship with firm growth. The dependent variable is a logarithmic value of a company's employee number, and with respect to continuing firms between 2001 and 2006, which was estimated using a fixed-effect model, by a balanced panel data for these two years. In Model 1, we've found that there is a positive correlation between patent applications and firm growth. Model 2 uses patents and a cross term of firm size and age in 2001, and we found that the smaller and younger the company is, the stronger is the positive correlation between patents and firm growth. Models 3 and 4 look at the relationship with open innovation. We could not see a relationship with company growth just by looking at the logarithmic values for inter-firm linkages and industry-academia linkages. However, we found that for inter-firm linkages, the smaller the firm is, the stronger is the relationship to firm growth.

(Table 17)

A positive coefficient of patent on firm's growth, particularly found in smaller and younger firms may be explained by selection bias, since a larger and an older firm with patent are more likely to survive in Table 16. This finding supports the risk hypothesis of patenting, that is, firms applying patent still faces greater risks associated with its commercialization than firms without patent. A younger and smaller firm is more vulnerable to such risk, and survival rate becomes smaller as compared to established large firms. As a result, younger and smaller firms with patent and survived in these two periods tend to show stronger growth performance. A stronger impact of inter-firm linkage for smaller firms may be due to the fact that collaborating with other firms mitigates commercialization risk associated with patented technology, particularly for smaller firms. Along this line, no size effect on industry-academia linkage can be understood that such activities are far from commercialization stage, so that risk mitigation effect by open innovation tends to be small.

5. Discussion and conclusions

This paper presents, for the first time, the results of a comprehensive analysis of the innovative activities of the entire population of Japanese firms by using a linked dataset of Establishment and Enterprise Census and the IIP Patent Database (JPO patent application data). As of 2006, it was found that about 1.4% of about 4.5 million firms filed some patents and substantial patenting activities were found not only in manufacturing field but also in a wide range of fields such as B2B services and financial sectors. In addition, firm's survival and growth are regressed with patenting and open innovation (measured by joint patent application with other firms and universities), and it is shown that innovative activities measured by patenting are positively correlated with such firm performance. It is also found that the relationship between patent and survival rate is stronger for larger firms, while that between patent and firm growth is stronger for smaller firms.

This paper uses patent application as an indicator of innovation. By applying for patents, firms can retain the fruits of their research, having cleared a certain level of technological risk. However, an economic risk remains as to whether this technological outcome will give rise to an economic return. In other words, while firms that apply for many patents have a large technological capacity, the other side of the equation is that they could be thought to also have a greater risk. According to the results of a regression analysis relating to survival probability, the number of patent applications (logarithmic) has a positive influence on continuation of a company, and this can be viewed as an expression of the effect of a technological capability. Also of interest are the papers by Esteve-Perez and Manez-Castillejo (2008) and Orgega-Argiles and Moreno (2007), which use R&D as an alternative index. In their analysis results, their literature showed that the positive relationship between R&D and company survival is particularly seen in the hi-tech industry, and this is consistent with our findings on innovation and a company's survival. Moreover, the researches by Cockburn and Wagner (2007) and Buddelmeyer et. al (2009) with respect to analyses concerning patents and survival rates are also useful. Most of these papers admit the positive relationship between both of these, but with respect to Buddelmeyer et. al (2009), analyses were conducted by separating between patents and patent stock that a company retains, and with patents and the patent applications that a company files each year. The former showed a positive effect and the latter showed a negative effect. Shedding light on this, patent applications are a sign that high-risk investment is happening, and due to it being a high-risk return, there is a negative impact on survival rate.

The findings in this study generally support the argument in Buddelmeyer et. al (2009), in a sense that patenting involves counteracting factors of "technological superiority" and "greater commercialization risk". The results in survival regressions can be explained by "greater commercialization risk" hypothesis, that is, small companies are more vulnerable to risks associated with patents, so that survival rate becomes lower. On the other hand, the growth regression results may be understood that "technology superiority" effect by patenting is more clearly expressed in smaller firms. However, the growth regressions are conducted only by surviving firms. Therefore, a further study is needed for evaluating "technology superiority effect" after controlling for sample bias associated with growth regressions.

Another contribution of this study is digging into the impact of open innovation for firm's growth, and it is found that inter-firm linkage is more strongly correlated with firm's growth for smaller firms. By applying patents with other firms, commercialization activities may be conducted jointly. In this sense, commercialization risk associated with patent is shared among these firms, and this risk mitigation effect may be greater for small firms. This logic is consistent with no size effect for industry-academic linkage, whose activities are generally far from commercialization stage.

One of implications from our study is that we reconfirm the importance of SME innovation policy. Our findings suggest that small firms are facing greater risks associated with patenting. A patent can be understood as an intermediate output in innovation process, but there is still great risk associated before the innovation process completes by commercialization of the technology. Therefore, it is necessary for the government to provide some supports, not only in research and development, but in technology commercialization activities.

Another implication is the importance of effective use of open innovation in a process of firm growth. By networking with other firms, smaller firms may be able to mitigate risk associated with innovation activities. Therefore, policy instruments for SME innovation are not only direct financial support, but also institutional arrangements to facilitate networking of small firms.

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Table 1: Number of establishments and employees in the census

Date	# of establishments		# of employment		emp/est
1981.7.1	6,290,703		45,961,266		7.31
1986.7.1	6,551,741	0.82%	49,224,514	1.38%	7.51
1991.7.1	6,559,337	0.02%	55,013,776	2.25%	8.39
1994.4.20	6,550,245	-0.05%	54,366,015	-0.39%	8.30
1999.7.1	6,203,249	-1.08%	53,806,580	-0.21%	8.67
2001.10.1	6,138,312	-0.52%	54,912,703	1.02%	8.95
2004.6.1	5,728,492	-2.28%	52,067,396	-1.76%	9.09
2006.10.1	5,722,559	-0.05%	54,184,428	2.01%	9.47

Table 2: Number of Establishments by type

	Single Est.	Headquarter	Branch	Total
2001 Survey	4,722,947	229,436	1,185,929	6,138,312
2006 Survey	4,238,068	228,664	1,255,827	5,722,559

Table 3: Linking performance with patent database

	2001	2006
# of firms	5,082,267	4,627,530
with patent	66,852	64,640
% with patent	1.32%	1.40%
# of patent	6,202,304	5,752,461
% of coverage	62.86%	58.30%

Table 4: Share of patenting firms by size (2006 data)

	With patent		W/O patent	All
0	28	(0.0%)	1,385,156	1,385,184
1	920	(0.1%)	627,732	628,652
2	2,155	(0.4%)	501,320	503,475
3	2,336	(0.6%)	374,286	376,622
4-5	4,724	(0.9%)	493,577	498,301
6-10	9,217	(1.7%)	544,238	553,455
11-100	32,688	(5.2%)	592,940	625,628
101-1000	11,343	(21.4%)	41,780	53,123
1001-	1,229	(39.8%)	1,861	3,090

Table 5: Share of patenting firms by establishment year (2006 data)

	With patent		W/O patent	All
-1954	8,273	(1.8%)	460,419	468,692
1955-64	7,934	(2.2%)	345,260	353,194
1965-74	12,355	(1.9%)	650,224	662,579
1975-84	11,052	(1.4%)	789,711	800,763
1985-94	12,989	(1.3%)	962,876	975,865
1995-99	5,332	(1.0%)	505,513	510,845
2000	1,302	(1.2%)	111,691	112,993
2001	1,080	(0.9%)	113,962	115,042
2002	1,005	(1.0%)	104,480	105,485
2003	985	(0.8%)	124,388	125,373
2004	1,009	(0.8%)	131,260	132,269
2005	745	(0.6%)	126,226	126,971
2006	457	(0.4%)	108,249	108,706

Table 6: Share of patenting firms by industry (2006 data)

	With patent		W/O patent	All
A . Agriculture	193	(1.6%)	12,013	12,206
B . Forestry	25	(1.8%)	1,411	1,436
C . Fisheries	25	(1.1%)	2,312	2,337
D . Mining	71	(3.1%)	2,309	2,380
E . Construction	5,810	(1.2%)	491,276	497,086
F . Manufacturing	29,117	(6.5%)	446,897	476,014
G . Electricity, Gas, Heat Supply and Water	91	(12.9%)	708	799
H . Information and Communications	3,251	(8.7%)	37,435	40,686
I . Transport	742	(0.9%)	85,209	85,951
J . Wholesale and Retail Trade	15,916	(1.4%)	1,163,064	1,178,980
K . Finance and Insurance	257	(0.7%)	34,280	34,537
L . Real Estate	845	(0.3%)	289,647	290,492
M . Eating and Drinking Places, Accommodations	608	(0.1%)	677,437	678,045
N . Medical, Health Care and Welfare	249	(0.1%)	264,929	265,178
O . Education, Learning Support	326	(0.2%)	131,486	131,812
P . Compound Services	258	(1.7%)	15,300	15,558
Q . Services, N.E.C.	6,856	(0.8%)	907,177	914,033

Table 7: Share of patenting firms by industry (2006data; manufacturing in detail)

	With patent		W/O patent	All
09 Manufacture of food	1,609	(4.0%)	40,167	41,776
10 Manufacture of beverages, tobacco	404	(6.6%)	6,084	6,488
11 Manufacture of textile mill products	807	(3.4%)	23,480	24,287
12 Manufacture of apparel	760	(2.4%)	32,332	33,092
13 Manufacture of lumber and wood products	473	(3.1%)	15,382	15,855
14 Manufacture of furniture and fixtures	499	(1.9%)	25,900	26,399
15 Manufacture of pulp, paper and paper products	834	(8.1%)	10,286	11,120
16 Printing and allied industries	942	(2.6%)	36,930	37,872
17 Manufacture of chemical and allied products	1,401	(34.2%)	4,101	5,502
18 Manufacture of petroleum and coal products	95	(19.8%)	479	574
19 Manufacture of plastic products	1,972	(10.4%)	19,019	20,991
20 Manufacture of rubber products	383	(7.4%)	5,178	5,561
21 Manufacture of leather tanning, leather products	199	(3.0%)	6,671	6,870
22 Manufacture of ceramic, stone and clay products	1,324	(7.2%)	18,285	19,609
23 Manufacture of iron and steel	461	(8.9%)	5,187	5,648
24 Manufacture of non-ferrous metals and products	408	(10.7%)	3,813	4,221
25 Manufacture of fabricated metal products	3,224	(5.3%)	60,628	63,852
26 Manufacture of general machinery	5,706	(10.7%)	53,230	58,936
27 Manufacture of electrical machinery, equipment	2,013	(13.8%)	14,604	16,617
28 Manufacture of ICT equipment	499	(17.0%)	2,933	3,432
29 Electronic parts and devices	1,172	(13.6%)	8,595	9,767
30 Manufacture of transportation equipment	1,332	(7.1%)	18,700	20,032
31 Manufacture of precision instruments and machinery	1,205	(15.6%)	7,702	8,907
32 Miscellaneous manufacturing industries	1,395	(5.1%)	27,211	28,606

Table 8: Entry, continue and exit of firm by size

	Entry	Continue		Exit
		2001	2006	
all firms	1.07%	1.47%	1.49%	0.93%
0	0.01%	0.00%	0.00%	0.00%
1	0.26%	0.07%	0.12%	0.19%
2	0.57%	0.26%	0.38%	0.47%
3	0.76%	0.48%	0.58%	0.68%
4-5	1.03%	0.82%	0.92%	1.05%
6-10	1.46%	1.55%	1.74%	1.68%
11-100	3.05%	5.55%	5.94%	3.83%
101-1000	11.08%	24.00%	23.48%	12.65%
1001-	21.18%	47.49%	41.93%	30.22%

Table 9: Entry, continue and exit of firm by establishment year

	Entry	Continue		Exit
		2001	2006	
-1954	-	1.78%	1.78%	0.80%
1955-64	-	2.19%	2.25%	0.92%
1965-74	-	1.80%	1.86%	0.94%
1975-84	-	1.36%	1.36%	0.91%
1985-94	-	1.29%	1.29%	1.06%
1995-99	-	0.93%	0.97%	0.96%
2000	-	0.73%	0.94%	0.70%
2001	1.05%	-	-	-
2002	0.99%	-	-	-
2003	0.79%	-	-	-
2004	0.78%	-	-	-
2005	0.59%	-	-	-
2006	0.42%	-	-	-

Table 10: Entry, continue and exit of firm by industry

	Entry	Continue		Exit
		2001	2006	
A . Agriculture	1.07%	1.82%	1.75%	0.67%
B . Forestry	2.45%	1.52%	1.57%	1.62%
C . Fisheries	1.62%	0.65%	0.97%	0.49%
D . Mining	1.37%	3.46%	3.21%	1.61%
E . Construction	0.90%	1.22%	1.22%	0.84%
F . Manufacturing	5.26%	6.01%	6.25%	3.27%
G . Electricity, Gas, Heat Supply and Water	4.23%	14.24%	13.99%	5.46%
H . Information and Communications	6.56%	9.29%	9.47%	6.55%
I . Transport	0.50%	0.98%	0.97%	0.39%
J . Wholesale and Retail Trade	1.17%	1.43%	1.39%	0.86%
K . Finance and Insurance	0.52%	0.82%	0.87%	0.53%
L . Real Estate	0.39%	0.24%	0.27%	0.40%
M . Eating and Drinking Places, Accommodations	0.05%	0.11%	0.11%	0.05%
N . Medical, Health Care and Welfare	0.13%	0.07%	0.08%	0.07%
O . Education, Learning Support	0.37%	0.19%	0.19%	0.12%
P . Compound Services	1.24%	1.64%	1.73%	1.24%
Q . Services, N.E.C.	0.92%	0.69%	0.70%	0.84%

Table 11: Entry, continue and exit of firm by industry (manufacturing in detail)

	Entry	Continue		Exit
		2001	2006	
09 Manufacture of food	2.54%	3.90%	4.06%	2.17%
10 Manufacture of beverages, tobacco	5.29%	6.33%	6.38%	3.38%
11 Manufacture of textile mill products	3.11%	3.36%	3.34%	1.22%
12 Manufacture of apparel	1.82%	2.29%	2.37%	0.96%
13 Manufacture of lumber and wood products	3.12%	2.81%	2.97%	1.40%
14 Manufacture of furniture and fixtures	1.91%	1.80%	1.89%	1.39%
15 Manufacture of pulp, paper and paper products	6.18%	7.23%	7.67%	3.93%
16 Printing and allied industries	2.13%	2.50%	2.55%	1.25%
17 Manufacture of chemical and allied products	15.66%	28.10%	28.48%	15.30%
18 Manufacture of petroleum and coal products	9.63%	16.75%	18.68%	9.43%
19 Manufacture of plastic products	7.02%	9.41%	9.80%	4.90%
20 Manufacture of rubber products	4.78%	6.92%	7.28%	2.32%
21 Manufacture of leather tanning, leather products	2.07%	3.07%	3.03%	1.29%
22 Manufacture of ceramic, stone and clay products	4.73%	6.61%	7.03%	3.47%
23 Manufacture of iron and steel	3.91%	8.67%	9.05%	3.94%
24 Manufacture of non-ferrous metals and products	7.18%	9.65%	10.12%	4.81%
25 Manufacture of fabricated metal products	3.60%	5.05%	5.26%	2.75%
26 Manufacture of general machinery	8.15%	9.52%	9.93%	6.97%
27 Manufacture of electrical machinery, equipment	10.50%	11.70%	12.45%	6.84%
28 Manufacture of ICT equipment	11.18%	14.45%	15.36%	9.90%
29 Electronic parts and devices	10.35%	11.79%	12.40%	6.37%
30 Manufacture of transportation equipment	4.64%	7.05%	7.02%	4.17%
31 Manufacture of precision instruments and machinery	12.96%	13.44%	13.66%	8.57%
32 Miscellaneous manufacturing industries	5.24%	4.59%	4.81%	3.16%

Table 12: Entry, continue and exit of firm and open innovation

	Inter firm network		U-I collaborations	
	2001	2006	2001	2006
Entry		41.7%		13.2%
Continue	37.4%	43.4%	12.0%	14.4%
Exit	33.7%		8.1%	

Table 13: Share of open innovation firm by size (only for continuing firms)

	Inter firm network		U-I collaborations	
	2001	2006	2001	2006
0	0.0%	20.0%	10.0%	20.0%
1	23.1%	29.3%	8.7%	10.6%
2	24.1%	30.1%	5.1%	7.3%
3	20.6%	27.6%	4.0%	6.0%
4-5	22.5%	29.4%	4.2%	6.3%
6-10	24.0%	32.1%	4.1%	6.1%
11-100	33.6%	41.6%	8.1%	11.0%
101-1000	60.1%	61.1%	26.8%	29.3%
1001-	78.4%	68.0%	55.3%	49.1%

Table 14: Share of open innovation firm by industry (only for continuing firms)

	# of firms	Inter firm network		U-I collaborations	
		2001	2006	2001	2006
A . Agriculture	165	27.3%	35.8%	9.7%	17.6%
B . Forestry	17	17.6%	29.4%	11.8%	11.8%
C . Fisheries	13	15.4%	23.1%	7.7%	15.4%
D . Mining	75	41.3%	53.3%	17.3%	20.0%
E . Construction	4,972	34.0%	39.7%	11.1%	12.2%
F . Manufacturing	24,780	38.5%	45.0%	10.9%	13.5%
G . Electricity, Gas, Heat Supply and Water	87	63.2%	67.8%	35.6%	42.5%
H . Information and Communications	1,860	29.1%	38.1%	6.8%	10.3%
I . Transport	637	41.4%	50.4%	8.3%	8.6%
J . Wholesale and Retail Trade	13,611	41.2%	45.7%	15.0%	16.8%
K . Finance and Insurance	173	37.6%	44.5%	11.0%	12.7%
L . Real Estate	545	23.3%	29.0%	4.6%	5.7%
M . Eating and Drinking Places, Accommodations	531	24.7%	26.4%	8.1%	8.7%
N . Medical, Health Care and Welfare	127	22.8%	29.9%	8.7%	15.7%
O . Education, Learning Support	168	25.0%	25.0%	14.9%	16.7%
P . Compound Services	222	0.0%	0.0%	71.6%	94.1%
Q . Services, N.E.C.	4,816	32.5%	39.8%	10.9%	14.2%

Table 15: Share of open innovation firm by industry (only for continuing firms; manufacturing in detai)

	# of firms	Inter firm network		U-I collaborations	
		2001	2006	2001	2006
09 Manufacture of food	1417	25.12%	29.78%	9.10%	12.00%
10 Manufacture of beverages, tobacco	366	26.78%	31.15%	11.20%	14.75%
11 Manufacture of textile mill products	760	37.24%	44.21%	9.08%	11.97%
12 Manufacture of apparel	665	20.75%	26.47%	2.71%	3.91%
13 Manufacture of lumber and wood products	413	29.54%	34.38%	7.75%	10.65%
14 Manufacture of furniture and fixtures	419	19.81%	26.25%	5.97%	8.35%
15 Manufacture of pulp, paper and paper products	714	34.31%	41.18%	5.46%	7.42%
16 Printing and allied industries	810	28.02%	34.32%	5.06%	6.17%
17 Manufacture of chemical and allied products	1169	57.31%	61.33%	26.43%	29.68%
18 Manufacture of petroleum and coal products	70	52.86%	57.14%	21.43%	30.00%
19 Manufacture of plastic products	1693	42.35%	50.97%	9.45%	11.70%
20 Manufacture of rubber products	327	44.65%	51.99%	11.93%	12.84%
21 Manufacture of leather tanning, leather products	183	15.85%	20.77%	1.09%	1.09%
22 Manufacture of ceramic, stone and clay products	1167	40.36%	48.41%	15.77%	19.88%
23 Manufacture of iron and steel	398	46.98%	51.76%	16.58%	17.84%
24 Manufacture of non-ferrous metals and products	349	54.44%	57.31%	16.62%	17.48%
25 Manufacture of fabricated metal products	2803	35.39%	43.74%	7.53%	10.31%
26 Manufacture of general machinery	4809	40.53%	46.60%	10.63%	12.89%
27 Manufacture of electrical machinery, equipment	1611	46.74%	53.01%	12.04%	14.65%
28 Manufacture of ICT equipment	413	44.07%	50.12%	13.32%	18.16%
29 Electronic parts and devices	935	45.35%	54.97%	12.51%	17.43%
30 Manufacture of transportation equipment	1178	48.47%	54.33%	16.47%	19.02%
31 Manufacture of precision instruments and machiner	983	40.69%	46.59%	13.22%	17.50%
32 Miscellaneous manufacturing industries	1128	24.20%	29.96%	4.79%	5.76%

Table 16: Firm’s survival and innovation activities (Probit Model)

	(1)	(2)	(3)	(4)
Patent	0.141	-0.254	-0.204	-0.389
	(24.15)**	(17.48)**	(10.42)**	(7.83)**
Log(emp)		0.094		-0.01
		(163.46)**		(5.31)**
Log(age)			0.183	0.148
emp=<100			(266.10)**	(142.60)**
Lof(emp)*log(age)				0.035
				(54.50)**
Log(emp)*patent		0.108		0.143
		(24.88)**		(8.03)**
Log(age)*patent			0.122	0.06
			(17.90)**	(3.44)**
Lof(emp)*log(age)				-0.016
*patent				(2.63)**
Constant	0.036	-0.141	0.118	0.084
	(1.00)	(2.79)**	(3.12)**	(2.23)*
Industry dummy	Yes	Yes	Yes	Yes
Size summy	Yes	No	Yes	No
Age summy	Yes	Yes	No	No
Observations	5037471	5037471	4456259	4456259

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

Table 17: Firm's growth and innovation activities (Fixed Effect Model)

	(1)	(2)	(3)	(4)
Log(patent)	0.026 (7.48)**	0.260 (19.78)**	0.025 (5.24)**	0.027 (5.25)**
Log(patent)*log(emp)		-0.018 (6.59)**		
Log(patent)*log(age)		-0.058 (12.85)**		
log(univ+1)			-0.004 (0.44)	0.033 (0.82)
log(firm+1)			0.004 (0.52)	0.275 (12.13)**
log(univ+1)*log(emp) *log(patent)				-0.01 (1.50)
log(firm+1)*log(emp) *log(patent)				-0.019 (4.34)**
log(univ+1)*log(age) *log(patent)				0.013 (1.01)
log(firm+1)*log(age) *log(patent)				-0.065 (8.67)**
Constant	3.471 (674.31)**	3.295 (602.60)**	3.470 (669.30)**	3.282 (613.47)**
Observations	101939	86259	101939	86259
Number of group	52799	44643	52799	44643
R-squared	0.00	0.01	0.00	0.01

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

Figure 1: Structure of IIP Patent Database

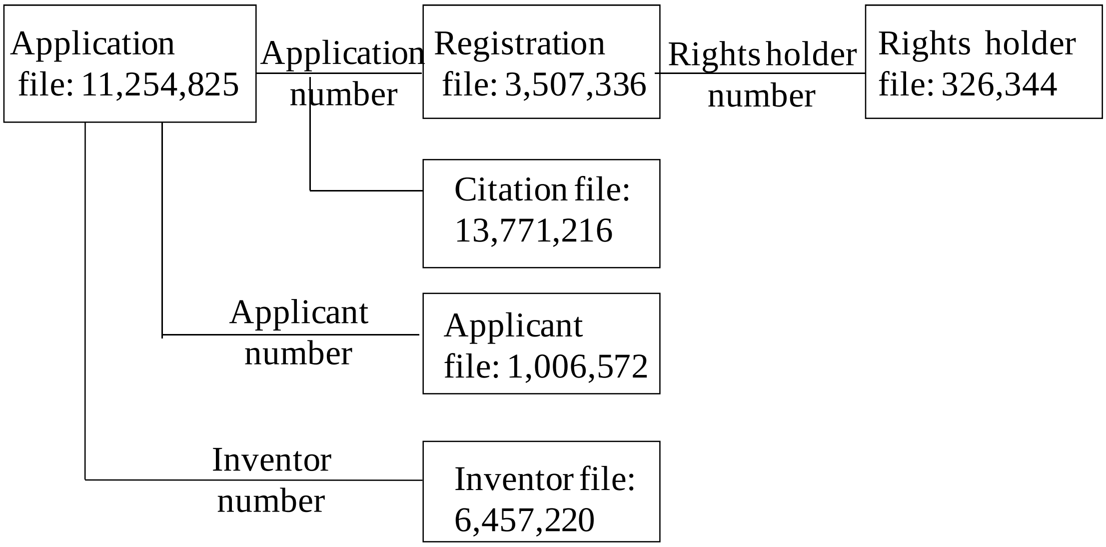

Figure 2: Cumulative number of firms by last year of patent applications