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Understanding External Technology Sourcing in New Product Development Projects: Bilateral vs. unilateral contracts

KANI Masayo
Tezukayama University

MOTOHASHI Kazuyuki
RIETI

Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

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Understanding External Technology Sourcing in New Product Development Projects: Bilateral vs. unilateral contracts†

KANI Masayo (Tezukayama University)

MOTOHASHI Kazuyuki (The University of Tokyo and RIETI)

Abstract

This paper provides empirical analyses to understand the management of external technology sourcing using a novel dataset of new product development (NPD) projects in Japanese firms and focusing on the difference between bilateral and unilateral contract-based alliances. External technology sourcing takes various forms that can be divided into two categories: bilateral alliances, such as joint research and development (R&D), and unilateral alliances, such as licensing and commissioned R&D. The former style involves the dynamic process of joint R&D with a partner, whereas the latter involves the straightforward process of technology acquisition from a partner. In the first analysis in this paper, the determinants of the sourcing strategy for each contract type are investigated, and we find that bilateral contracts are more often used for exploratory projects, whereas in-house development is more often used for exploitation projects. Unilateral contracts are more relevant for projects mitigating contractual hazards. The second analysis looks into the relationship between the type of technology sourcing and its performance. We find that bilateral contract-based technology sourcing is more likely to lead to novel innovation than in-house development, but this difference in performance disappears when controlling for the type of NPD project and the firm's managerial resources.

Keywords: External technology sourcing, Exploration-exploitation, Transaction costs economics

JEL classification: O32; L24; O33

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1. Introduction

Knowledge is currently widely distributed in the world. Therefore, it is more efficient to tap into external technological resources than to stick to in-house development in the innovation process (Chesbrough, 2003). The open innovation model becomes more and more relevant in today's business environment of increasing division of innovative labor, particularly in science-based industries (Arora et. al, 2001), and there has been a growing number of papers on open innovation (Dahlander and Gann, 2010). However, external technology sourcing cannot be achieved simply by market transactions between buyers and sellers but rather involves a complex process of interactions with technology providers. Teece (1988) lists the factors involved in this process, such as difficulty in explicitly describing the task requirements, relation-specific assets, and risk of information leakage to competitors.

Therefore, disentangling the complexity in external technology sourcing in the internal innovation process is important to manage open innovation effectively. The structure of the alliance takes various forms, such as equity joint venture, collaborative research, and licensing, and the form is determined by the resource characteristics of firms and the resource type of the partner firm (Das and Teng, 2000). The effectiveness of the governance mechanism is critical to a successful alliance outcome, and a substantial literature addresses the question of whether equity ownership mitigates potential risks associated with the opportunistic behavior of the alliance partner (Kale and Singh, 2009).

This study focuses on non-equity alliances and compares two types of technology sourcing contracts, i.e., bilateral contracts, such as joint R&D, which involve two-way flows of technology and substantial interactions with a partner, or unilateral contracts, such as licensing and commissioned R&D, which involve rather straightforward technology acquisition from a partner (Mowery et. al, 1996). We posit that the choice of contract type depends on various factors such as the characteristics of the product development project and technology market conditions. We use a novel dataset at the product development project level based on a large-scale survey conducted by RIETI (Research Institute of Economy, Trade and Industry) for Japanese firms. Project-level data allows us to investigate the factors behind the choice of contract type in more detail as compared to firm-level data such as those obtained by the Community Innovation Survey.

The empirical analysis in this paper consists of two parts. First, we examine the choice of alliance strategy with an external organization given three options: bilateral contract-based alliances (joint venture, joint R&D), unilateral contract-based alliances (licensing, commissioned R&D), and not sourcing (completely in-house development). We investigate the determinants of the external technology sourcing decision, differentiating between the above three options. Second, we analyze the relationship between the choice of alliance strategy and performance, measured by the innovativeness of the new developed product.

In addition to comparing alliance types, this study also investigates the management options of in-house development (not sourcing), since an alliance may not be the best choice under some conditions. Based on past literature comparing unilateral and bilateral technology using alliance data (Oxley, 1997; Colombo, 2003), our paper sheds new light on this issue by reframing the research question to address the firm's decision making on new product development directly, based on its existing internal management resources. A substantial number of papers analyze the make-buy decision in R&D projects (Cassiman and Veugelers, 2006, Ceccagnoli et. al, 2010). However, the reality is that a manager has to decide whether to use external sources and the type of alliance (joint R&D, licensing, commissioned R&D, etc.) at the same time. This paper combines these two themes in the literature and empirically investigates the manager's decision using project-level data.

This remainder of this paper is structured as follows. Section 2 provides a typology of alliance strategies and theoretical hypotheses. Section 3 presents a description of the study's survey and variables used for our empirical model. Section 4 shows the results of two econometric analyses: the choice of external technology sourcing and the effect of the choice on the market. Section 5 concludes.

2. Typology of alliance strategies and theoretical hypotheses

2.1. Empirical literature on sourcing by type of contract-based alliance

External technology sourcing has been studied from several perspectives. One perspective is in terms of the firm's boundary, called the make-buy decision. The 'make *or* buy' decision on governance structure has been discussed based on transaction cost economics (TCE) (Williamson, 1985; Klein, 2005). The 'make *and* buy' decision has been studied in the field of knowledge management because the combination of or complementarity between internal and external innovation is the key issue. Cassiman and Veugelers (2006) empirically show contextual variables that affect the choice of innovation strategy—'NoMake&Buy,' 'MakeOnly,' 'BuyOnly,' and 'Make&Buy'—using Belgian survey data on innovation[1].

[1] The measures of 'Buy' consist of alliance strategies to source external technology, such as M&A, joint venture, license-in, and R&D commission.

Previous empirical studies on interfirm alliance strategies for external technology sourcing, focusing on 'buy' in the make-buy decision, examine the choice between non-equity alliances (or contract-based alliances) and equity alliances because they focus on the governance form to mitigate contractual hazards based on the idea of market-hierarchy in TCE (Oxley, 1997). Dividing non-equity alliances into simple contracts and more complex contracts, Mowery et al. (1996), who examine the effect of interfirm knowledge transfers, propose a typology of alliances: unilateral contract-based alliances such as licensing, bilateral contract-based alliances such as joint development, and equity joint ventures. Oxley (1997) and Colombo (2003) employ this typology of alliances in empirical studies on the choice of alliance, using a database on alliance agreements.

Since these previous studies use the database on alliance agreements, they are limited to alliances and do not include the choice of completely in-house development. However, when firms make a decision, they have three alternatives, (1) producing technology by themselves, (2) purchasing it from the market for technology, or (3) making it jointly with partners (Das and Teng, 2000), rather than taking a nested decision of first choosing whether to source external technology and then whether to conduct collaboration or licensing if sourcing. In our study, including the choice of completely in-house development, we have three alternatives: unilateral contract-based alliances, bilateral contract-based alliances, and not sourcing[2].

The unilateral contract-based alliances are to perform firms' own activities with technology or services provided in accordance to the contract without much coordination or collaboration, e.g., licensing and R&D contracts. The unilateral contracts are exchanges of technology for a cash payment and arm's length contracts to acquire the focal technology. The aim of unilateral contract-based alliances is to increase the speed and the flexibility of technology development in association with shortened product lifecycles. Since they are more tightly packaged, interfirm knowledge transfers are limited in these contracts as compared with bilateral contract-based alliances that lead to learning opportunities (Mowery et al., 1996).

In unilateral contract-based alliances, in order to accumulate knowledge and technology in the focal field, firms must recognize what they need and accurately assess the external technology provided by potential partners based on their complete and specific technology. Reduction of search costs depends on conditions of the technology

[2] Since our data of alliance strategies for technology mainly consist of non-equity alliances, we employ the typology of unilateral contract-based alliances and bilateral contract-based alliances. Although we cannot separate joint ventures from equity alliances within the category of collaborative R&D, the samples related to equity alliances, such as M&A and investment, are dropped.

market. Besides, it is possible to decrease transaction costs with capabilities to access to market for the technology, to find the technology, and to contract with the appropriate partners.

On the other hand, bilateral contract-based alliances are intended to share resources with each other and work together, e.g., collaborative R&D. Bilateral contracts are beneficial not only to develop a new product but also to provide more opportunities for learning than unilateral contract-based alliances (Das and Teng, 2000). With organizational learning as a part of the broad resource-based view (RBV), firms are motivated to make bilateral contract-based alliances because they allow firms to obtain resources/expertise from other firms as well as to retain and develop their own resources/expertise by combining their own resources/expertise with the resources/expertise of the counterpart (Kogut, 1988). Firms that intend to accumulate knowledge and technology through NPD for future business opportunities would prefer bilateral alliances to unilateral alliances. The advantage that bilateral contract-based alliances provide learning opportunities is appropriate for exploration to pursue knowledge development for a changing scope.

Taken together, bilateral contract-based alliances involve a dynamic process of joint R&D with a partner, whereas unilateral contract-based alliances involve rather straightforward technology acquisition from a partner.

2.2. Theoretical hypotheses on the choice of alliance strategy

Prior research on alliance strategies has mostly applied transaction costs economics (TCE) and the resource-based view (RBV) as the theoretical background. These perspectives have different criteria; the TCE approach has the underlying idea of 'minimizing the sum of production and transaction costs,' whereas the RBV approach is based on 'maximizing firm value through pooling and utilizing valuable resources' (Kogut, 1988; Das and Teng, 2000). We suggest that considering both perspectives enhances understanding of external technology sourcing. In fact, Williamson (1999) discusses the relation between governance and competence, and several scholars address the combination of TCE and RBV (Madhok, 2002; Jacobides and Winter, 2005; Mayer and Salomon, 2006). We propose hypotheses on the factors influencing the management decision of bilateral contract, unilateral contract, or not sourcing (in-house development), taking into account both TCE and RBV.

2.2.1. Exploration-exploitation type projects

To understand external technology sourcing in NPD, we begin by considering the resources utilized in NPD projects, which include all assets, capabilities, organizational processes, firm attributes, information, and knowledge denoted in RBV (Barney, 1991). Resource allocation for the project is relevant to the type of project: exploratory or exploitation. The notion of exploration-exploitation is derived from March's (1991) framework in organizational learning. March (1991) addresses the essences of these types; exploration is 'experimentation with new alternatives,' and exploitation is 'refinement and extension of existing competences.' When considering knowledge management through the lens of exploration-exploitation, exploration is knowledge development for changing scope from an organization's existing knowledge base and skills, whereas exploitation is knowledge utilization on the path of the organization's existing knowledge base (Leivinthal and March, 1993; Lavie et. al., 2010).

Among various studies that build on the exploration-exploitation framework of organization learning, scholars have investigated the relationship between exploration-exploitation and strategic alliances to explore firms' dynamic processes through alliances. Koza and Lewin (1998) argue that the choice of entering into an alliance is characterized in terms of the motivation to exploit an existing capability or to explore new opportunities. Rothaermel and Deeds (2004) show the NPD system integrated with components: exploration alliances, products in development, exploitation alliances, and products on the market.

Thus, exploratory type projects cover products in a new business line to change firms' scope. When firms proceed with exploratory type projects, they choose a mode with more learning opportunities because it would allow them to obtain new opportunities and learn from the partner's expertise. On the other hand, exploitation type projects are products in an existing business line with products that have already been developed and introduced into markets. When firms have accumulated resources for a business field, they have an incentive to develop new products in house without external sourcing. Considering the case between bilateral contract-based alliances and in-house development on the continuum, it can be efficient to acquire a specific technology with a cash payment while mainly developing in house, that is, forming a unilateral contract-based alliance, because firms can take advantage of the speed and flexibility of technology development. Thus, we identify alliance forms in order from most to least motivation to explore for new opportunities: bilateral contract-based alliances, unilateral contract-based alliances, and not sourcing.

Hypothesis 1: Firms with exploratory type projects make bilateral contract-based alliances to explore new opportunities through interaction alliances. As projects' tendencies for exploitation increase, firms would choose a mode that exploits more internal existing resources: unilateral contract-based alliances and then completely in-house development.

2.2.2. Absorptive capacity

Considering resources, as in the discussion on exploration-exploitation type projects, Cohen and Levinthal (1990) emphasize absorptive capacity as the organizational capability for innovation activity, which is the ability to recognize, assimilate, and apply external information. Zahra and George (2002) propose four organizational capabilities of knowledge acquisition, assimilation, transformation, and exploitation in the reconceptualization of absorptive capacity. Thus, absorptive capacity is a key factor in whether or not firms make alliances such as collaboration and licensing with an external organization. Firms with higher absorptive capacity can gain more benefits from alliances with external organizations by receiving large knowledge transfers from partners and effectively utilizing external technology in internal development.

Hypothesis 2: Firms with higher absorptive capacity choose to source external technology in NPD. Otherwise, firms implement completely in-house development.

2.2.3. Contractual hazards: Transaction cost economics

In transaction cost economics (TCE), which is another perspective of the theoretical background on the choice of alliance strategy, the governance decision depends on the level of contractual hazards attributed to bounded rationality and opportunism (Williamson, 1996). Although firms would choose an internalization mode such as in-house activities or integration when seriously concerned about contractual hazards that create high transaction costs, firms can choose alliances with external organizations otherwise[3].

Asset specificity, which refers to the degree to which assets can be redeployed to alternative uses, would pose contractual hazards due to the potential for an ex-post holdup problem and thus increases governance costs to overcome the hazards (Williamson, 1991; Williamson, 1996; Klein, 2005). Furthermore, the appropriability concern has been discussed as a form of contractual hazard (Pisano, 1990; Oxley, 1997; Mayer and Salomon, 2006)[4]. In weak appropriability regimes (Teece, 1986) and with

[3] Teece (1986) indicates that the appropriability regime and the nature of complementary assets are key components in a decision flow chart for integration versus contract.

[4] Mary and Salomon (2006) identify three sources of contractual hazards: (1) when

difficulty specifying relevant activities in contracts and monitoring prescribed partners' activities (Oxley, 1997), firms have appropriability concerns in transactions due to the potential for leakage and expropriation of intellectual property. Valuable knowledge is at risk of misappropriation by partners because applications-level know-how cannot be fully specified in a contract aside from knowledge protected by intellectual property rights (Pisano, 1990).

Pisano (1990) empirically examines how two contractual hazards—small numbers bargaining hazards and appropriability concerns—influence the choice of whether pharmaceutical firms undertake completely in-house R&D projects or alliance projects with an external organization. Oxley (1997) empirically shows that firms choose more hierarchical alliance forms when appropriability concerns are more severe by measuring components of appropriability concerns such as alliance scope and complexity. Firms choose in-house mode because governance costs increase when it is difficult to make a complete contract covering all potential situations. Using a database on alliance agreements, a market-hierarchy continuum of alliance forms is defined as 'unilateral contractual agreements,' 'bilateral contractual agreements,' and 'equity-based alliances.' Oxley (1997) denotes that both parties to the transaction are willing to mitigate contractual hazards by shifting along the market-hierarchy continuum when they are aware of the potential for the partner's opportunistic behavior. Whereas unilateral contractual agreements are simple market transactions, equity-based alliances are closest to in-house mode in the hierarchy. In contractual agreements, bilateral contractual agreements are chosen when the hazards are not too severe because 'both parties have a continued interest in the maintenance of the arrangement, and ex-post haggling will be reduced' (Oxley, 1997)[5]. Therefore, we argue that depending on the degree to which firms are exposed to contractual hazards in transactions, firms would choose one alternative along the continuum: unilateral contract-based alliances, bilateral contract-based alliances, and in-house development.

Although contractual hazards are distinguished by transactions, firms may take measures to mitigate contractual hazards. Scholars have found that alliances are designed to protect valuable knowledge from partners' opportunistic behavior. Examples

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assets are specific to transactions, firms choose internalizing mode to avoid the ex-post hold-up problem, (2) when firms have a fear of not transferring adequately because of incomplete contracts, firms internalize transaction, and (3) when firms cannot observe the quality of output ex-post, they have an incentive to internalize it.

[5] Since there is a high degree of uncertainty over the behavior of the contracting parties, firms select collaboration to monitor each other's efforts and performance though collaboration (Kogut, 1988).

of these studies include building relational capital between alliance partners by Kale et al. (2000), narrowing alliance scope by Oxley and Sampson (2004), and a choice of partners by Li et al. (2008). Mayer and Salomon (2006) argue that firms with higher technological capabilities would have lower governance costs of contractual hazards because technological capabilities can help to develop governance capabilities to identify appropriate technology, monitor partners' performance, and make a more complete contract. This capability corresponds to absorptive capacity, as discussed above. Differences in capabilities would lead firms to exogenously choose different forms if facing similar levels of contractual hazards (Mayer and Salomon, 2006).

Hypothesis 3: If firms can keep contractual hazards low, firms select unilateral contract-based alliances. As contractual hazards increase, firms would choose a form with more hierarchy: bilateral contract-based alliances and then completely in-house development.

3. Data and Variables

In this study, we use data from the Survey of New Product Development by the Research Institute of Economy, Trade and Industry (RIETI) in 2011, targeting 17,997 business units of Japanese firms, of which 3,705 responded (response rate = 20.6%)[6]. We explain the survey in detail in Appendix 1. Further, for 1,390 business units (38% of total responses), which introduced new products between 2008 and 2010, information was collected on the product with the most sales among new products[7]. Therefore, the information collected by this survey is at the project level, instead of the level of the whole firm. The advantage of this dataset, compared with company-level data, is that we can identify alliance forms and types of projects. To examine the NPD process incorporating internal development with external technology, as shown in Figure 1, we classify the 1,390 respondents into two groups depending on whether they used mainly internal development or external development in the NPD process. The group using internal development is a majority (1,199 respondents; 86%), whereas the group using external development is a minority (168 respondents; 12%), with 23 non-respondents. The group that undertook external development includes several kinds of businesses. One type is a firm that introduces a product developed (and manufactured) by another firm and then sells this product through their sales network without internal R&D

[6] Kani and Motohashi (2013) investigate the choice of alliance partner in NPD using the survey's data, by distinguishing between two types of technology partnerships: whether the technology partner is a business partner or not.
[7] Products new to the firm are defined as substantially improved or entirely new.

expenditure. The other type is a firm that subcontracts another firm to produce to order using the contractee's design, such as original equipment manufacturing (OEM). Since this paper focuses on the NPD process combining external technology with internal development efforts, we drop the respondents using mainly external development. After excluding mainly external development, we use 1,199 respondents with mainly internal development in this study.

(Figure 1)

3.1. Dependent variables

Focusing on mainly internal development in Figure 1, we divide into two groups based on whether or not external technology sourcing is used. The alliance strategy variable is based on the question—"How did you engage in developing a prototype for the focal new product?" Respondents selected from 6 items: M&A or investment, collaborative R&D or joint venture, licensing, research commissioned or consulting, informal sourcing such as reverse engineering, and otherwise. We define a discrete dependent variable that takes on three outcomes: *Bilateral contract-based alliances* ('*Bilateral*'; answering collaborative R&D or joint venture; 170 obs.), *Unilateral contract-based alliances* ('*Unilateral*'; answering license-in or research commissioned; 185 obs.), and *Not sourcing* (otherwise; 591 obs.)[8].

3.2. Explanatory variables

In this section, we denote the explanatory variables corresponding with the three hypotheses that we proposed in Section 2. A description of the variables is provided in Table 1, Table 2 shows the descriptive statistics for each alliance strategy, and Table 3 is a matrix of correlation.

(Table 1)

(Table 2)

(Table 3)

3.2.1. Exploration-exploitation type project

We measure exploration-exploitation type projects using two variables based on a typology developed by Danneels (2002) to test Hypothesis 1. Danneels (2002), who

[8] This question allowed multiple answers. We drop observations choosing M&A or investment and choosing both collaborative R&D and licensing. Observations choosing both collaborative R&D and research commission are defined as collaboration. Thus, after dropping observations with missing data in addition to the above, the valid number of mainly internal development observations is 946, not 1,199.

explores the impacts of the NPD process on the renewal of firm competences/resources in the exploration-exploitation framework, provides the typology linking between customer competence and technological competence. Customer competence is formed by knowledge of customer needs, sales distribution, the communication channel, and company reputation. Technological competence is formed by the ability to design and manufacture a product, such as plant/equipment and manufacturing/engineering know-how.

To consider which competences/resources firms explore through NPD, we identify types of projects—exploration or exploitation—by whether or not firms newly source marketing resources, e.g., the sales distribution channel, and production resources, e.g., machinery and skilled employees, built on the typology of Danneels (2002). As we argued above, firms would be more likely to make bilateral contract-based alliances in exploratory type projects. Furthermore, we test whether or not the impacts of marketing-exploratory projects and production-exploratory projects are different.

New sales channel. This dummy variable takes the value 1 if the firms developed new sales channels to commercialize the product, otherwise 0.

New production factor. This dummy variable takes the value 1 if the firms acquired new production factors such as equipment or employees who have skills beyond those of existing employees, otherwise 0.

Although we find in the descriptive statistics in Table 2 that these two variables have the highest rates in *Bilateral*, the differences between *Bilateral* and *Unilateral* are small.

3.2.2. Absorptive capacity

For Hypothesis 2, R&D intensity, which is defined as R&D expense divided by sales, is used as a proxy for absorptive capacity (Cohen and Levinthal, 1990). For the firms with high R&D intensity, external technology sourcing, such as bilateral and unilateral contract-based alliances, is beneficial for NPD because the firms can effectively absorb external organizations' expertise.

In the survey, the R&D intensity in a business unit is indicated by a categorical response: 0%, 0 to 1%, 1 to 3%, 3 to 5%, 5 to 10%, and more than 10%. Since according to the report of the *Survey of Research and Development* in FY2010, R&D intensity in Japanese firms implementing R&D activities is 3.22%, we use two variables to indicate higher R&D intensity.

5%≤R&D intensity<10%. This dummy variable takes the value 1 if the proportion of R&D expenditure to sales is from 5% to 10%, otherwise 0.

10%≤R&D intensity. This dummy variable takes the value 1 if the proportion of R&D expenditure to sales is more than 10%, otherwise 0.

Table 2 shows that the shares of firms with over 10% R&D intensity in *Bilateral* and *Unilateral* are both more than double that of *Not sourcing*. The share of firms with R&D intensity between 5% and 10% is higher for *Unilateral* than for the other alliance types.

3.2.3. Mitigating contractual hazards

In Hypothesis 3, we address contractual hazards as determinants of the alliance strategy. The appropriability concern in contractual hazards is that proprietary information and technology are at risk of misappropriation in a given project (Mayer and Salomon, 2006). Although firms intend to fully specify a contract and monitor counterparts' activities, this results in high contract governance costs depending on the characteristics of the technology used for the new products, as discussed in 2.2.3.

If the technology of the object of protection can be identified clearly (e.g., scientific-based knowledge and codification), it is more likely to be patented (Arora and Gambardella, 2010). Thus, considering technological characteristics, firms would be more able to define a contract for technology sourcing in projects where patented technology is used. We consider that unilateral contract-based alliances would be chosen for new products with patented technology because firms can keep the risk of misappropriation low given the characteristics of the technology.

Patented product. This dummy variable takes the value 1 if the new product is patented (or filed), otherwise 0.

In addition, firms with higher technological capabilities would have lower governance costs for contractual hazards because technological capabilities develop governance capabilities to identify appropriate technology, monitor partners' performance, and write a more complete contract (Mayer and Salomon, 2006). Since firms owning patents for new products have sufficient technological capabilities in the focal field to patent the technology, they would be likely to choose unilateral contract-based alliances. This is considered in the same way as absorptive capacity, as mentioned above. Although R&D

intensity using as a measure of absorptive capacity represents general technological capability in the business unit, we focus on the specific technological capability for the focal field by considering whether or not firms own patents.

Own patents. The dummy variable takes the value 1 if the firm owns patents for the new product, otherwise 0.

From the descriptive statistics in Table 2, we find that the shares of both patented products and owning the patents are slightly higher in *Bilateral* than in *Unilateral*. Since *Own patents* is highly correlated with *Patented product* according to the correlation matrix in Table 3, we test the effects of the variables in separate empirical models.

3.3. Control variables

Additionally, we control for several other variables of product and organization factors: *Information sources* (3 variables), *Non-core field*, *Specific customer* (2 variables), *New bus. unit*, *Affiliated transaction* (2 variables), *Firm size*, *Firm age*, and *Category of new products* (20 variables).

Among the factors characterizing projects/products, the first is the information source in the NPD process. Backer, et al. (2008) provide a model that includes spillovers and ex-post contracting problems as factors determining the form and performance of strategic alliances. Belderbos, et al. (2004) show the impacts of different types of incoming spillovers on R&D partnerships based on different purposes:

- information from the supplier is related to production and cost reduction,
- information from the customer leads to market adaptation,
- information from universities and government institutions provides cutting-edge research and technological opportunities.

Since information sources characterize projects/products, we measure three types of information sources at conceptualization[9].

Supplier infor. at concept. This dummy variable takes the value 1 if the information source at conceptualization is the supplier, otherwise 0.

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[9] In the survey we asked questions about information sources at two stages of conceptualization and making prototypes: "Which outside organization do you utilize information from?" Since the dependent variable is the alliance strategy at the stage of making prototypes, we should use the data on information sources at the stage of conceptualization to avoid an endogeneity problem.

Customer infor. at concept. This dummy variable takes the value 1 if the information source at conceptualization is the customer, otherwise 0.
University infor. at concept. The dummy variable takes the value 1 if the information source at conceptualization is a university/government lab, otherwise 0.

In Table 2, whereas the difference in *supplier information at conceptualization* between *Not sourcing* and *Unilateral* is 8.7%, there are no differences in *customer information at conceptualization* across the three alternatives. As for *University information at conceptualization*, *Bilateral* and *Unilateral* are about 10% higher than *Not sourcing*.

Second, the choice of alliance strategy is influenced by whether the NPD project is in the core business field or not because there are fewer accumulated resources in non-core businesses than in core businesses. As well as exploratory type projects, firms may encourage bilateral contract-based alliances to learn from the counterpart in business fields of less expertise.

Non-core field. This dummy variable 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, otherwise 0.

In Table 2, we find that the *Bilateral* group has a larger share of projects implemented in the non-core business field than the other groups.

Third, we include variables of customer types. Whether the firm is selling to specific customers or not would influence the decision of the NPD process.

Single specific customer. This dummy variable takes the value of 1 if the product is sold to one specific customer, otherwise 0.
Multiple specific customers. This dummy variable takes the value of 1 if the product is sold to multiple specific customers, otherwise 0.

In addition to the above, we include 20 dummy variables representing new product categories.
Considering the organization factor, we control for features of the business unit and the firm: whether the business unit is new or not, whether there is an affiliated business or not, firm size, and firm age[10].

[10] The data source for firm age and the number of employees is COSMOS2, a dataset

New bus. unit: This dummy variable takes the value of 1 if the firm started the business unit less than five years ago, otherwise 0.

Supplier in group: This dummy variable takes the value of 1 if the firm mainly receives supplies from affiliated companies, otherwise 0.

Customer in group: This dummy variable takes the value of 1 if the firm's main customers are affiliated companies, otherwise 0.

Firm size: We use the logarithm of the number of employees in a firm.

Firm age: We use the logarithm of the firm age.

4. Empirical Analysis

4.1. Decision of alliance strategy for external technology sourcing

This paper provides two empirical analyses to comprehensively understand the firms' activities to source external technology and combine this technology with their own development. First, we analyze the determinants of alliance strategies to incorporate external technology for a firm's own development of new products. Second, we evaluate the effects of external technology sourcing on the products new to the market, using alliance strategies as the treatment variables (Figure 2).

(Figure 2)

In the first analysis, we employ a multinomial logit model to examine which factors influence the choice of alliance strategy for external technology sourcing, using a discrete dependent variable that takes on three outcomes: *Bilateral contract-based alliances* (collaborative R&D or joint venture), *Unilateral contract-based alliances* (license-in or research commissioned), and *Not sourcing*[11]. Table 4 reports the values of the average marginal effects of the variables on the probabilities of choosing each alternative. The base model presents the results for the base regression on only control variables.

Model (1) shows the results for testing Hypothesis 1, which regards exploration-exploitation type projects. Both *New sales channel* and *New production factor* have statistically significant positive effects on *Bilateral*[12]. Compared with projects with

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[11] Since we conducted the survey by business units, out of 979 responses, there are 114 responses that reflect multiple business units from one company. We carry out a robustness check for the sample excluding responses from multiple business units from the same company. Although the size of the estimated coefficients changes slightly, we confirm essentially similar results.

[12] We take note of the endogeneity problem caused by the timing of acquiring marketing/production factors and selecting alliance strategies at the stage of making a

existing production factors (or existing customers), the probability of choosing bilateral contract-based alliances increases 6.2% (or 5.2%), whereas the probability of choosing in-house development decreases 7.4% (or 8.2%). The results indicate that firms with exploratory type projects facilitate bilateral contract-based alliances, whereas firms with exploitation type projects develop in house. We show the effects of not only production exploratory type projects, which are directly related to the technology, but also customer exploratory type projects. Although Hypothesis 1 predicts that the unilateral contract-based alliances fall between bilateral contract-based alliances and in-house development on the continuum, the results of Model (1) show insignificant effects on both *New sales channel* and *New production factor*. The reason may be that we use dichotomy variables, which represent whether the project is the exploratory type or the exploitation type.

In Model (2), we find that R&D intensity over 10%, *10%≤R&D intensity*, has a positive effect on *Bilateral* and that the impact of *5%≤R&D intensity<10%* on *Unilateral* is significant and positive. Hypothesis 2, which means that firms with higher absorptive capacity facilitate external technology sourcing, is supported.

The results of Model (3) show that *Patented product* has a statistically significant positive effect on *Unilateral*. New product projects using patented technology have a 6.5% higher probability of choosing unilateral contract-based alliances compared to projects without patents. *Patented product* has an insignificant effect on *Bilateral*, which is predicted to fall between *Unilateral* and *Not sourcing* on the continuum. As with Hypothesis 1, this effect is likely because the variable for moderating the contractual hazard is a dichotomy. Hypothesis 3 is partially supported.

In model (4), which covers all three Hypotheses 1-3, we confirm similar results to the results in each previous model aside from a statistically insignificant effect of R&D intensity on *Bilateral*. *Patented product* might cancel out the effect of high R&D intensity because firms introducing new products using patented technology would have high technological capabilities. We ensure the robustness of the results on exploration-exploitation type projects with Model (5), which excludes *New sales channel* to avoid the endogeneity problem. Model (6) is the estimation model that includes *Own patents* instead of *Patented product* since we expect that *Own patents* indicates the effect of mitigating contractual hazards with technological capabilities in the focal field. *Own patents* has a statistically significant positive effect on *Unilateral*, similar to the effect

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prototype. Although the processes of acquiring production factors or developing sales channels occur after making a prototype, it could be predetermined whether or not firms have equipped complementary assets for the product at the stage of making a prototype. We also implement a robustness check by dropping *New sales channel* in Model (5).

of *Patented product*. R&D intensity becomes statistically insignificant on both *Bilateral* and *Unilateral*. This result would suggest the difficulty of separating specific technological capabilities from general technological capabilities using *Own patents* and R&D intensity.

Furthermore, we find some empirical evidence from the results for control variables by considering all models. First, we find a relationship between the information source and the alliance strategy. Firms that get information from suppliers, *Supplier infor. at concept*, have about a 4% higher probability of choosing unilateral contract-based alliances. Having a university and government lab as an information source, *University infor. at concept*, has a significantly positive effect on both *Bilateral* and *Unilateral* external technology sourcing, and the effect on *Bilateral* is larger than on *Unilateral*. In NPD projects introducing cutting-edge knowledge based on science, firms facilitate external technology sourcing with both bilateral and unilateral contract-based alliances. The probability of choosing *Bilateral* is about 10% higher than when not sourcing university information.

Second, we find the probability of bilateral contract-based alliances increases in fields other than the main field, *Non-core field*. Considering that firms have fewer resources in the non-core fields than in the core field, this result may be related to the argument of exploratory type projects in Hypothesis 1. However, there is little difference in the results for *Non-core field* between the base model and Model (1), which adds two variables representing exploratory type projects. Therefore, *Non-core field* captures some features of products. Mairesse and Mohnen (2010) argue that firms conduct collaboration in R&D to share knowledge, to benefit from complementarities, to reduce risk, and to save on costs.

Third, two variables consider the age of the organization: *New bus. unit* and *Firm age*. Although the effect of *New bus. unit* is insignificant, *Firm age* has a significantly positive effect on *Bilateral* in some models. This implies that mature firms facilitate bilateral contract-based alliances in NPD. Zahra and George (2002) suggest 'potential absorptive capacity' to acquire and assimilate external knowledge and 'realized absorptive capacity' for transformation and exploitation. If mature firms develop potential absorptive capacity through experience, which is suggested in Zahra and George (2002), these firms are likely to implement external technology sourcing. Considering managerial resources are required to involve an external organization, mature firms would better utilize external technology because they have business experience and reputations by path-dependence.

With respect to model specification, we conduct a specification test for IIA (the independence of irrelevant alternatives) based on a seemingly unrelated estimation model, since the Hausman test does not work. The test does not statistically reject the null hypothesis of IIA. Thus, it suggests the absence of a nested choice such that *Bilateral* and *Unilateral* are chosen in the stage of external technology sourcing after deciding whether or not to use external technology sourcing.

4.2. Effect of alliance strategy on innovativeness

How does external technology sourcing impact innovation? Mairesse and Mohnen (2010) indicate that researchers explore the determinants of innovation using innovation surveys. Much remains unexplained by the variables from these surveys. To better understand 'innovation,' in the second analysis of this paper we explore the effect of the alliance strategy on the innovativeness of the developed new product.

Our dataset consists of products new to the firms, not including products that are simply rearrangements of existing designs. Among products new to the firms, there are two types of products, those for existing markets and those for new markets, and we identify each with the following question.

New to market: This dummy variable takes the value of 1 if the product was released ahead of other firms, otherwise 0.

Figure 3 shows the proportions of products new to the market, *New to market*, by alliance strategy. Bilateral contract-based alliances have the highest rate of products new to the market, which is 52.5%. *Bilateral* is 8.7% higher than *Not sourcing*, which is the lowest of the three groups. When we test the difference between the two alliance strategies, we find that there is a statistically significant difference between *Not sourcing* and *Bilateral*.

(Figure 3)

Although the proportion and the simple test suggest that the choice of bilateral contract-based alliances is related to whether the product is new to the market, the strategy could be related to covariates that also affect the market of the new product. For example, a patented product is correlated with strategy selection, especially for unilateral contract-based alliances, as we showed above, and the product market also depends on patents because patents give the owners exclusive rights. Therefore, we estimate the effect of external technology sourcing on the market, controlling for covariates using the explanatory and control variables in the first analysis with the augmented inverse-probability weighting estimator. We estimate the average treatment effect (ATE) of external technology sourcing on the new product market. As an outcome variable to represent whether the product is new to the market, we use the dummy variable *New to market*. The treatment variables are alliance strategies: *Not sourcing*, *Bilateral*, and *Unilateral*. The covariates for the treatment variable are both the explanatory variables and control variables in the first analysis, and the covariates for the outcome variable are the same variables as the treatment as well as the two new variables, whether or not the market is a consumer market and whether or not the firm introduced process innovation between 2008 and 2010[13].

Table 5 shows the average estimated outcomes of products new to the market with the alliance strategy as *Potential outcome*. Although *Not sourcing* increases by about 1.5% compared with Figure 3, the rates of both strategies of external technology sourcing, *Bilateral* and *Unilateral,* decrease by about 3.8% and 0.8%, respectively. By controlling covariates, we find that none of the average treatment effects of alliance strategies are statistically significant.

(Table 5)

In summary, technology sourcing by bilateral contract such as joint R&D is more likely to lead to new-to-the-market product innovation, but after controlling for covariates such as the type of project (exploration vs. exploitation), the firm's absorptive capacity, and the level of contractual hazard, this higher likelihood is no longer statistically significant. Development of new-to-the-market innovation involves significant market risk, as compared to new-to-the-firm (but not to the market) innovation that has been tested in the existing market already. This study shows that the likelihood of developing a new-to-the-market product is determined not by the style of external contract but by internal resources, such as complementary assets to see an exploration project through and absorptive capacity.

5. Concluding Remarks

In this study, we provide empirical analyses to understand how firms source external technology and combine it with their own development in NPD by using a novel dataset about NPD projects in Japanese firms. We consider the choice between three alternatives: bilateral contract-based alliances (joint venture, joint R&D), unilateral contract-based alliances (licensing, commissioned R&D), and not sourcing (completely in-house development). The bilateral contract involves a dynamic process of joint R&D with a partner, whereas the unilateral contract involves rather straightforward technology acquisition from a partner.

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13 Although it is difficult to check the condition of unconfoundedness, the violation of which causes omitted variable bias, causal inference provides that estimated values are closer to the true causal effect than a simple comparison between groups.

In the first analysis, the determinants of the sourcing strategy by contract type are investigated, and we find that the bilateral contract is used more for exploratory type projects, whereas firms choose in-house development for exploitation type projects. The unilateral contract is more relevant for projects moderating contractual hazards. The second analysis looks into the relationship between technology sourcing and its performance and finds that bilateral contract-based technology sourcing is more likely to lead to new-to-the-world innovation than in-house development, but this difference in performance disappears when the type of NPD project and the firm's managerial resources are controlled.

One of contributions of this study is empirically investigating the determinants of firm's decision on external technology sourcing. This study not only tests the make-buy decision of technology but also the impact of the type of contract, bilateral or unilateral, in the case of the buy decision, to confirm some regularities regarding the type of project (exploration or exploitation), the absorptive capacity, and the level of contractual hazard, predicted by both the TCE and RVB theories. These findings can serve as useful inputs to managers when they make decisions regarding external technology sourcing in a product development project.

Another contribution is looking into the interactions between internal resources and external technology sourcing. This study finds that external technology sourcing is not a panacea for developing an innovative new product. Rather, developing new-to-the-market innovation more effectively comes only after conducting external technology sourcing under adequate conditions/abilities such as exploratory type projects, mitigation of contractual hazards, and high absorptive capacity. Particularly, bilateral contract type alliances involving substantial knowledge generation interactions with partners make projects successful when leveraging internal resources. This study provides empirical evidences to support the paradigm of open innovation that firms create new value by combining internal and external idea.

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Figures and Tables

Figure 1. Strategy for the new product development process

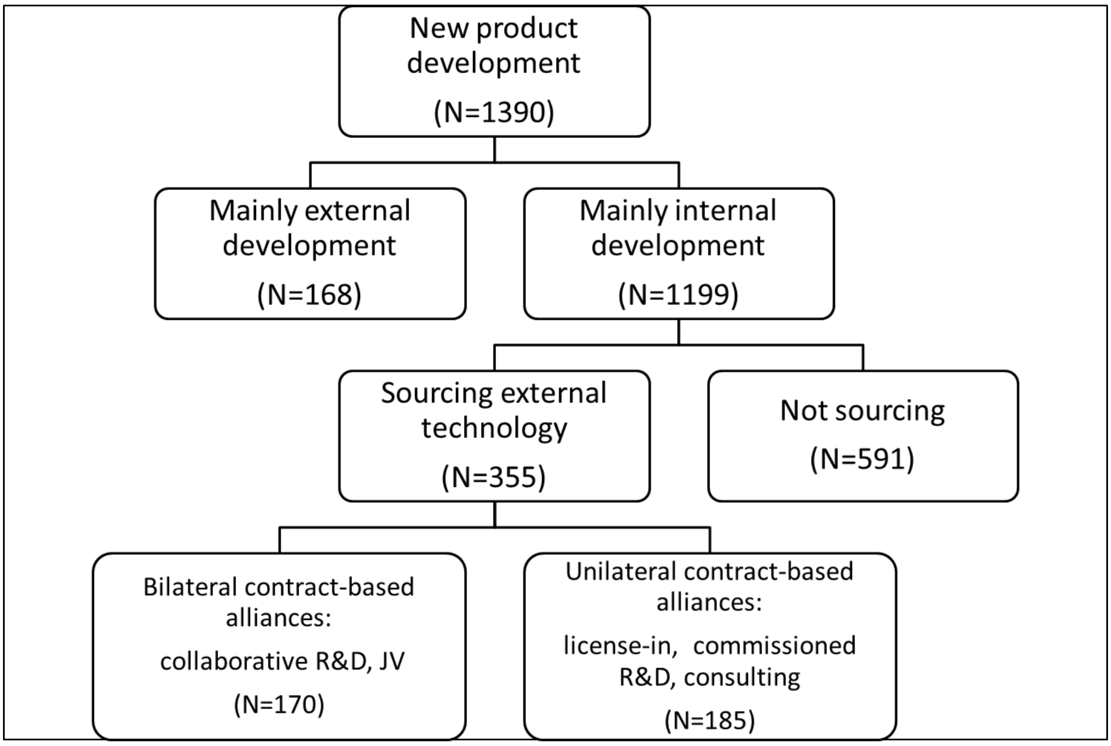


Figure 2. Framework to understand external technology sourcing

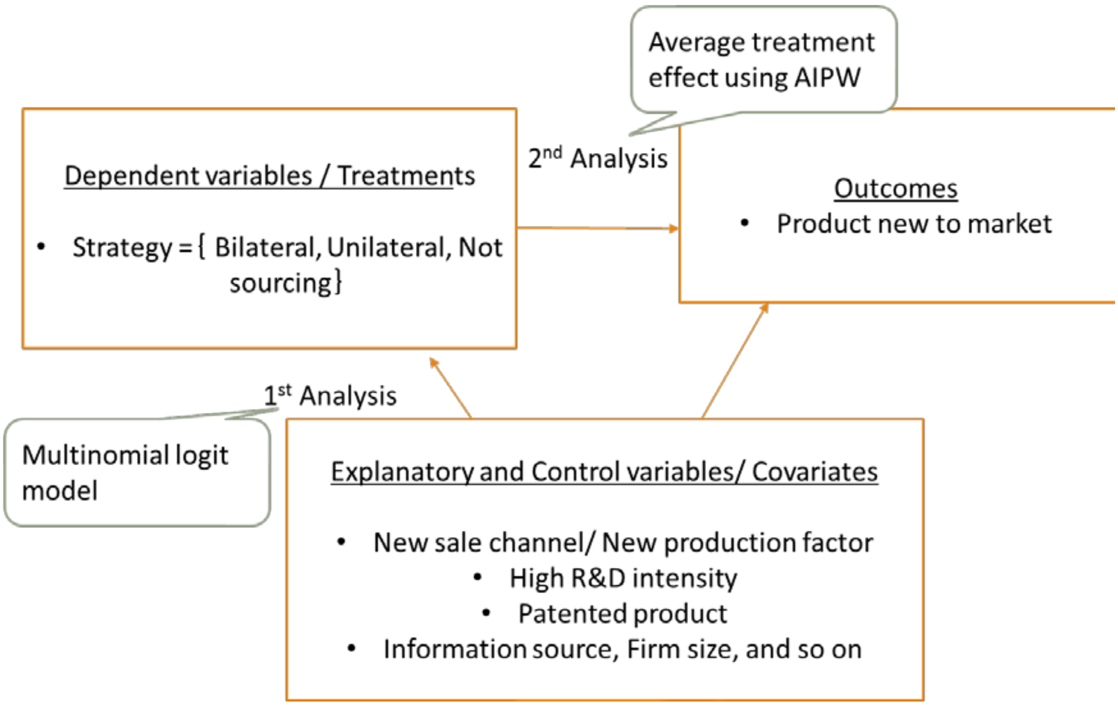
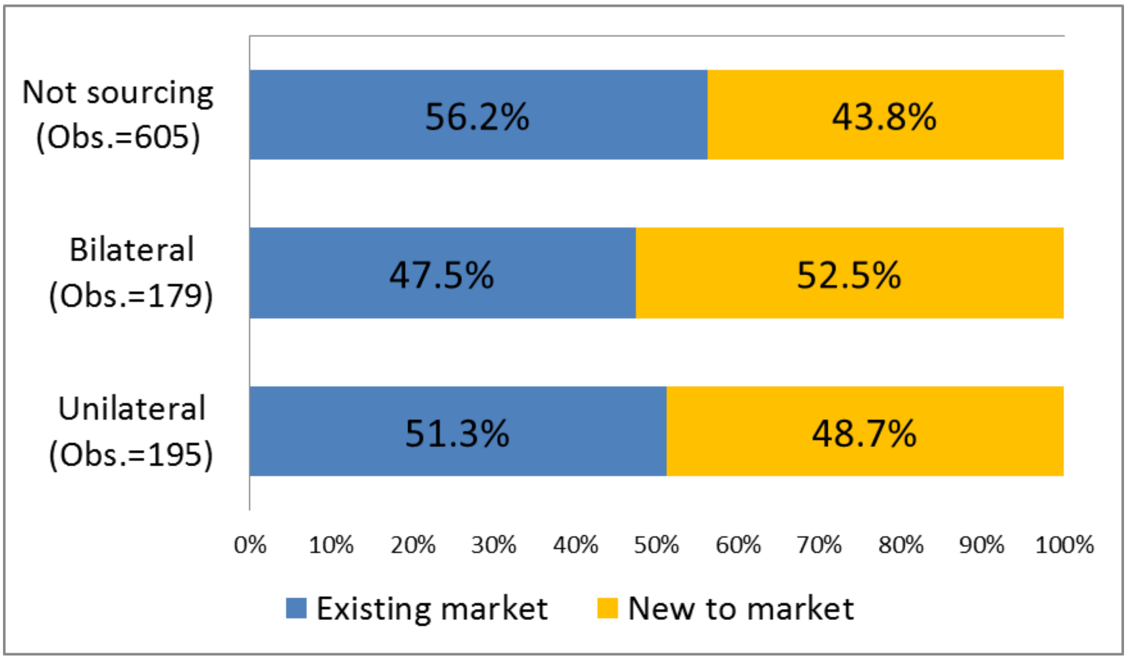


Figure 3. The new product is on the existing market or on the new market



A	B	Difference(A,B)	S.E.
Bilateral	Not sourcing	0.087**	0.043
Unilateral	Not sourcing	0.049	0.042
Bilateral	Unilateral	0.038	0.053

Note: Difference (A,B) shows the difference in the proportion of products new to the market between A and B. We use a two-sample test of proportions. H0: No difference in the proportion of products new to the market.

Table 1. Description of variables

Variable name	Definition
New sales channel	1 if the firm developed new sales channels for the new product, otherwise 0
New production factor	1 if the firm acquired new production factors for the new product, e.g. machinery, otherwise 0
5%≤R&D intensity <10%	1 if R&D/Sales in the business unit is from 5% to 10%, otherwise 0
10%≤ R&D intensity	1 if R&D/Sales in the business unit is over 10%, otherwise 0
Patented product	1 if the new product is patented (or filed), otherwise 0
Own patents	1 if the firm owns patents for the new product, otherwise 0
Supplier infor. at concept	1 if information source at conceptualization is supplier, otherwise 0
Customer infor. at concept	1 if information source at conceptualization is customer, otherwise 0
University infor. at concept	1 if information source at conceptualization is university/government lab, otherwise 0
Non-core field	1 if the product is in other than main business field, otherwise 0
Single specific customer	1 if one specific customer, otherwise 0
Multi specific customer	1 if a few specific customers, otherwise 0
New bus. unit	1 if the business unit is new, otherwise 0
Supplier in group	1 if supplier is in group, otherwise 0
Customer in group	1 if customer is in group, otherwise 0
Firm size	Logarithm of number of employees
Firm age	Logarithm of firm age
Category of new products	20 dummy variables representing new products categories

Table 2. Descriptive statistics

Variable name	Not sourcing		Bilateral		Unilateral		Total	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
New sales channel	0.415	0.493	0.553	0.499	0.528	0.500	0.463	0.499
New production factor	0.246	0.431	0.380	0.487	0.338	0.474	0.289	0.454
5%≤R&D intensity <10%	0.111	0.314	0.101	0.302	0.138	0.346	0.114	0.318
10%≤ R&D intensity	0.038	0.191	0.089	0.286	0.077	0.267	0.055	0.228
Patented product	0.413	0.493	0.536	0.500	0.497	0.501	0.453	0.498
Own patents*	0.368	0.483	0.456	0.500	0.427	0.496	0.395	0.489
Supplier infor. at concept	0.298	0.458	0.363	0.482	0.385	0.488	0.327	0.469
Customer infor. at concept	0.736	0.441	0.737	0.441	0.728	0.446	0.734	0.442
University infor. at concept	0.073	0.260	0.184	0.389	0.159	0.367	0.110	0.313
Non-core field	0.192	0.394	0.302	0.460	0.267	0.443	0.227	0.419
Single specific customer	0.074	0.263	0.162	0.369	0.123	0.329	0.100	0.300
Multi specific customer	0.283	0.451	0.324	0.469	0.267	0.443	0.287	0.453
New bus. unit	0.167	0.373	0.207	0.406	0.231	0.422	0.187	0.390
Supplier in group	0.223	0.417	0.201	0.402	0.287	0.454	0.232	0.422
Customer in group	0.198	0.399	0.156	0.364	0.272	0.446	0.205	0.404
Firm size	5.183	1.444	5.182	1.502	5.125	1.637	5.171	1.494
Firm age	3.535	0.906	3.643	0.815	3.479	0.900	3.543	0.890
N	605		179		195		979	

Note: N of *Own patents* is different from the others: 587, 169, 185, and 941, respectively.

Table 3. Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 New sales channel	1.000																
2 New production factor	0.223	1.000															
3 5%≤R&D intensity <10%	−0.076	−0.059	1.000														
4 10%≤ R&D intensity	0.028	0.078	−0.085	1.000													
5 Patented product	0.007	0.021	0.128	0.119	1.000												
6 Own patents	−0.014	0.015	0.101	0.099	0.864	1.000											
7 Supplier infor. at concept	0.015	0.045	−0.052	0.015	−0.102	−0.095	1.000										
8 Customer infor. at concept	−0.038	−0.050	0.079	−0.029	0.027	0.044	−0.044	1.000									
9 University infor. at concept	0.090	0.124	0.058	0.039	0.125	0.089	−0.048	−0.131	1.000								
10 Non-core field	0.120	0.022	0.013	−0.004	−0.026	−0.060	0.019	−0.030	0.023	1.000							
11 Single specific customer	−0.094	−0.018	0.026	−0.016	−0.053	−0.081	−0.015	0.120	−0.071	0.048	1.000						
12 Multi specific customer	0.020	0.050	0.012	0.030	0.143	0.166	0.060	0.016	0.054	0.013	−0.210	1.000					
13 New bus. unit	0.226	0.090	−0.012	0.018	−0.060	−0.087	0.023	−0.040	0.049	0.138	0.028	−0.011	1.000				
14 Supplier in group	0.070	0.092	0.022	−0.042	−0.003	0.017	0.069	−0.028	0.056	0.015	−0.010	0.022	−0.065	1.000			
15 Customer in group	0.028	0.072	−0.035	0.008	−0.063	−0.022	0.043	−0.019	−0.001	0.010	0.066	−0.014	−0.067	0.531	1.000		
16 Firm size	−0.084	0.019	0.141	−0.056	0.345	0.370	−0.033	0.133	0.030	−0.036	−0.044	0.116	−0.149	−0.015	−0.097	1.000	
17 Firm age	0.006	−0.023	0.054	−0.094	0.073	0.075	0.016	0.045	0.009	0.007	0.004	0.042	−0.072	−0.104	−0.082	0.299	1.000

Table 4. Results of multinomial logit model estimation for sourcing external technology

	Base model			Model (1)			Model (2)			Model (3)		
	Not sourcing	Bilateral	Unilateral	Not sourcing	Bilateral	Unilateral	Not sourcing	Bilateral	Unilateral	Not sourcing	Bilateral	Unilateral
New sales channel				−0.082***	0.052*	0.030						
				(0.032)	(0.027)	(0.027)						
New production factor				−0.074**	0.062**	0.012						
				(0.033)	(0.027)	(0.028)						
5%≤R&D intensity <10%							−0.024	−0.042	0.066*			
							(0.050)	(0.043)	(0.040)			
10%≤ R&D intensity							−0.161***	0.083*	0.078			
							(0.062)	(0.044)	(0.051)			
Patented product										−0.107***	0.042	0.065**
										(0.035)	(0.028)	(0.029)
Supplier infor. at concept	−0.072**	0.031	0.041	−0.072**	0.032	0.040	−0.071**	0.029	0.042	−0.080**	0.035	0.045*
	(0.032)	(0.025)	(0.026)	(0.032)	(0.025)	(0.027)	(0.032)	(0.025)	(0.026)	(0.032)	(0.025)	(0.026)
Customer infor. at concept	−0.002	−0.006	0.008	−0.006	−0.001	0.007	−0.003	−0.004	0.007	−0.005	−0.005	0.011
	(0.034)	(0.028)	(0.028)	(0.034)	(0.028)	(0.028)	(0.034)	(0.028)	(0.028)	(0.034)	(0.028)	(0.028)
University infor. at concept	−0.202***	0.116***	0.086**	−0.181***	0.101***	0.080**	−0.196***	0.116***	0.080**	−0.186***	0.110***	0.076**
	(0.047)	(0.035)	(0.037)	(0.047)	(0.036)	(0.037)	(0.046)	(0.035)	(0.037)	(0.046)	(0.035)	(0.037)
Non-core field	−0.081**	0.063**	0.019	−0.074**	0.059**	0.015	−0.082**	0.064**	0.018	−0.085**	0.064**	0.021
	(0.037)	(0.028)	(0.031)	(0.036)	(0.028)	(0.031)	(0.037)	(0.028)	(0.031)	(0.036)	(0.028)	(0.031)
Single specific customer	−0.141***	0.100**	0.041	−0.158***	0.110***	0.048	−0.145***	0.104***	0.041	−0.153***	0.105***	0.048
	(0.050)	(0.039)	(0.042)	(0.049)	(0.039)	(0.043)	(0.050)	(0.039)	(0.043)	(0.051)	(0.039)	(0.042)
Multi specific customer	−0.010	0.027	−0.018	−0.006	0.025	−0.019	−0.011	0.028	−0.017	−0.008	0.026	−0.018
	(0.035)	(0.028)	(0.030)	(0.035)	(0.028)	(0.030)	(0.035)	(0.028)	(0.030)	(0.035)	(0.028)	(0.030)
New bus. unit	−0.045	0.004	0.041	−0.017	−0.015	0.032	−0.044	0.003	0.041	−0.048	0.006	0.042
	(0.038)	(0.031)	(0.031)	(0.038)	(0.032)	(0.031)	(0.038)	(0.031)	(0.031)	(0.038)	(0.031)	(0.031)
Supplier in group	−0.022	−0.006	0.027	−0.009	−0.015	0.024	−0.028	−0.001	0.029	−0.023	−0.005	0.028
	(0.042)	(0.035)	(0.033)	(0.042)	(0.035)	(0.033)	(0.042)	(0.035)	(0.033)	(0.042)	(0.035)	(0.033)
Customer in group	0.000	−0.057	0.057*	0.002	−0.058	0.057*	0.001	−0.059	0.057*	−0.002	−0.057	0.058*
	(0.044)	(0.037)	(0.034)	(0.044)	(0.037)	(0.034)	(0.044)	(0.037)	(0.034)	(0.044)	(0.037)	(0.034)
Firm size	0.002	−0.007	0.005	0.001	−0.007	0.006	0.001	−0.006	0.005	0.012	−0.011	−0.000
	(0.011)	(0.009)	(0.010)	(0.011)	(0.008)	(0.010)	(0.011)	(0.008)	(0.010)	(0.011)	(0.009)	(0.010)
Firm age	−0.014	0.022	−0.008	−0.012	0.021	−0.009	−0.016	0.025*	−0.008	−0.019	0.024	−0.005
	(0.018)	(0.015)	(0.015)	(0.019)	(0.015)	(0.016)	(0.019)	(0.015)	(0.016)	(0.019)	(0.015)	(0.016)
Log pseudo likelihood	−844.511			−835.778			−839.772			−839.637		
Pseudo R-squared	0.072			0.082			0.077			0.077		
Chi-square	131.54***			148.14***			145.27***			139.93***		
N	979			979			979			979		

Note: The base category is 'No sourcing'. Values are the marginal effects of the independent variables on the probability choosing the alternative. The marginal effect for factor levels is the discrete change from the base level. Values in parentheses are robust standard errors. The dummy variables of new product categories and a constant are dropped from the table. *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 4. Results of multinomial logit model estimation for sourcing external technology (continued)

	Model (4)			Model (5)			Model (6)		
	Not sourcing	Bilateral	Unilateral	Not sourcing	Bilateral	Unilateral	Not sourcing	Bilateral	Unilateral
New sales channel	−0.078**	0.049*	0.029				−0.078**	0.055**	0.023
	(0.031)	(0.027)	(0.027)				(0.032)	(0.027)	(0.027)
New production factor	−0.071**	0.058**	0.012	−0.088***	0.070***	0.018	−0.071**	0.056**	0.015
	(0.033)	(0.027)	(0.028)	(0.032)	(0.026)	(0.027)	(0.033)	(0.028)	(0.028)
5%≤R&D intensity <10%	−0.033	−0.035	0.068*	−0.025	−0.039	0.065	−0.046	−0.016	0.062
	(0.050)	(0.043)	(0.039)	(0.050)	(0.043)	(0.039)	(0.051)	(0.043)	(0.040)
10%≤ R&D intensity	−0.125**	0.061	0.064	−0.125**	0.061	0.064	−0.158**	0.077	0.081
	(0.063)	(0.045)	(0.051)	(0.062)	(0.044)	(0.051)	(0.064)	(0.047)	(0.051)
Patented product	−0.092***	0.033	0.058**	−0.097***	0.036	0.061**			
	(0.034)	(0.028)	(0.029)	(0.035)	(0.028)	(0.029)			
Own patents							−0.083**	0.023	0.059**
							(0.035)	(0.029)	(0.029)
Supplier infor. at concept	−0.078**	0.034	0.044*	−0.077**	0.033	0.044*	−0.074**	0.026	0.049*
	(0.032)	(0.025)	(0.027)	(0.032)	(0.025)	(0.027)	(0.032)	(0.026)	(0.027)
Customer infor. at concept	−0.009	0.000	0.009	−0.010	0.000	0.009	−0.014	0.002	0.012
	(0.034)	(0.028)	(0.028)	(0.034)	(0.028)	(0.028)	(0.034)	(0.028)	(0.029)
University infor. at concept	−0.162***	0.097***	0.065*	−0.168***	0.100***	0.068*	−0.160***	0.078**	0.082**
	(0.047)	(0.035)	(0.037)	(0.046)	(0.035)	(0.037)	(0.047)	(0.037)	(0.038)
Non-core field	−0.078**	0.061**	0.017	−0.087**	0.068**	0.019	−0.078**	0.060**	0.018
	(0.036)	(0.028)	(0.030)	(0.036)	(0.028)	(0.031)	(0.036)	(0.028)	(0.031)
Single specific customer	−0.169***	0.115***	0.054	−0.156***	0.108***	0.048	−0.150***	0.098**	0.052
	(0.050)	(0.038)	(0.043)	(0.051)	(0.038)	(0.043)	(0.050)	(0.040)	(0.043)
Multi specific customer	−0.006	0.024	−0.019	−0.006	0.025	−0.019	0.010	0.025	−0.034
	(0.034)	(0.028)	(0.030)	(0.034)	(0.028)	(0.030)	(0.035)	(0.028)	(0.031)
New bus. unit	−0.021	−0.013	0.033	−0.038	−0.002	0.040	−0.028	−0.016	0.044
	(0.038)	(0.031)	(0.031)	(0.038)	(0.031)	(0.031)	(0.038)	(0.032)	(0.031)
Supplier in group	−0.014	−0.011	0.025	−0.020	−0.008	0.028	−0.020	−0.005	0.026
	(0.041)	(0.035)	(0.033)	(0.041)	(0.035)	(0.033)	(0.041)	(0.035)	(0.032)
Customer in group	−0.001	−0.058	0.059*	0.004	−0.062*	0.059*	0.006	−0.064*	0.058*
	(0.043)	(0.036)	(0.034)	(0.043)	(0.036)	(0.034)	(0.043)	(0.037)	(0.033)
Firm size	0.009	−0.009	0.000	0.011	−0.011	−0.001	0.013	−0.008	−0.005
	(0.011)	(0.009)	(0.010)	(0.011)	(0.009)	(0.010)	(0.012)	(0.009)	(0.010)
Firm age	−0.018	0.024	−0.006	−0.021	0.026*	−0.005	−0.039**	0.030*	0.009
	(0.019)	(0.015)	(0.016)	(0.019)	(0.015)	(0.016)	(0.019)	(0.015)	(0.017)
Log pseudo likelihood	−828.070			−831.267			−786.038		
Pseudo R-squared	0.090			0.087			0.095		
Chi-square	165.72***			157.10***			165.61***		
N	979			979			941		

Table 5. Estimated average treatment effects of alliance strategies on products new to the market

	Potential outcomes
Not sourcing	0.453
Bilateral	0.487
Unilateral	0.479

A	B	ATE(A,B)	S.E.
Bilateral	Not sourcing	0.034	0.042
Unilateral	Not sourcing	0.026	0.035
Bilateral	Unilateral	0.008	0.048

Note: Treatment variable = {Not sourcing, Bilateral, Unilateral}. ATE(A,B) shows the estimated average treatment effect of A relative to B.

Appendix: Survey of New Product Development on Japanese firms

A survey of new product development on Japanese firms was conducted by the Research Institute of Economy, Trade and Industry (RIETI). The survey responses consist of 17,172 firms with a single business unit and 825 business units from 241 firms with multiple business units in the Manufacturing and Service industry listed in the Corporate Profile Database (COSMOS2) by the Teikoku Databank. The questionnaire was sent by mail, and sales or marketing managers were asked to answer questions about the focal business unit. The questionnaire includes some questions designed by The Duke/Georgia Tech American Competitiveness Survey, (Arora et al., 2014). The number of effective responses is 3,705, which means that the rate of response is 20.6%. Table A1 shows there is no significant difference in response rates across firm sizes.

For the question of "In 2010, have you earned sales from any new products or services introduced since 2008?" 1,390 business units (38% of total number of responses) answered that they had introduced new products or services. Table A2 shows the distribution of respondents by industry, which refers to the main business category and does not refer to the new product category used in the empirical analyses. We find that 'Pharmaceutical,' 'Medical machinery,' and 'Measurement, optical equipment' have high rates of introducing new products.

Table A1. Distribution of responses by firm size

(by # of employees)	# of samples	% of respondents
1-10	923	20.9%
11-50	2,912	23.5%
51-100	5,163	23.0%
101-1000	7,708	17.7%
1001-	1,291	21.3%
Total	17,997	20.6%

Table A2. Industrial distribution of respondents introducing new products

(by industry)	# of samples	% of introducing new products
Food product and tabacco	306	59.3%
Textile and apparel	109	39.4%
Wood, funiture, pulp, paper, etc.	253	28.6%
Chemical (excl. products)	99	51.5%
Pharmaceutical	57	75.0%
Chemical product	57	55.4%
Oil and coal products	131	22.9%
Primary metal	162	29.8%
Metal product	232	29.0%
General machinery	291	39.1%
Electrical machinery (excl. component)	176	46.3%
ICT machinery	132	44.7%
Electronics devise, IC	106	42.9%
Automotive	206	26.0%
Other transportation machinery	57	21.1%
Medical machinery	32	68.8%
Measurement, optical equipment	57	68.4%
Other manufacturing	370	37.2%
IT service	335	33.4%
Information service	151	20.1%
Engineering related service	86	36.5%
Others	82	20.7%
Unclassified	194	33.2%
Total	3705	37.7%