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Determinants of Demand for Technology in Relationships with Complementary Assets among Japanese Firms*

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Abstract: *There has been growing interest in open innovation, where firms create value by combining internal and external ideas. Technology insourcing, however, has not been satisfactorily investigated in the empirical literature compared to technology outsourcing. In this paper, we examine the determinants of external technology sourcing by the type of counterpart in the new product development (NPD) process. We use a novel dataset at the product level, compiled by the Research Institute of Economy, Trade and Industry in 2011. We distinguish whether the technology partner is also a business partner, such as a supplier or customer. Our findings show that when the technology partner is not a business partner, patents play an important role in moderating the transaction costs in a partnership. On the other hand, when the technology partner is also a business partner, we find co-specialisation of technology and its complementary assets with the partner firm.*

Keywords: technology sourcing, co-specialisation, complementary assets, division of innovative labour

JEL Classification: D22, L22, O32

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1. Introduction

The division of innovative labour is progressing in high-tech sectors, such as for software and pharmaceutical products; consequently, the effective use of external knowledge sources has become an important issue in the technology management of firms (Arora, Fosfuri, and Gambardella, 2001). Intense product competition induces firms to speed up their research and development (R&D) processes so that they are inclined to seek an open-innovation model instead of in-house development (Motohashi, 2005). Therefore, we can see a growing trend in the size of the technology market through patent licensing (Arora and Gambardella, 2010). However, the process of new product development (NPD) is too complex to be decomposed into separate activities, so the knowledge generation process for NPD is mostly constrained within a firm or a limited number of business partners (Arora, Fosfuri, and Gambardella, 2001). Teece (1998) lists three reasons why this is the case: (1) difficulty in explicitly describing the task requirements, (2) the use of -specific assets, and (3) the risk of information leakages to competitors.

This paper empirically investigates how to manage such difficulties by using data from a questionnaire survey on the source of knowledge for NPD in Japanese firms. Here, we explicitly treat complementary assets to technology, such as marketing, human resources and channels to understand the determinants of external technology sourcing, since our survey data cover the whole process of innovation until a new product is introduced into the market. We also shed new light on the differences in the management of technology sourcing by the type of counterpart, whether it is the firm's business partner (supplier or customer) or not. There are a substantial number of empirical studies that investigate the nature of technology sourcing (Cassiman and

Veugelers, 2006; Ceccagnoli et al., 2010; Gooroochurn and Hanley, 2007), but they do not consider the simultaneous occurrence of technology and business transactions. From our survey, we find that a substantial number of external partners in the NPD process are also business partners. Therefore, the innovative division of labour does not occur independently from the business relationship (Arora, Fosfuri, and Gambardella, 2001).

In many cases, the NPD process at business-to-business firms is jointly organised by the firms and their customers. A typical example is found in the relationship between an automobile assembler and a parts company. In many cases, the parts supplier jointly develops new products with its customer, the assembler, instead of producing a product completely specified by the customer (Dyer, 1996). In cases such as this, co-specialisation of relation-specific investment is facilitated more by long-term supplier–manufacturer relationships than relationships between those dealing with pure technology transactions in market-based competition (Jacobides and Winter, 2005). Therefore, this paper distinguishes between two types of technology partnerships – whether a technology partner is a business partner or not – to more clearly understand the mechanism of technology sourcing in the NPD process.

The remainder of this paper is structured as follows. Section 2 provides the framework for our empirical analysis. We conduct a survey of the literature on theories of technology sourcing and firm boundaries in the NPD process, starting from transaction cost theory combined with some management literature on the resource-based view (RBV) to construct our analytical framework. Section 3 presents a description of the study's survey and the variables used for our empirical model. Section 4 shows the results of the econometric analysis of the determinants of technology sourcing. Section 5 summarises our main findings and provides further research questions.

2. Framework of the Empirical Analysis

Based on the framework of transaction costs introduced by Coase (1937), the boundary of the firm, that is, the make-or-buy decision, is determined by the relative costs of an internal exchange compared to an external exchange. The earliest literature on the make-or-buy decision addressed the choice between external sourcing and in-house procurement, and then modelled firms as choosing between markets and hierarchies, as expressed by the title of Williamson's book in 1975 (Klein, 2005). Williamson (1991) develops transaction cost economics and distinguishes between market, hybrid, and hierarchy organisation forms. A hybrid form is a non-standard, vertical, contractual arrangement, such as a long-term contract, partial ownership agreement, franchise, network, or alliance. Joskow (2005) reviews the causes and consequences of vertical forms and the relationships between vertical integration (or hierarchy) and substitute, non-standard, vertical, contractual (or hybrid) arrangements, both theoretically and empirically. Empirical studies of a firm's boundary decision, as reviewed by Klein (2005) and Lafontaine and Slade (2007), use the organisation form defined as 'make, buy, or hybrid' as the dependent variable, and introduce asset specificity, uncertainty, complexity, and frequency as explanatory variables.

More importantly, asset specificity is an important factor in a firm's boundary decision, and higher asset specificity has a higher value under the condition of a specific utilisation or relationship. Similarly, a relationship-specific investment involves investing in assets that support a specific trading relationship, including both specialised physical and human capital, along with intangibles such as R&D and firm-specific knowledge or capabilities (Klein, 2005). Even if an investment is efficient, firms will not invest in relationship-specific assets because once relationship-specific investments have been made, owners of the assets can face a hold-up problem; vertical contracts mitigate the hold-up problem. Williamson (1991) expresses the governance cost of each organisation form (market, hybrid, and hierarchy) as a function of asset specificity and denotes that the organisation form changes from market to hybrid and then to hierarchy as asset specificity increases.

In addition, property rights theory based on more formal economic modelling has developed and addressed the firm boundary questions (Hart, 1995). Property rights theory focuses on the investment incentives of players in a joint production system and suggests that asset specificity in relationship-specific investment leads to lower incentives for players who fear an ex-post hold-up problem by their counterparts. Therefore, greater asset specificity makes vertical integration more efficient, as is the case in transaction cost theory. However, it should be noted that technological complexity and uncertainty of a joint project do not always lead to vertical integration in this model. For example, if a supplier and manufacturer are involved in a joint production activity, technological complexity in the upstream activity induces a higher marginal return to the supplier's investment. As a result, separation of the supplier and the manufacturer becomes more efficient compared with integration by the manufacturer's ownership of the supplier's asset (Lafontaine and Slade, 2007; Acemoglu et al., 2010).

Transaction cost theory (as well as property rights theory) addresses mainly the cost of the transaction but not so much its potential gain. If a large gain is expected from a market transaction, a firm may prefer 'buy' instead of 'make', even if the transaction cost is high. The potential gain from ‘buy’ instead of ‘make’ comes from managerial resources on the seller side, which are difficult for the buyer to make by itself. The resource-based view (RBV) theory perceives a firm’s assets as a source of competitiveness that differentiates it from other firms. Organisational capabilities and accumulated technology with economic value are rare and highly difficult to imitate to create a sustainable advantage vis-à-vis a firm’s competitors, so these resources cannot easily be transferred between firms (Barney, 1991). According to the RBV, inter-firm collaboration occurs in the process of accessing complementary assets in other firms instead of minimising the transaction cost associated with such a partnership (Madhok, 2002).

Jacobides and Winter (2005) combine the ideas of transaction cost theory and the RBV to illustrate a dynamic mechanism of the capability specialisations of industry players (co-specialisation), which changes the transaction costs among them. This mechanism starts with the selection of partners in a space where different assets are distributed among firms. Then, a firm starts determining an institutional setting for the lower transaction cost. Using a market intermediary or consultancy service is one solution. In addition, repeated interactions with one partner substantially reduce the transaction cost of the partnership. In a world of decreasing transaction costs, co-specialisation of a firm’s investment increases the firm’s capability. This leads to further development of intermediation services and drives down the transaction cost.

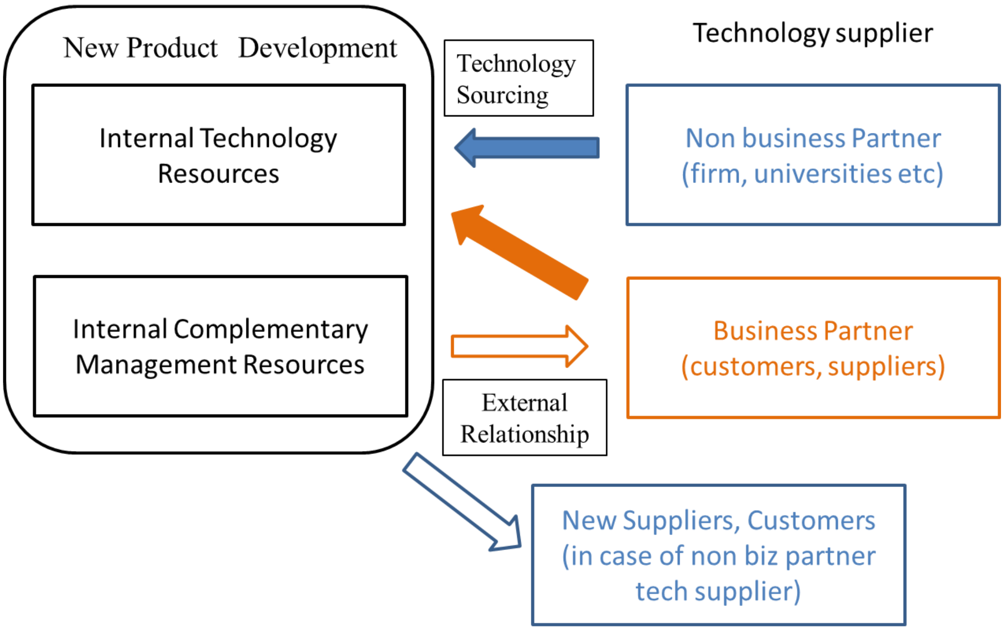
Lavie (2006) proposes that the asset can be shared, instead of being mutually exclusive, taking into account the non-rival nature of knowledge and technology. Empirically, the existence of shared technology resources is supported by the fact that internal R&D activities and the adoption of external technology are often not mutual substitutes but complements. The R&D boundary decision is considered as make-and-buy and not make-or-buy. Cassiman and Veugelers (2006) investigate the innovation strategies of ‘NoMake&Buy’, ‘MakeOnly’, ‘BuyOnly’, and ‘Make&Buy’ using survey data on innovation in the Belgian manufacturing industry. They suggest that internal R&D and external knowledge acquisition are complementary innovation activities and that the ‘Make&Buy’ strategy increases the share of sales from new products. However, the degree of complementarity is sensitive to other elements of the firm’s strategic environment. An effective intellectual property rights protection industry, effective strategic protection, and basic R&D reliance increase the probability of adopting the ‘Make&Buy’ strategy.

The portion of appropriated rent from the shared resources is called an appropriated relational rent and is determined by various factors, including the relative absorptive capacity and relative scope/scale of resources (Lavie, 2006). The absorptive capacity is the learning capability from an alliance, such as the acquisition of external technology and its exploitation to gain economic rent (Cohen and Levinthal, 1990). The relative absorptive capacity reflects the efficiency of rent extraction from the shared resources. As for the size of the appropriated relational rent, the size of the potential shared resources does matter. In this sense, a relatively smaller firm may be able to gain from an alliance with a larger firm with wider and greater resources (Lavie, 2006).

In addition, in the course of interaction with partners, a technology is exposed to other companies, making it difficult to appropriate the rent arising from that technology. R&D partnerships have both a spillover effect, which broadens a firm’s own technology base, and a heightened risk of technology leakage, which reduces the likelihood of appropriating rents from the technology. Methods to increase a technology’s ability to appropriate rent, in addition to intellectual property rights protection, include the complexity of product design and speed of development (Levin et al., 1986). Some research findings indicate that firms with a greater ability to control the outside spillover effect are able to pursue more partnerships (Cassiman and Veugelers, 2002).

Based on the discussions above, we propose a framework of empirical investigations in Figure 1. A novel part of this study is analysing the determinants of external technology sourcing by the type of counterpart, i.e. whether the counterpart is a firm's business partner (supplier or customer) or not. In the NPD process, a firm relies solely on its internal technology resources or in-source external technologies as well. We consider whether the determinants of the make-or-buy decisions change with the type of the potential counterpart (technology supplier). In the case of a business partner that is a technology supplier, the complementary managerial resources to technology in the NPD process, such as marketing channels, are also related to the technology partner. Therefore, the two parties involved in the technology transactions are supposed to have a mutual understanding in their business. In contrast, if a firm insources technology from a non-business partner, technology transactions occur independently from their business transactions, so the complementary resources for appropriating rents from technology are not related to the technology supplier.

Figure 1. A Business Partner or Non-business Partner as the Technology Supplier in the New Product Development Process



Therefore, technology transactions with a business partner are conducted in close coordination in the entire NPD process between a seller and a buyer, including appropriating rents from technology, while technology sourcing from a non-business partner is managed purely by technology transactions in the market. Consequently, it is presumed that transaction cost theory is more relevant for considering the determinants of technology transaction with a non-business partner. In contrast, technology sourcing from business partners is based on the idea of mutually beneficial managerial resources, not only of technology but also complementary assets, such as specialised inputs and marketing channels.

3. Data and Variables

3.1 Survey of new product development

We conducted a survey of 18,000 business units of Japanese firms in 2011, of which 3,705 responded (response rate = 20.6%). In this survey, NPD is defined according to the *Oslo Manual* of the Organisation for Economic Co-operation and Development. Further, we identified the sources of information for NPD for 1,390 business units (38% of the total number of responses) that introduced new products between 2008 and 2010.

To consider the innovation activities for a new product, we categorise our data by innovation strategy (Figure 1). First, we classify the activities into two categories depending on whether they are mainly internal or external development:

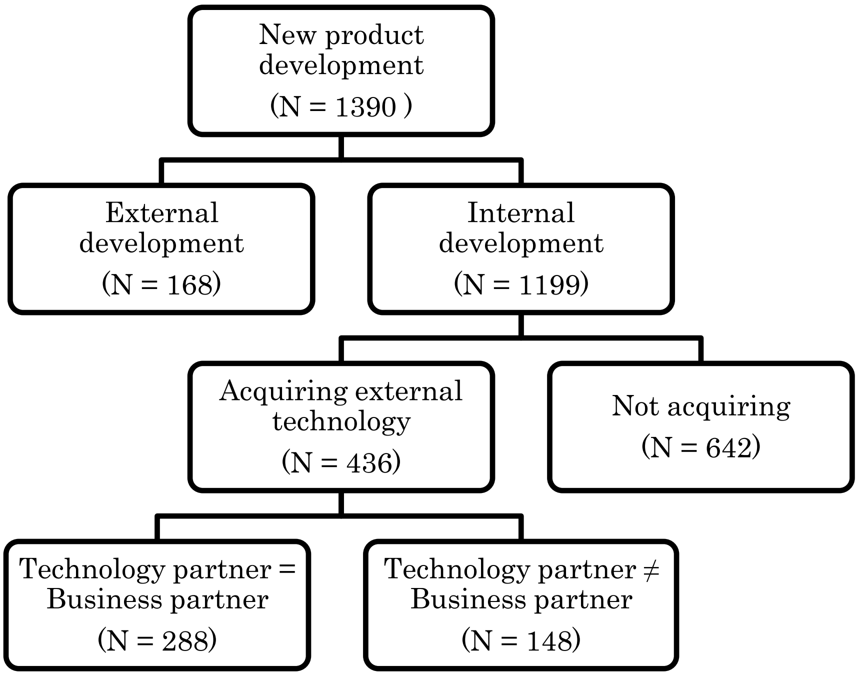
- Internal development: firms mainly develop the new product or service by themselves.
- External development: outside organisations mainly develop the new product or service.

The vast majority of the sample (1,199 firms 86%) undertook internal development, while the remainder (168 firms; 12%) undertook external development. The group that undertook external development includes two types of businesses. The first type comprises firms that introduced a product that firms had developed (and manufactured) and then sold through their sales network without internal R&D expenditure. The other type comprises firms that subcontracted to produce an order using a design from the contractees. We consider the differences in the structure of innovation between these businesses and those who chose to develop the products by themselves. Therefore, in this paper, we analyse the group with internal development. Among the terminology of Cassiman and Veugeles (2006), that is, ‘NoMake&Buy’,

‘MakeOnly’, ‘BuyOnly’, and ‘Make&Buy’, our study focuses on ‘MakeOnly’ and ‘Make&Buy’, which involve internal development activity.

For the units with internal development, we determine whether they formally acquired external technology and how they acquired it. In Figure 2, the number of firms ‘acquiring external technology’ is the number of firms that developed the prototype using at least one of the formal ways, such as entering into a contract with outside organisations, mergers and acquisitions or investment, joint ventures or collaborative R&D, licencing, or R&D commission or consulting (436 units).

Figure 2. Innovation Strategy for the New Product Development Process



Note: The sample sizes in the lower levels do not fully match the number in the higher levels because of inconsistencies in the available data.

Furthermore, we focus on the type of technology partner. Figure 2 illustrates the NPD process incorporating external technologies. A discussion on the firm’s boundary of technological development is made whether there is an external collaborator for technological contents (technology partner). The NPD process, however, involves not only technological development but also product conceptualisation to take into account market needs. For example, automotive parts manufacturers often jointly develop parts with their customers, the automotive manufacturers. In such cases, the automotive manufacturers provide both external technologies and customers. The decision to incorporate external technologies is made in conjunction with the client, leaving the firm in question with no choice. Incorporating external technologies from a particular customer or supplier is not an isolated technology market issue but rather calls for consideration within an analytical framework that includes the relationship with business partners.

Therefore, we divide the sample of firms acquiring external technology by the type of partner: technology partner = business partner (T = B); and technology partner ≠ business partner (T ≠ B). Although the type of technology partner cannot be observed from the dataset, we can use information about the most important source of knowledge at the prototyping stage to distinguish whether T=B or T≠ B.

[1] Of the units, 66% of those who acquired external technology entered a transaction with a partner with whom they had a business relationship (23% with suppliers and 43% with customers). We define these samples as T = B.

The NPD process is too complex to decompose into separate activities, so the knowledge generation process for NPD is mostly constrained within a firm or a limited

[1] Survey question: In developing this product, did you utilise information from any of the following? Please reply and classify by 'conceptualisation stage' and 'prototyping stage'. (Check the most important source of knowledge.)
Respondent's choices: supplier; customer; another firm in your industry; consultant; engineering service provider or commercial laboratory; university; government laboratory; information on patents; public domain, such as publications or public meetings; or collaboration between your firm and others.

number of business partners (Arora et al., 2001). In our survey, the following items inquire whether new investments in complementary assets related to new products are made:

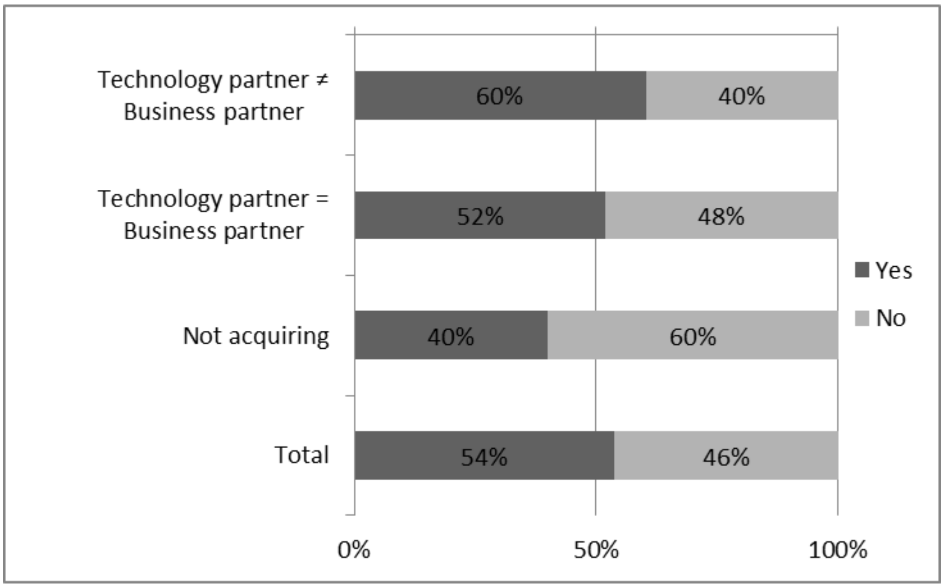
New channel: 'Did you develop new sales and distribution channels to commercialise the product?'

New production factor: 'Did you buy new types of equipment or hire employees with skills different from those of existing employees?'

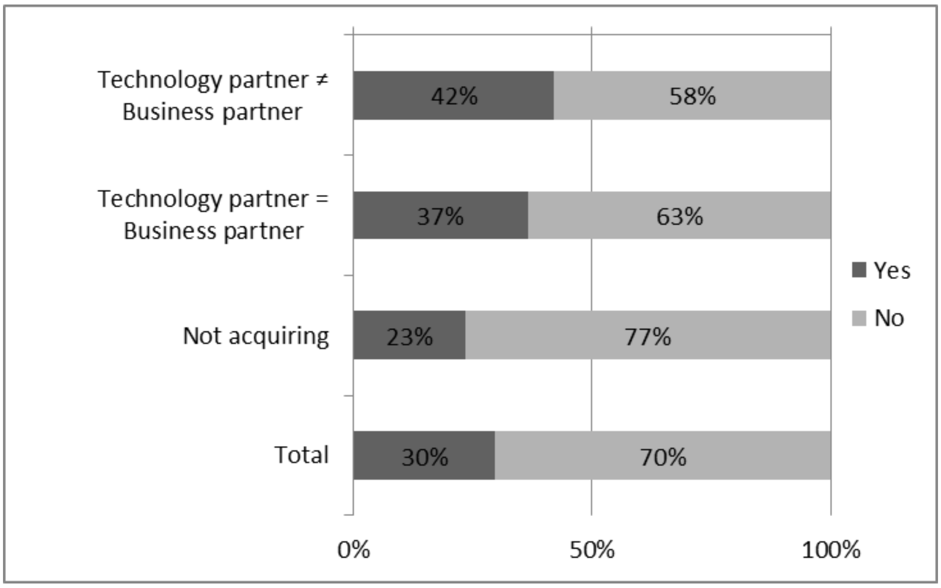
As shown in Figure 3, the groups acquiring external technology have higher requirements of new complementary resources, and the requirements of the group acquiring from T ≠ B are higher than those of the group acquiring from T = B in both items. Therefore, in the case of T = B, it is more likely for a firm to use the required marketing channels and new employees for the new products of the business partner. In contrast, in the case of T ≠ B, a firm invests in these complementary assets by itself.

Figure 3. Requirements for New Complementary Resources

New channel: 'Did you develop new sales and distribution channels to commercialise the product?'



New factor: 'Did you buy new types of equipment or hire new employees with skills different from those of existing employees?'



3.2 Dependent variables

We conduct two regression analyses to examine the determinants of external technology sourcing in the NPD process, as described in Section 4. In the first regression, using a probit model, the dependent variable is a dummy equal to 1 if the firm acquires external technology (a*cquiring*). In the second regression analysis, where we employ a multinomial logit model, the dependent variable is a set of three discrete choices: *Technology partner ≠ Business partner (T ≠ B)*; *Technology partner = Business partner (T = B)*; or *Not acquiring*.

3.3 Explanatory variables

To acquire external technology in the NPD process, we use the following explanatory variables related to transaction cost theories, and the degree of co-specialisation of technology and complementary assets based on the RBV in order to identify which factors are more relevant in the case of technology transactions of *T ≠ B* or *T = B*.

3.3.1 Transaction cost

Patent: A dummy variable that takes the value 1 if the respondents own the patents of the product.

As described in Section 2, asset specificity and uncertainty play important roles in determining a firm's boundary. In terms of technology transactions, a patent plays an important role in moderating transaction costs. First, intellectual property ownership mitigates the risk of an ex-post hold-up problem because it can be more easily traded with other parties. A related argument regarding patents is that patent information is disclosed to the public, which reduces information asymmetry between the technology owner and potential users.

3.3.2 Resource-based view

R&D: The propensity of R&D expenditure to sales in a business unit (the R&D intensity) is indicated by a categorical response, 0%, 0%–1%, 1%–3%, 3%–5%, 5%–10%, and more than 10%, on a scale of 0, 0.5, 1.5, 4, 7.5, and 10. In addition, *R&D0*, *R&D1*, *R&D2*, *R&D3*, *R&D4*, or *R&D5* take the value 1 if the survey respondent answered 0%, 0%–1%, 1%–3%, 3%–5%, 5%–10%, or more than 10%, respectively.

The magnitude of relational rent is affected by a variety of factors in the partner relationship, but first there is a positive relationship with absorptive capacity. Absorptive capacity comprises the capabilities of acquisition and assimilation, bringing in the technology from the partner, and the transformations and exploitations embodying the technology in new products and capturing the rent (Zahra and George, 2002). The greater these capabilities, the higher the rent that can be expected to be obtained from alliances, meaning that external partnerships will be pursued more proactively.

Different business: A dummy variable that takes the value 1 if the business category of the respondent's firm is different from the new product category, which consists of 90 categories.

Experience: A dummy variable that takes the value of 1 if the respondent's firm was filed more than 5 years ago.

Whether the NPD project is related to the firm's main business or a new field depends on its managerial resources and capabilities. A firm will gain relatively more from the partner by entering into alliances in fields in which it has less expertise. In contrast, a firm with substantial assets has less incentive to collaborate with others in the same field (Lavie, 2006). Here, we investigate the possible co-specialisation of technology and complementary assets. Studies have found that a pharmaceutical firm with larger marketing assets has less incentive to pursue technology insourcing (Ceccagnoli et al., 2010).

3.3.3 Control variables

A technology sourcing decision is complicated in nature. There are a substantial number of control variables that should be considered in our empirical model. The first is the speed of the innovation process.

First mover: A dummy variable that takes the value of 1 if the product was released ahead of other firms.

Internal departments could be an obstacle to acquiring external technology (i.e. an internal hampering factor), which Allen and Katz (1982) point out as the 'not-invented-here' syndrome. Internal departments are also a hampering factor in our survey. The other variables are control variables.

Not invented here: A dummy variable that takes the value of 1 if the respondent checked the item: 'Another department resists acquiring external information.'

To maximise the return from a technology partnership, it is also important to control any potential damage from an unintentional information leakage. Therefore, the following variable is also included:

Risk of divulging: A dummy variable that takes the value of 1 if the respondent checked the item: 'The risk from divulging internal information is too large.'

Finally, we control for the characteristics of a firm, its business relationships, and industry as follows:

Employee: We use the logarithm of the number of employees in the firm.

Start-up: A dummy variable that takes the value of 1 if the firm is a start-up, defined as being in business for less than 5 years.

Single specific customer: A dummy variable that takes the value of 1 if the product is sold to one specific customer.

Multiple specific customers: A dummy variable that takes the value of 1 if the product is sold to multiple specific customers.

Affiliated supplier: A dummy variable that takes the value of 1 if the firm mainly receives supplies from affiliated companies.

Affiliated customer: A dummy variable that takes the value of 1 if the firm's main customers are affiliated companies.

Industry dummy variables: To control for industry characteristics, we include seven dummy variables: chemicals, pharmaceuticals, electronics, machinery, transportation, instruments, and IT services.

Table 1 presents the summary statistics of the variables according to the type of technology acquisition: ‘acquiring from T $\neq$ B’, ‘acquiring from T = B’, or ‘not acquiring’. In both ‘acquiring from T $\neq$ B’ and ‘acquiring from T = B’, the score of R&D intensity and the rates of the product, which is from a non-core business field, *different business*, or released ahead of other firms, *first mover*, are higher than in ‘not acquiring’. In contrast, in ‘acquiring from T $\neq$ B’, more than half of the firms own patents for the new product, and the proportion of products for specific customers is higher than those in the other two groups in ‘acquiring from T = B’. We can observe the different attributes by the type of partner and external technology acquisition. Table 2 shows the correlation matrix.

Table 1. Descriptive Statistics

	Technology partner ≠ Business partner	Technology partner = Business partner	Not acquiring	Total
Patent	0.541	0.424	0.356	0.401
	(0.5)	(0.495)	(0.479)	(0.49)
R&D	3.373	3.432	2.854	3.086
	(3.284)	(3.014)	(2.748)	(2.913)
Different business	0.279	0.297	0.193	0.233
	(0.45)	(0.458)	(0.395)	(0.423)
Experience	0.762	0.775	0.827	0.804
	(0.427)	(0.418)	(0.379)	(0.397)
First mover	0.508	0.534	0.443	0.477
	(0.502)	(0.5)	(0.497)	(0.5)
Not invented here	0.090	0.068	0.058	0.065
	(0.288)	(0.252)	(0.233)	(0.247)
Risk of divulging	0.426	0.411	0.380	0.395
	(0.497)	(0.493)	(0.486)	(0.489)
Employee	4.933	5.240	5.137	5.136
	(1.551)	(1.567)	(1.392)	(1.466)
Start-up	0.033	0.025	0.038	0.034
	(0.179)	(0.158)	(0.191)	(0.181)
Single specific customer	0.057	0.174	0.082	0.103
	(0.234)	(0.38)	(0.274)	(0.305)
Multiple specific customers	0.205	0.347	0.286	0.292
	(0.405)	(0.477)	(0.452)	(0.455)
Affiliated customer	0.213	0.225	0.203	0.210
	(0.411)	(0.418)	(0.402)	(0.408)
Affiliated supplier	0.213	0.284	0.219	0.236
	(0.411)	(0.452)	(0.414)	(0.425)
N	122	236	503	861

R&D = research and development.

Note: The values are the sample means. Standard deviations are in parentheses.

Table 2. Correlation Matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Dep.ver.(Acquring)	1													
2	Patent	0.108	1												
3	R&D	0.095	0.240	1											
4	Different business	0.114	−0.048	−0.028	1										
5	Experience	−0.070	0.082	0.026	−0.163	1									
6	First mover	0.081	0.348	0.160	−0.005	−0.014	1								
7	Not invented here	0.036	0.034	−0.032	−0.045	0.047	−0.016	1							
8	Risk of divulging	0.037	0.135	0.064	0.004	0.064	0.065	0.009	1						
9	Employee	0.000	0.358	0.102	−0.056	0.140	0.148	0.092	0.099	1					
10	Start-up	−0.027	0.018	0.049	−0.012	−0.054	−0.037	0.055	0.047	−0.075	1				
11	Single specific customer	0.085	−0.106	0.030	0.047	−0.034	−0.057	−0.028	−0.001	−0.047	0.064	1			
12	Multiple specific customers	0.014	0.164	0.073	0.009	0.034	0.068	−0.003	0.083	0.119	−0.091	−0.218	1		
13	Affiliated customer	0.022	−0.021	−0.059	−0.015	0.068	−0.088	0.095	−0.038	−0.096	0.014	0.068	0.002	1	
14	Affiliated supplier	0.048	0.015	−0.043	−0.009	0.061	−0.043	0.064	0.016	−0.023	0.048	0.000	0.047	0.566	1

N=861

R&D = research and development.

4. Econometric Analysis

We analyse, for firms that mainly develop new products or services by themselves, the factors that determine whether a firm acquires external technology. First, we estimate the probit model of whether the firms decide to acquire external technology, as reported in Table 3. The coefficients show the marginal effects of these factors on the probability of external technology acquisition.

Owning patents for the new product (*patent*) has a positive effect on the probability of external technology acquisition. This result suggests that a firm acquires external technology if its in-house technology is adequately protected by patents because of the decreasing transaction costs of preventing opportunistic behaviour by a counterpart. Although *patent* could indicate evidence of being high-tech, we consider that it would be possible to identify this effect to some extent by controlling for R&D intensity and the industry dummy variables. Regarding the R&D intensity, in regression (1), there is a possibility that the effect of patent protection is overestimated because the marginal effect of *patent* largely decreases from 0.266 to 0.094 when we closely examine R&D intensity using the dummy variables in regression (2). Furthermore, for the willingness to acquire external technology, regressions (3) and (4) present the estimation results excluding units that do not have the willingness to acquire external knowledge or technology. This is to clearly identify the effect of firms moderating transaction costs by owning patents. We observe that the magnitudes of all the marginal effects decrease when comparing regressions (1) and (3), although there is no change in statistical significance. Therefore, the overestimation of *patent* in regression (1) could be caused by units that have no willingness for external knowledge or technology acquisition rather than R&D intensity because there is no difference between the results of regressions (3) and (4).

Table 3. Results of Probit Model Estimation for External Technology Acquisition

	(1)	(2)	(3)	(4)
	Acquiring	Acquiring	Acquiring	Acquiring
Patent	0.266**	0.094**	0.094**	0.088**
	(0.108)	(0.041)	(0.042)	(0.043)
R&D	0.030*		0.015**	
	(0.016)		(0.006)	
R&D1		−0.004		−0.003
		(0.101)		(0.101)
R&D2		0.006		0.031
		(0.102)		(0.101)
R&D3		0.037		0.067
		(0.104)		(0.104)
R&D4		0.003		0.048
		(0.110)		(0.112)
R&D5		0.201*		0.218*
		(0.119)		(0.118)
Different business	0.323***	0.124***	0.142***	0.145***
	(0.107)	(0.041)	(0.042)	(0.042)
Experience	−0.217*	−0.081*	−0.082*	−0.080*
	(0.116)	(0.044)	(0.046)	(0.046)
First mover	0.118	0.044	0.057	0.057
	(0.095)	(0.036)	(0.037)	(0.037)
Not invented here	0.260	0.105	0.081	0.086
	(0.179)	(0.068)	(0.069)	(0.069)
Risk of divulging	0.056	0.019	0.017	0.015
	(0.091)	(0.034)	(0.035)	(0.035)
Employee	−0.042	−0.011	−0.021	−0.017
	(0.034)	(0.013)	(0.013)	(0.013)
Start-up	−0.363	−0.147	−0.110	−0.123
	(0.243)	(0.091)	(0.094)	(0.095)
Single specific customer	0.338**	0.131**	0.140**	0.140**
	(0.153)	(0.058)	(0.061)	(0.061)
Multiple specific customers	−0.003	−0.005	−0.020	−0.027
	(0.103)	(0.038)	(0.040)	(0.040)
Affiliated customer	−0.028	−0.016	−0.020	−0.023
	(0.134)	(0.050)	(0.051)	(0.051)
Affiliated supplier	0.180	0.074	0.088*	0.093*
	(0.127)	(0.048)	(0.050)	(0.050)
Pseudo R2	0.043	0.047	0.050	0.053
Log Likelihood	−559.354	−557.183	−513.248	−511.915
N	861	861	792	792

R&D = research and development.

Note: Values in parentheses are robust standard errors. The coefficients are the marginal effects of the independent variable of the probability of external technology acquisition. The marginal effect for the factor levels is the discrete change from the base level. The industry dummy variables and the constant are dropped from the table. *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.

R&D, which shows the category variable depending on the R&D intensity, has a positive and significant effect on acquiring external technology. Furthermore, in regression (2), when we replace *R&D* with *R&D1*, *R&D2*, *R&D3*, *R&D4*, and *R&D5*, only the coefficient with the highest level of R&D intensity, *R&D5*, is positive and has a significant effect. This result implies that this group, which has more than 10% R&D intensity, increases the probability of external R&D acquisition rather than being monotonically increasing as a function of R&D intensity. Therefore, external collaboration is found particularly in high-tech firms.

We find significantly positive effects of *different business*, indicating that the probability of utilising an external technology increases by about 10% when a firm is not familiar with the business field. In addition, we find negative and statistically significant coefficients for *experience*. This is because a firm gains relatively more from the partner by entering into alliances in fields in which it has less expertise.

Next, we divide acquiring external technology by the type of partner and investigate the factors influencing the choice probability of acquiring from T ≠ B, acquiring from T = B, or not acquiring using the multinomial logit model. As discussed in Section 3.2, those who acquire technology from their business partners (T = B) invest less in complementary assets, such as new marketing channels and personnel, compared to firms acquiring from T ≠ B, which suggests the possibility of the division of labour in technology and complementary assets with their business partners. Table 4 shows the estimation results using multinomial logit models in which we use the following alternatives: *Technology partner ≠ Business partner (T ≠ B)*, *Technology partner = Business partner (T = B)*, and *Not acquiring*.[1] Note that our

[1] The base category is '*not acquiring*'. We conduct a specification test for the independence of irrelevant alternatives based on a seemingly unrelated estimation model since the Hausman test does not work. We cannot reject the equality of the common coefficients across the original

estimation model is not a sequential decision process of acquiring or not, followed by acquiring from T ≠ B or acquiring from T = B.

Table 4. Results of Multinomial Logit Model Estimation for External Technology Acquisition

	(5)			(6)			(7)		
	Technology partner ≠ Business partner	Technology partner = Business partner	Not acquiring	Technology partner ≠ Business partner	Technology partner = Business partner	Not acquiring	Technology partner ≠ Business partner	Technology partner = Business partner	Not acquiring
Patent	0.114***	−0.025	−0.089**	0.118***	−0.029	−0.088**	0.118***	−0.034	−0.084**
	(0.027)	(0.037)	(0.040)	(0.027)	(0.038)	(0.041)	(0.027)	(0.039)	(0.042)
R&D				0.004	0.011*	−0.014**			
				(0.004)	(0.006)	(0.006)			
R&D1	−0.029	0.029	−0.000				−0.039	0.042	−0.003
	(0.060)	(0.099)	(0.102)				(0.061)	(0.100)	(0.101)
R&D2	−0.091	0.099	−0.009				−0.081	0.117	−0.036
	(0.063)	(0.098)	(0.102)				(0.063)	(0.099)	(0.101)
R&D3	−0.056	0.100	−0.043				−0.045	0.119	−0.075
	(0.064)	(0.098)	(0.104)				(0.064)	(0.099)	(0.103)
R&D4	−0.047	0.054	−0.007				−0.034	0.090	−0.056
	(0.068)	(0.106)	(0.111)				(0.070)	(0.108)	(0.112)
R&D5	0.006	0.192*	−0.198*				−0.006	0.227**	−0.221*
	(0.070)	(0.110)	(0.119)				(0.071)	(0.112)	(0.120)
Different business	0.033	0.086**	−0.119***	0.047*	0.089**	−0.136***	0.044	0.095***	−0.139***
	(0.028)	(0.034)	(0.039)	(0.028)	(0.036)	(0.040)	(0.028)	(0.036)	(0.041)
Experience	−0.037	−0.042	0.079*	−0.055**	−0.025	0.081*	−0.055**	−0.024	0.079*
	(0.028)	(0.039)	(0.043)	(0.028)	(0.041)	(0.045)	(0.028)	(0.041)	(0.045)
First mover	−0.014	0.058*	−0.044	−0.023	0.079**	−0.056	−0.021	0.077**	−0.056
	(0.024)	(0.032)	(0.035)	(0.025)	(0.033)	(0.037)	(0.025)	(0.033)	(0.037)
Not invented here	0.061	0.041	−0.102	0.057	0.024	−0.081	0.056	0.028	−0.084
	(0.046)	(0.064)	(0.066)	(0.047)	(0.067)	(0.068)	(0.047)	(0.067)	(0.068)
Risk of divulging	0.021	−0.003	−0.018	0.026	−0.010	−0.016	0.027	−0.012	−0.015
	(0.024)	(0.030)	(0.034)	(0.025)	(0.032)	(0.035)	(0.025)	(0.032)	(0.035)
Employee	−0.021**	0.010	0.011	−0.022**	0.001	0.021	−0.020**	0.003	0.017
	(0.009)	(0.011)	(0.013)	(0.010)	(0.012)	(0.013)	(0.010)	(0.012)	(0.013)
Start-up	−0.044	−0.098	0.143	−0.036	−0.076	0.112	−0.033	−0.089	0.123
	(0.061)	(0.086)	(0.090)	(0.064)	(0.086)	(0.091)	(0.062)	(0.089)	(0.093)
Single specific customer	−0.094*	0.195***	−0.101*	−0.083*	0.199***	−0.116*	−0.085*	0.199***	−0.114*
	(0.050)	(0.045)	(0.059)	(0.050)	(0.048)	(0.061)	(0.051)	(0.048)	(0.061)
Multiple specific customers	−0.081***	0.072**	0.008	−0.101***	0.076**	0.025	−0.097***	0.066*	0.032
	(0.029)	(0.034)	(0.039)	(0.031)	(0.036)	(0.040)	(0.031)	(0.036)	(0.041)
Affiliated customer	0.009	−0.025	0.016	−0.002	−0.016	0.018	−0.005	−0.016	0.021
	(0.035)	(0.046)	(0.050)	(0.037)	(0.047)	(0.051)	(0.037)	(0.048)	(0.052)
Affiliated supplier	−0.031	0.100**	−0.069	−0.024	0.108**	−0.084*	−0.025	0.112**	−0.087*
	(0.033)	(0.042)	(0.048)	(0.035)	(0.044)	(0.049)	(0.034)	(0.044)	(0.049)
Pseudo R2		0.069			0.068			0.073	
Log Likelihood		−758.386			−703.903			−700.390	
N		861			792			792	

R&D = research and development.
Note: For the multinomial logit model estimation, the base category is 'not acquiring'. Values in parentheses are robust standard errors. The coefficients are the marginal effect of the independent variable on the probability of external technology acquisition. The marginal effect for the factor levels is the discrete change from the base level. The industry dummy variables and the constant are dropped from the table. *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.

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estimation, the estimation without acquiring from T ≠ B, or the estimation without acquiring from T = B. The results indicate not statistically rejecting the null hypothesis of the independence of irrelevant alternatives.

We find significantly positive effects of *patent* on the probability of acquiring from T $\neq$ B, which indicates that the probability of acquiring external technology from other suppliers and customers increases by about 10% when firms own the patents for their products. Therefore, the probability of internalisation of the NPD process decreases by owning patents. Although the estimation results of the probit models in Table 3 show only the positive effects on external technology acquisition, we can identify the effect of patents depending on the partner type. This result suggests that the moderating effect of patents can be found particularly in the case of pure technology asset insourcing without interactions with complementary assets.

Positive coefficients for R&D intensity are found, conversely, in firms acquiring from T = B. This supports the hypothesis of co-specialisation between technology assets (for the technology acquirer) and complementary assets (for its business partner). Furthermore, *different field* has positive and significant effects on the probability of acquiring from T = B, further supporting the co-specialisation hypothesis. When a firm develops a new product in a field that is not its main business, it has less incentive to invest in its less-competitive resources, such as marketing channels and personnel. Therefore, such firms tend to rely on the resources of their business partners by focusing on technological development activities.

As shown by the positive and statistically significant coefficients for *experience* in the 'not acquiring' group, firms have less incentive to collaborate with others if firms have substantial business experience in the field of the NPD. This result can be explained by the RBV, which states that firms tend to invest in their relatively competitive assets by themselves.

First mover positively affects the probability that firms assimilate technology from business partners. This result implies that although products that are released ahead of other firms involve large commercial risks, alliances with business partners might mitigate these risks.

Single specific customer and *multiple specific customers* positively affect the probability that firms adopt external technology from business partners, but negatively affect the probability that firms acquire external technology from other suppliers and customers. For a technology transaction with different types of partners, the factor of specific customers has a completely different effect on external technology sourcing. Moreover, the marginal effect of *single specific customer* of about 20% is larger than that of multiple customers because asset specificity is higher. In addition, *affiliated supplier* has a positive and statistically significant coefficient. A potential hold-up problem associated with asset specificity could be mitigated by the partners' equity ownership.

5. Concluding Remarks

In this paper, we present an empirical analysis of the division of innovative labour in the NPD process by using novel survey data covering not only the technological development but also the market introduction of the new product. A focus of our analysis is the division of labour related to a firm's innovative technology and its complementary resources with other firms. We found that the determinants of a firm's external collaboration for technology differ completely by the type of partner, that is, whether the technology partner is also a business partner, such as a supplier or customer (T = B), or not (T $\neq$ B).

In the case of T $\neq$ B, we found the moderating effect of patents on the cost of technology transaction to be a determinant of external technology sourcing. However, there is no evidence of co-specialisation of complementary assets with other firms. In addition, such firms invest more in new marketing channels and personnel than firms sourcing technology from their business partners (T = B). Therefore, these firms pursue their own new business development strategies and complement their technology resources with those of other firms. Such technology transactions require patent protection to mitigate potential hold-up problems in the relationships with their technology partners.

In contrast, the determinants drawn from the RBV work in the case of T = B, and patents are not a relevant factor here. We would expect that co-specialisation of managerial resources with partner firms, particularly for complementary assets, are well developed for this group of firms. These firms deal more with specific customers and are likely to have equity linkages with their suppliers. Therefore, we would expect that these firms have substantially invested in relational assets with their partners. The existence of such a relationship (or equity linkage) enables co-specialisation of managerial resources related to NPD.

In this paper, we investigated the complex nature of technology collaboration. A clear finding from our study is the importance of forming a business relationship, instead of only pursuing a technology transaction, to address the question of the innovative division of labour. We found two distinct patterns for the cases of T ≠ B and T = B. The next question following from our research is which pattern is more efficient in which condition. A co-specialisation pattern should be more efficient for a partnership, but the transaction cost theory (as well as the property rights theory) suggests that relation-specific asset investments incur a hold-up problem, so that the amount of the cost (or reduced incentive for investment according to the property rights theory) has to be deducted from the partnership's value added. Our study suggests that such potential loss can be controlled by relational assets with partners.

Of course, the effectiveness of such relational assets differs by industry. In the case of the automobile industry, close communication between the supplier and the manufacturer is important for developing a high-quality car. In contrast, technology transactions by patents have increased in the pharmaceutical industry. However, we need a clearer understanding of the relational assets to answer questions such as ‘How does a firm maintain a good balance between relational asset investment and flexibility?’, ‘How does a firm form an effective relationship with its partner?’, and ‘Is partial equity ownership feasible?’ These are some future directions following our work.

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