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Technology Sourcing in New Product Development Projects: When and How to Use External Resources?

Masayo KANI

Faculty of Economics and Business Management, Tezukayama University

Kazuyuki MOTOHASHI

Department of Technology Management for Innovation, University of Tokyo

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Tezukayama University

Research Institute for Economics and Business

7-1-1 Tezukayama, Nara 631-8501, Japan

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Masayo Kani[a]

Tezukayama University

Kazuyuki Motohashi[bc]

University of Tokyo, RIETI

ABSTRACT

This paper provides empirical analyses aimed at expanding our understanding of the management of external technology sourcing in new product development. The study focuses on the difference between bilateral contract-based alliances such as joint R&D and unilateral contract-based alliances such as licensing and commissioned R&D. The former involves acquiring a partner's knowledge in order to broaden a firm's own knowledge base; the latter involves simply leveraging a partner's specialized knowledge. We investigate the relationship between the characteristic of NPD project and the type of technology sourcing that is most appropriate, building on the knowledge-based view. Using a novel dataset of 994 new product development projects in Japanese firms, the study found that a firm is likely to use external technology sourcing in projects beyond the scope of the firm's core business as an efficient option for knowledge utilization and that the type of sourcing used will differ between large and small firms. Furthermore, we find that the relationship between technology sourcing type and projects in non-core business circumstances differs depending on the source of the new product concept. In case that the concept for the NPD project comes from customers (i.e., it is a demand pull project), the firm is likely to choose bilateral contracting when it is in a non-core business field to make up for its lack of market knowledge in that field. Our findings develop insight into alliance forms in NPD building on the knowledge-based view.

Keywords: alliance formation; external technology sourcing; information source; knowledge-based view; new product development.

JEL classification: O32; L24; O33

[a] Associate professor, Faculty of Economics and Business and Management, Tezukayama University, 7-1-1 Tezukayama, Nara 631-8501, Japan. E-mail address: mkani@tezukayama-u.ac.jp, tel: +81-742-48-7148. Corresponding author.

[b] Professor, Department of Technology Management for Innovation (TMI), University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan. E-mail address: motohashi@tmi.t.u-tokyo.ac.jp, tel: +81-3-5841-1828, fax: +81-3-5841-1829.

[c] Research Institute for Economy, Trade and Industry, 1-3-1 Kasumigaseki Chiyoda-ku, Tokyo 100-8901, Japan.

INTRODUCTION

More than ever, knowledge today is widely distributed throughout the world. Consequently, in the innovation process, it is often more efficient to tap into external technological resources than to stick to in-house development (Chesbrough, 2003). The "inbound" or "outside-in" mode of open innovation is becoming more and more relevant in a business environment characterized by an increasing division of innovative labor, particularly in science-based industries (Arora *et al.*, 2001). Indeed, there has been a growing number of papers on open innovation (Dahlander and Gann, 2010; West and Bogers, 2013). However, external technology sourcing cannot be achieved simply by market transactions between buyers and sellers; rather, it involves a complex process of interactions with technology providers. When engaging in external technology sourcing, a firm faces difficulty in explicitly describing task requirements and relation-specific assets, and risks information leakage to competitors (Teece, 1988). Disentangling this complexity in the internal innovation process is thus highly important when attempting to manage open innovation effectively.

External technology sourcing has been studied from several perspectives. In terms of the governance structure of the firm, the "make or buy" decision has been discussed based on transaction cost economics, showing that the relative transaction costs between "make" and "buy" typically determine the firm's governance form (Williamson, 1985; Klein, 2005). However, the reality is more complicated. Cassiman and Veugelers (2006) empirically show contextual variables that affect the choice of innovation strategies—"No Make & Buy," "Make Only," "Buy Only," and "Make & Buy"—and that the latter generally dominates the other modes. This is consistent with an open innovation model that combines external ideas and internal ones for creating new value, where the firm chooses both to "make" and "buy" rather than do either separately. Thus, in order to innovate by using externally-sourced technology, complementary technology resources (i.e., absorptive capacity, Cohen and Leventhal, 1990) are required. In addition, complementary non-technological resources such as manufacturing facilities, marketing channels, and the knowledge required play crucial roles (Arora *et al.*, 2001).

Other empirical studies focus on the "buy" aspect of the make-buy decision and examine the choice between equity alliances and non-equity (or contract-based) alliances (Oxley, 1997; Kale and Singh, 2009; Reuer *et al.*, 2016). Further dividing non-equity alliances into simple and more complex contracts, Mowery, *et al.* (1996), who examined the effect of inter-firm knowledge transfers, proposed a typology of alliances—unilateral contract-based alliances such as licensing, bilateral contract-based alliances such as joint development, plus equity joint ventures. Oxley (1997) and Colombo (2003) employ the typology of alliances in their empirical studies of the choice of alliance formation, using a database on alliance agreements. Das and Teng (2000) explain the relationship between structural forms of alliance (i.e., unilateral or bilateral contracts) and resource types (i.e., property-based or knowledge-based resources).

These two strains of the literature—investigating the make-buy decision (or when to buy) and determining what type of alliance to form (i.e., deciding on either a unilateral or bilateral contract)—rarely overlap. This paper fills the gap by comparing three options of technology sourcing for firms: (a) internal sourcing (i.e., in-house development only), (b) use of an external unilateral contract, or (c) implementation of an external bilateral contract. We assume that the firm chooses its technology sourcing option from one of these three options and that it does not make its decisions sequentially, such as first deciding whether to make or buy, then deciding which type of alliance to use.

To address this decision problem, the present study considers the situation of a firm about to begin a new product development project (hereafter, NPD project). We investigate the relationship between the type of NPD project and the style of technology sourcing that is most appropriate, building on a knowledge-based view. The knowledge-based view provides insight into the firm's boundaries through the lens of efficiency in knowledge management (Kogut and Zander, 1992; Grant and Baden-Fuller, 2004; Nickerson and Zenger, 2004). Previous studies have investigated firm alliances in terms of knowledge formation, examining such features as the relationship between innovative outcomes and prior alliance types (Al-Laham et al, 2010), knowledge characteristics (Carayannopoulos and Auster, 2010; Clercq and Dimov, 2008), and alliance partner diversity (Hagedoorn et al.,2018; Degener et al., 2018), partner knowledge diversity (Choi, 2020).

We address the choice of technology-sourcing types in NPD projects considering the scope and types of knowledge required. With respect to the scope of the required knowledge, we focus on the incongruity between the knowledge domain and product domain within the firm; as for the types of knowledge needed, the question is whether significant knowledge regarding the new product will come from customers or from universities, and whether the project is of the demand pull or technology push type. It is noteworthy that the two approaches to knowledge management as it relates to alliance formation proposed by Grant and Baden-Fuller (2004), who differentiate knowledge accessing and knowledge acquiring, illustrate the above typology of alliances—unilateral contract-based alliances and bilateral contract-based alliances. Thus, this paper develops the make-buy decision in NPD projects with the knowledge-based view.

We use a novel dataset at the product development project level. The dataset is based on a large-scale survey of Japanese firms conducted by RIETI (Research Institute of Economy, Trade and Industry). Using project-level data allows us to investigate the factors behind the choice of sourcing type in greater detail than would be the case with firm-level data such as the data produced from a *Community Innovation Survey*. Specifically, we focus on the types of new product development project and consider how project-specific variables interact with firm-level characteristics such as firm size, the size of absorptive capacity, and various (non-technological) complementary assets of the firm as a whole.

The remainder of the paper is structured as follows: Section 2 provides a typology of alliance strategies and the study's hypotheses; Section 3 presents a description of the study's survey and the variables used for the empirical model; Section 4 shows the results of the study's econometric analysis; Section 5 offers conclusions and suggests areas for further study.

THEORY AND HYPOTHESES

Type of Technology Sourcing

The types of alliances formed for external technology sourcing can be classified into non-equity alliances (or contract-based alliances), such as joint R&D, manufacturing, and marketing contracts, and equity-based alliances, such as joint ventures and minority equity investments (Oxley, 1997, Kale and Singh, 2009). Contract-based alliances can be further broken down into unilateral contract or bilateral contract types according to the direction of the knowledge flow (Mowery *et al*., 1996, Das and Teng, 2000). In this paper we focus on contract-based alliances for external technology sourcing.

Unilateral contract-based alliances are used for the firm's own activities involving technology or services provided in accordance with a contract that requires little coordination or collaboration, e.g., licensing and R&D contracts. Unilateral contracts exchange technology for cash payment; they are arm's-length contracts used to acquire the focal technology. The principal aim of unilateral contract-based alliances is to increase the speed and flexibility of technology development in connection with a shortened in-product lifecycle. Since these contracts tend to be tightly packaged, inter-firm knowledge flow is limited as compared to bilateral contract-based alliances that lead to increased learning opportunities (Mowery *et al.*, 1996).

With unilateral contract-based alliances, firms are required to recognize exactly what they need and accurately assess the external technology that can be provided by potential partners based on their specific technological competencies. Search costs depend on conditions within the technology market. Transaction costs can be reduced by having capabilities that allow ready access to the technology market, precisely specifying the required technology, and integrating it well into the firm's internal knowledge base.

In contrast, bilateral contract-based alliances are used to share resources with alliance partners and to work together, e.g., in collaborative R&D. Relative to unilateral contract-based alliances, bilateral contract alliances are beneficial to the firm not only in developing a new product but also in providing more opportunities for learning (Das and Teng, 2000). Taking a broad resource-based view, firms are motivated to form bilateral contract-based alliances as they allow the firm to acquire resources/expertise from other firms as well as develop their own resources and expertise by combining them with the resources and expertise of their counterparts (Kogut, 1988). Firms seeking to accumulate knowledge and technology through new product development for future business opportunities tend to prefer bilateral alliances to unilateral ones. The advantage is that bilateral contract-based alliances provide learning opportunities appropriate for the exploration and pursuit of knowledge development that broadens the scope of the firm's knowledge base.

To investigate external technology sourcing though the lens of knowledge management, we consider the above types of technology sourcing—bilateral contract-based alliances and unilateral contract-based alliances—building on a knowledge-based view.

Grant and Baden-Fuller (2004) proposed two approaches to forming alliances—the knowledge acquisition approach and the knowledge accessing approach—based on the concept of a knowledge-based view. The knowledge acquisition approach, which is primarily studied in organizational learning, argues that firms make alliances to learn, acquire their partners' knowledge, and broaden their knowledge base. This type of approach corresponds to exploration or knowledge generation, as conceptualized by March (1991) and Spender (1992). Lavie *et al*. (2010) refer to exploration as "a shift away from an organization's current knowledge base and skills." Al-Laham et al. (2010), who examine patent productivity enhanced by prior collaborative research agreements and prior licensing agreements in the biotechnology industry and building on acquiring and accessing knowledge in alliances, indicate that increased interaction with partners in collaborative research increases the impact of the alliance on innovation performance. Thus, we consider that the bilateral contract-based alliance is consistent with the knowledge-acquisition approach.

In contrast, the knowledge-accessing approach views an alliance as the means to access the knowledge of a partner rather than acquiring new knowledge to exploit complementarities. Here, the intention is to maintain the firms' differentiated base of specialized knowledge. This approach is related to the exploitation or knowledge application to which March (1991) and Spender (1992) refer. Lavie *et al*. (2010) explain exploitation as "building on the organization's existing knowledge base." Since knowledge provides both economies of scale and scope, it is more efficient to apply a knowledge base to a large number of products. If the firm intends to develop products by relying solely on its internal knowledge, the problem of underutilized knowledge arises, as the firm must amass a broad range of internal knowledge, only some of which may be fully utilized (Grant and Baden-Fuller, 2004). Alliances accessing the knowledge of partners without broadening the firm's in-house knowledge base can address this problem of underutilized knowledge. In this sense, we consider unilateral contract-based alliances as consistent with the knowledge-accessing approach.

Efficiency in knowledge utilization: incongruity between knowledge domains and product domains

The choice of technology sourcing depends on the heterogeneity of the NPD project. Since knowledge (particularly tacit knowledge) is not easily transferred between firms (Kogut and Zander, 1992), a firm should generally use its internal technological resources to the extent possible for NPD projects.

Grant and Baden-Fuller (2004) extend the idea of knowledge management by defining knowledge domains and product domains separately. In terms of efficient knowledge utilization, these two layers should overlap within the firm. However, new product development projects may require knowledge that does not exist internally. In such cases, the firm must choose whether to develop the knowledge itself or source it from the outside. The make-buy decision regarding the required knowledge is determined by whether the sought-after knowledge can be utilized for (potential) product domains. In NPD projects where there is substantial incongruity between knowledge domains and product domains, the firm will generally choose external sourcing as the efficient option in its knowledge management. In product domains that the firm has developed, Kogut and Zander (1992) indicate that the firm should internally develop knowledge similar to their current knowledge because of path dependence. Additionally, a firm enters into alliances to create options in situations where knowledge utilization is uncertain in future product domains (Grant and Baden-Fuller, 2004; Caner and Tayler, 2015). Thus, for new product development beyond the scope of a firm's core business, where the incongruity between knowledge domains and product domains will be relatively large compared to a project within its core business field, outside sourcing is likely to be more efficient than internal development. This logic brings us to the following hypothesis:

Hypothesis 1 (H1): A firm uses external sources more for non-core NPD projects than for core projects.

Efficiency in knowledge integration: combinative capability

Recent studies on the sources of innovation tend to focus on the internal perspective, discussing the company's internal competence to assimilate and combine external knowledge (Stefano et al., 2012). In knowledge application, the efficiency of accessing knowledge is relevant to not only knowledge utilization but also to knowledge integration whereby the firm combines knowledge from different sources and produces new products (Frishammar et al., 2012). Kogut and Zander (1992) argue that a firm's combinative capabilities enable it to exploit its knowledge and tap the unexplored potential of technology. Yeoh and Roth (1999) point out the integrative capabilities that deploy or use resources and develop from accumulated resources. Phene and Almedia (2008) describe the firm's combinative capabilities as the managerial capabilities to integrate and recombine knowledge. Accordingly, we need to consider the capabilities of the firm to integrate knowledge when it uses external sourcing in a non-core NPD project.

Since a large firm generally has the combinative capabilities that come with having engaged in multiple business projects, such firms tend to access external knowledge rather than acquiring it. As for the problem of underutilized knowledge, accessing a partner's knowledge is more efficient than acquiring it, as accessing external knowledge prevents firms from having excess knowledge capacity (Grant and Baden-Fuller, 2004). On the other hand, for a small firm, external sourcing should involve interaction with a partner that enables combining external knowledge with internal knowledge, especially when the firm is inferior in its combinative capability for accessing knowledge and integrating it into its internal resources. Thus, in technology sourcing for non-core NPD projects, large firms will generally prefer knowledge accessing (i.e., unilateral contracts), while small firms will tend to choose knowledge acquisition (i.e., bilateral contracts).

With regard to the knowledge transferred in technology sourcing, with unilateral contracts, explicit knowledge such as patents are traded in exchange for payment, while, with bilateral contracts, tacit knowledge or knowhow can flow in both directions (Das and Teng, 2000). It is presumed that a large firm with substantial internal tacit knowledge is inclined more toward unilateral contracts for its technology sourcing, since the aim is to apply technology that the firm does not possess. In addition, such explicit knowledge is easier to transfer and integrate for non-core business NPD. In contrast, a small firm is likely to seek tacit knowledge as well as explicit knowledge via bilateral contracts in order to fill the gap between its internal knowledge portfolio and the knowledge required for non-core business NPD. Of course, with bilateral contracts, the firm not only acquires its partner's knowledge; it also needs to share its knowledge with the partner (Lavie *et al*., 2010). A large firm with substantial knowledge sources would likely be reluctant to get involved in such a process, while a small firm would suffer less potential damage by giving away its knowledge. Therefore,

Hypothesis 2 (H2): In non-core NPD projects, a large firm is more likely to conduct external technology sourcing by means of unilateral contracts, while a small firm is more likely to use bilateral contracts.

Broadening knowledge base or leveraging specialized knowledge: demand pull or technology push

Firms involve external actors such as customers, suppliers, and academic institutions in the innovation process not only as co-developers but also as informal information sources. When leveraging external knowledge in NPD projects, a firm will choose the knowledge sourcing style that allows them to most efficiently manage the knowledge base required for the new product. The decision is, in part, influenced by the project type. We consider two types of projects, "technology push" projects, which involve innovation derived from science and technology, and "demand pull" projects, which involve innovation arising from demand (Stefano et al., 2012). A relevant factor here is whether the original idea comes from universities (i.e., technology push) or from the firm's customers (i.e., demand pull). This has significant impact on the firm's make- or-buy decision, and on the choice of contract type—unilateral or bilateral—if the decision is to "buy."

National innovation surveys in various countries have indicated that customers are the most important source of innovative ideas (Thether, 2002; Berderbos *et al.*, 2004). In support of this conclusion, Von Hippel (1986) argues that innovation is predominantly derived from customer ideas. The reason for this seems fairly straightforward: the expected value of an innovation project increases if it has been driven by a customer's idea since this raises the probability of commercial success. Hence, customer co-creation, which is referred to as customer involvement or customer participation, has been discussed as an initiator of successful innovation (Gemser and Perks, 2015, Cui and Wu, 2017; Nambisan, 2002; Fang, 2007). [1]

A firm gains value by acquiring information on the needs and desires of customers and incorporating these needs and desires into its product specifications, particularly when it results in significant economies of scale that produce lower costs (Kaplan and Haenelein, 2006). This clearly requires a close coordination between customer needs and the producers' technology (Stump et al., 2002). Since customer needs are complex, sticky, and costly to transfer to producers, detailed interactions are needed even if the firm cannot fully overcome the difficulty of transferring the information (von Hippel, 2001). Learning and broadening the knowledge base through iterative interaction in an alliance corresponds to the knowledge acquisition approach of Grant and Baden-Fuller (2004). If acquiring customer knowledge raises the probability of commercial success sufficiently to make the NPD project viable, the firm is likely to use external sourcing via bilateral contracts that involve more intense cooperation with the customer. In addition, any new product developments will be mutually beneficial to the firm and the customer. Thus, both parties have substantial incentives to share their knowledge, with less risk of helping potential competitors (Lavie *et al*., 2010).

Hypothesis 3a (H3a): In cases of technology sourcing, an NPD project based on customer ideas tends to favor the use of bilateral contracts.

Scholars have investigated knowledge transfer between universities and firms as a crucial source of innovation. In an NPD project based on ideas from a university, the firm can apply cutting-edge research and technological opportunities to produce new and innovative products. In such cases, the firm intends to leverage the specialized knowledge of the university but has no desire to broaden its in-house knowledge, so that the distinction between the knowledge bases of the firm and the university can be maintained. In this situation, where specialized knowledge is needed and differentiation is acceptable, knowledge accessing rather than knowledge acquisition is appropriate, which means that a unilateral contract will serve the needs of the firm (Grant and Baden-Fuller, 2004). Additionally, such science-based knowledge tends to be sufficiently codified and explicit to transfer readily across the organization (Arora *et al*., 2001). While it has been found that unilateral contracts are relatively efficient in transferring codified knowledge, bilateral contracts are better suited for tacit and uncodified knowledge interactions (Das and Teng, 2000).

Hypothesis 3b (H3b): In cases of technology sourcing, an NPD project based on the ideas of universities tends to favor unilateral contracts.

Interaction of demand-pull/technology-push with abundance of internal knowledge

A new product development process entails matching the firm's knowledge domains to the technology specifications required for a new target product (Grant and Baden-Fuller, 2004). To explain the incentive to use external technology sourcing, Hypotheses 1 deals with the firm's internal knowledge relative to the knowledge domain required for the new product, considering the elements of efficiency in knowledge utilization. Hypothesis 3 focuses on whether development of the new product is driven by customer knowledge (i.e., demand pull) or technological advancements coming from universities (i.e., technology push) and how this determines the appropriate type of external technology sourcing in terms of efficiency in knowledge management.

These two dimensions of NPD project types are related. Since the incongruity between knowledge domains and product domains develops the incentives to use external technology sourcing, the firms engaging non-core business projects have more preference for the focal type of external technology sourcing in demand pull projects or technology push projects.

When the concept for product development derives from the customer, the new product is essentially demand-driven and requires market knowledge. If that project is in a non-core business field, the firm likely lacks the necessary business knowledge in that field; thus, it would be expected to search for such knowledge from without. In this case, the process of new product development involves substantial interactions between the firm and its partner in order to combine both parties' knowledge. In such situations, the firm seeks a knowledge acquisition-type collaboration (i.e., a mutual exchange of knowledge) rather than simple knowledge access (i.e., incorporating specific knowledge without providing its own knowledge to the collaborating partner) (Grant and Barden-Fuller, 2004). Cui and Wu (2017), who examine the effect of two forms of customer involvement, as an information source and as a co-developer of innovative output, indicate that a firm with a low experimental NPD approach can expect greater benefit when the customer is involved as co-developer through the knowledge learning process. In addition, agency costs associated with the bilateral contracts appropriate to knowledge acquisition are lower in this case, since the project partner is also a potential business partner (Eisenhardt, 1989).

Hypothesis 4a (H4a): In cases when the information source of an NPD project is a customer, the firm uses bilateral contracts more for non-core NPD projects than for core projects.

Where technology "pushes" a project—that is, when a new product idea comes from a university—the firm must make substantial efforts to convert a technological breakthrough to a marketable product. If the project relates to the firm's core business, it will involve adjusting source technology to an existing and well-known market. Therefore, the project will tend to be managed more appropriately via a bilateral contract between the firm with market knowledge and its counterpart with technological knowledge. Since the new technology is likely beyond the capacity of the firm, using internal knowledge (rather than external sourcing) is not an option, and the firm is likely to choose bilateral contract-type technology sourcing. On the other hand, if the NPD project relates to a non-core business, technology adjustments to accommodate a specific business domain are not really required since the firm's focus will be on developing market knowledge for the product being developed. In this case, the firm is likely to choose the buy-in type (i.e., unilateral contract) of external technology sourcing. Here, of course, internal sourcing is again not an option, as the required knowledge is beyond the firm's business domain on both the technology and market sides.

Hypothesis 4b (H4b): In cases where the information source for an NPD project is a university, the firm uses unilateral contracts more for non-core NPD projects than for core projects.

We summarize our conceptual framework in Figure 1.

'Insert Figure1 here'

DATA AND METHODS

Data

In this study, we used data from a mail questionnaire survey conducted by the Research Institute of Economy, Trade and Industry (RIETI) in 2011. The survey targeted 17,997 business units of Japanese firms; 3,705 responses were received (response rate = 20.6%). The survey target included 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. For the 1,390 business units (38% of total responses) that had introduced new products between 2008 and 2010, we collected information related to the product with the most sales among the unit's new products. Thus, the collected information pertains to the project level rather than the general level of the firm. The novel dataset enables us to examine the relationship between the decision on external technology sourcing and types of projects in NPD. The survey design, based on the survey of Arora, *et al.* (2016), included various survey items on the external technology sources used in the new product development process.

To examine the NPD process incorporating internal development with external technology, we classified the 1,390 respondents into two groups based on whether they mainly used internal development or external development. In all, 1,199 respondents (86%) were placed in the internal development group; a much smaller number (168 respondents; 12%) comprised the external development group, with 23 non-respondents. The external development group included several kinds of businesses. Some in this group introduced a product that was developed (and manufactured) by another firm, selling it through their sales network without any internal R&D expenditure. Others subcontracted with another firm to custom produce their product using the contractual counterpart's design, such as in original equipment manufacturing (OEM). Since this paper focuses on the NPD process that combines external technology with internal development efforts, we eliminated the 168 respondents that were mainly using external development, leaving us with 1,199 respondents who utilized (mainly) internal development.

Dependent variables

We divided the remaining respondents into two groups based on whether they also used external technology sourcing. The external technology sourcing variable was based on the question, "How did you engage in developing a prototype for the focal new product?" Respondents selected one of six possible responses: M&A or investment, collaborative R&D or joint venture, licensing, research commissioned or consulting, informal sourcing such as reverse engineering, and other. Our primary variable is a discrete dependent variable that accommodates three outcomes: bilateral contract-based alliances (*bilateral*; answering collaborative R&D or joint venture; 179 observations), unilateral contract-based alliances (*unilateral*; answering license-in or research commissioned; 196 observations), and internal sourcing, where the product is developed exclusively in-house without any external technology sourcing (*internal sourcing*; 608 observations). We dropped observations in which the response was M&A or investment (22 observations) or indicated both collaborative R&D and licensing (12 observations), since our research focuses on non-equity alliances (or contract-based alliances). Observations where the response was both collaborative R&D and research commission are defined as collaboration. Thus, after dropping observations with missing data in addition to the above-mentioned cases, the number of valid mainly internal development observations was 994 (of the initial 1,199). In the model, a binary variable combining unilateral contract-based alliances and bilateral contract-based alliances is referred to as *external sourcing*; it indicates that external technology sourcing was used in the firm's NPD.

Independent variables

Incongruity between knowledge domains and product domains (i.e., based on a core or a non-core field). The variable *non-core field* indicates whether an NPD project is in a non-core business field. The assumption is that there is a substantial incongruity between knowledge domains and product domains in projects stemming from non-core fields. This binary variable takes a value of 1 if the main business category of the respondent's business unit is different from the new product's category (90 categories in all). This variable is used for testing Hypotheses 1 and 2, where we consider that NPD projects within the core business field involve congruity between knowledge domains and product domains, while non-core projects involve incongruity.

Technology push or demand pull (i.e., whether the concept comes from a university or a customer). We argue that the source of an idea for a new product is relevant to decisions regarding external sourcing. Accordingly, we defined variables to be used as proxies for NPD type—technology push or demand pull—in testing Hypothesis 3. In the survey, we asked questions about information sources at both the conceptualization stage and the prototype stage: “From which outside organization do you utilize information?” Respondents selected the most important source from eleven types of organizations. The alternatives included supplier, customer, another firm in the same industry, consultant, engineering/research service provider, university, government lab, patent research information, open information source, collaboration between your firm and others, and other. We decided to use the data on information sources at the conceptualization stage rather than the prototype stage, since, during the earlier stage, information is supposed to be a predetermined factor before technology sourcing choices are made. We divided the eleven types of organizations into four categories and focused on two information source variables at the conceptualization stage: The binary variable *concept from customer* takes a value of 1 if the most important information source at conceptualization is a customer; the binary variable *concept from university* takes a value of 1 if the most important information source at the conceptualization stage is university or government labs. We added a third binary variable, *concept from supplier*, which takes a value of 1 if the respondent indicated that a supplier was the most important information source; it indicates another type of business partner information source other than a customer. In the questionnaire, we included an alternative for jointly creating the concept with an external partner (of any type) rather than relying solely on an external partner for the new product conceptualization and added the dummy variable, *joint conceptualization*, in order to control for such a choice. (It should be emphasized that both *concept from customer* and *concept from university* correspond to cases in which the idea came exclusively from the indicated source rather than through a cooperative effort between firm and source.) The other types of organizations are included in the category of “others,” which is a reference category.

Control variables. We controlled for several other product and organizational factors that might influence the decision regarding external sourcing for NPD. These included *patented product*, *specific customer* (two variables), *high R&D intensity*, *new business unit*, *affiliated transaction* (two variables), *firm employee*, *firm age*, and *category of new product* (20 variables).

The first of these variables relate to product characteristics. There are two types of technologies used in NPD—property-based technology and knowledge-based technology. Although property-based technology is protected by intellectual property rights, knowledge-based technology raises concerns regarding appropriability (Das and Teng, 2000). 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). Thus, we control for whether the new product uses patented technology in order to capture the impact of this factor on the choice of external sourcing. The binary variable *patented product* takes a value of 1 if the new product is covered by one or more patents (or patents pending).

Whether the firm is selling to specific customers may influence the NPD process decision. To deal with this factor, we established three categories: The binary variable *single specific customer* takes a value of 1 if the product is sold to one specific customer firm; the binary variable *multiple specific customers* takes a value of 1 if the product is sold to multiple specific customer firms. The reference category includes many and unspecified customer firms, consumers, and others.

We next considered other factors of the organization. R&D intensity, defined as R&D expense divided by sales, is used as a proxy for technological capability. For firms with high R&D intensity, external technology sourcing such as bilateral and unilateral contract-based alliances is beneficial for NPD, as the firm can effectively absorb the external organization's expertise. In the survey, the R&D intensity in a business unit was 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, the average R&D intensity in Japanese firms implementing R&D activities is 3.22 percent, we defined the binary variable *R&D intensity* $\geq$ *5%* , which takes a value of 1 if the ratio of R&D expenditure to sales is more than 5%, as an indicator of high R&D intensity.

Whether the business unit has business experience is relevant to Hypothesis 2. To control for this at the business unit level, we included the binary variable *new business unit*, which takes a value of 1 if the firm started the business unit less than five years earlier.

We also control for whether the unit's main business transactions are with an affiliated business. The variable *supplier in group* takes a value of 1 if the respondent mainly receives supplies from affiliated companies; the binary variable *customer in group* takes a value of 1 if the respondent's main customers are affiliated companies.

As for other organizational factors, we controlled for the firm's size and age. The variable *firm employee* is the logarithm of the number of employees in the firm; the variable *firm age* represents the logarithm of the age of the firm. (The data source for firm age and number of employees is Teikoku Databank, COSMOS2.)

In addition to the control variables, we included twenty dummy variables representing new product categories. Table 1 shows the descriptive statistics; Table 2 gives the correlation matrix. In addition to the descriptive statistics for the entire sample (ALL), the table provides statistics for large- and small-firm subsamples (LARGE and SMALL) using the median number of employees for firms in the survey (136) to differentiate the two groups. We employ analyses for the two subsamples to test Hypothesis 2.

'Insert Table 1 here'

'Insert Table 2 here'

Hypothesis Testing Methodology

Our hypotheses predict a relationship between the choice of external technology sourcing and the type of NPD project. To analyze the choice problem, we employ two econometric models: a probit model using a binary variable indicating whether the firm is sourcing external technology and a multinomial logit model using a discrete dependent variable that takes on one of three values to indicate either a bilateral contract-based alliance (i.e., a collaborative R&D or joint venture), a unilateral contract-based alliance (i.e., license-in or research commissioned), or internal sourcing (i.e., in-house development with no external sources).[2]

With respect to model specification for the multinomial logit model, we conducted a specification test for IIA (the independence of irrelevant alternatives) based on a seemingly unrelated estimation model, since the Hausman test did not work. The results of all models shown below did not statistically reject the IIA null hypothesis.[3] This suggests the absence of a nested choice in which a bilateral or unilateral contract is chosen *after* a decision to use external technology sourcing is made. In addition, as a robustness check, we tested the model using the entire sample, including data from the group of respondents who had indicated that they relied mainly on external development. Similar results were produced.

Since the parameter estimates of the probit and multinomial logit models do not directly show choice probabilities, we report the average predicted probability and the average marginal effects (AME) using a post-estimation computation procedure. The AME for a binary variable shows the change in the probability of choosing the alternative when the variable value changes from 0 to 1. For example, our calculation of the AME of a non-core business project is as follows: We first calculate the predicted probability of choosing the alternative assuming that the project falls within the core business even though the project is in a non-core business. Similarly, we calculate the predicted probability assuming the project falls within a non-core business. We then take the difference in the two probabilities, which gives the marginal effect of a non-core business project for that respondent. The AME is the average of these differences for all respondents.

RESULTS

Table 3 gives the AME values for the choice probabilities of external technology sourcing using the parameter estimates of the probit model in which the binary variable *external sourcing* is the dependent variable. As shown for model (1) using data from all firms, the probability of external sourcing for NPD projects in a non-core business field is 0.091 higher than for projects in a core field ($p < 0.05$), thus this result supports H1. We find that a firm uses external technology sourcing when there is incongruity between knowledge domains and product domains. Efficient knowledge utilization, as proposed by Grant and Baden-Fuller (2004), is one promising approach to understanding the basis for external technology sourcing.

Also provided here are results for the large and small firm subsamples that were formed by using the median number of employees (i.e., 136) to differentiate the two groups. As shown in model (2), large firms have a higher probability of external sourcing for NPD in a non-core business field than in their core business field (AME = 0.164, $p < 0.01$); for the small firms featured in model (3), there is no statistically significant difference (AME = 0.009, $p = 0.852$).

‘Insert Table 3 here’

Since external technology sourcing includes two different types of sourcing, i.e., unilateral contract-based alliances and bilateral contract-based alliances, we examine the sourcing decision in terms of three alternatives: *internal sourcing*, *bilateral contract*, and *unilateral contract*. Table 4 reports the AME values for the probabilities of choosing each of the various alternatives based on the parameter estimates of the corresponding multinomial logit model.

Models (5) and (6) show the results for the large and small firm subsamples, respectively. For the large firms in model (5), when the firm develops a product in a non-core business field, the probability of choosing a unilateral contract-based alliance is 0.102 greater than when it develops a product in its core business field ($p < 0.05$), while the probability of choosing internal sourcing (i.e., in-house development) is lower by 0.162 ($p < 0.01$). This result supports H2, which states that large firms have a greater incentive to access required knowledge for an NPD project by using unilateral contract alliances for non-core projects because it is an efficient way to access external technology—unless it involves holding excess knowledge that can be underutilized.

By contrast, the results pertaining to small firms in model (6) show that the probability of selecting a bilateral contract-based alliance increases by 0.079 ($p < 0.1$) for projects in a non-core field (versus a core business field), while the probability of selecting a unilateral contract-based alliance decreases by 0.070 ($p < 0.1$). Although it is generally difficult for small firms to access and integrate external knowledge into internal resources, external sourcing that involves fairly extensive interaction with a partner enables these small firms to accomplish the task more easily. Owing to the offsetting effects of the positive change in the probability of a bilateral contract and the negative change in the probability of a unilateral contract, small firms showed no difference in the probability of selecting external technology sourcing for projects in non-core and core business field (model (3) of Table 3). The results here support H2, which states that small firms are more likely to make bilateral contract-based alliances for NPD projects in a non-core business field.

'Insert Table 4 here'

As for the relationship between the information source for a new product idea and the firm's choice of external technology sourcing, we examine the effect of *concept from customer* and *concept from university* in model (4) of Table 4. However, since Table 4 presents only comparisons with the reference category, we also report all four comparisons for customer and supplier, university, joint conceptualization, and others. The first section of Table 5 shows the average predicted probabilities for choosing a particular alternative when the product is assumed to be incorporating information from each source category even though the product is based on information from another source. In the second part of the table, (a) Difference, we report the difference between the predicted probability for a customer source and the predicted probability for the other four organization categories. Although there is a difference between "customer" and "others," we find no statistical difference between customer and supplier ($p = 0.333$) or university ($p = 0.153$), apart from a project involving joint conceptualization where joint development using a bilateral contract is indicated. The predicted probability of internal sourcing in a project based on customer information is 0.646 ($p < 0.01$); thus, we conclude that the firm in such cases will choose in-house development without external sourcing and that it will involve customers as informal information sources rather than as co-developers, though the firm seeks knowledge on both customer and market for its new product. This result does not support H3a.

'Insert Table 5 here'

When a university is the information source for a new product idea, the predicted 0.393 probability of a unilateral contract shown in Table 5 is the largest of the probability values. The third section of Table 5, (b) Difference, shows the difference between the predicted probability for the university case and the predicted probability for each of the other four organization sources. As for the difference in the probability of choosing a unilateral contract, we find that the probability for the case in which the project comes from the idea of a university increases by 0.217 ($p < 0.05$) compared to the case in which the project comes from a customer's idea. We also find that, while the probability of a unilateral contract in a project based on university information is higher than in the case in which the project is based on the idea of a supplier, the difference is not statistically significant (Difference = 0.145; $p = 0.128$). It appears that not all differences are statistically significant because of the large standard error due to the variety of university and industry collaborations (UIC). These results partially support H3b, which states that projects based on ideas from universities tend to use unilateral contract-type alliances. In these projects, accessing knowledge is more efficient because firms generally intend to leverage a university's specialized knowledge, which is differentiated from internal knowledge, rather than acquiring it (i.e., where there is no intention to broaden the firm's knowledge base). Moreover, in terms of efficiency of knowledge transfer, this arrangement is appropriate for accessing knowledge in a way that enables the firm to package its technology as more explicit knowledge.

It should be noted that the predicted probability of choosing a bilateral contract in the case of university (0.300) is greater than the predicted probability in the case of supplier (0.144) (Difference = 0.155, $p < 0.1$) and the predicted probability in the case of customer 0.178, though there is no statistical difference between the university and customer cases (Difference = 0.122, $p = 0.153$). Thus, bilateral contracts as well as unilateral contracts are relevant styles for external technology sourcing in technology push types of NPD projects.

We list results for several other variables representing product and organizational factors in Table 4. With respect to product factors, for small firms, a patented product has a statistically significant positive effect on the probability of a unilateral contract (model (6)) (AME = 0.103, $p < 0.05$), whereas the effect on the probability of internal sourcing is significantly negative (AME = -0.129, $p < 0.01$). Overall, projects using a patented technology have a 0.103 higher probability of choosing a unilateral contract than projects not using a patented technology. The implication is that small firms tend to prefer not to develop the product completely in-house. For large firms, by contrast, choosing none of the alternatives is significantly influenced by whether or not the new product uses a patented technology (p =

0.442, 0.951, and 0.293, respectively). These results suggest that alliances with small firms are more closely related to the patent system.

In terms of customer type, which is another product-related factor, for small firms, single specific customer has a significantly positive effect on the selection of a bilateral contract and a negative effect on internal sourcing. The results show a 0.110 higher probability of choosing a bilateral contract ($p < 0.1$) and 0.149 lower probability of in-house development in an NPD for a single specific customer ($p < 0.05$), as compared to the reference category. For small firms, an NPD project for a single customer requires closer communication with the customer, which would explain why a bilateral contract is preferred.

With regard to organizational factors, we find that higher R&D intensities for large firms have no significant effect on any of the alternatives, whereas in small firms with higher R&D intensities, the probability of unilateral contracting increases by 0.190 ($p < 0.01$), while the probability of internal sourcing decreases by 0.192 ($p < 0.01$) compared with the case of firms with lower R&D intensity (i.e., R&D intensity of less than 5%). This result implies that the only units accessing external knowledge well are technology-intensive units nested in small firms, denoting a difference in the capabilities of large and small firms when engaging in external technology sourcing in a project pertaining to a non-core field.

Next, we estimated a model adding the interaction term *noncore* × *information source*, where *information source* consists of four binary variables: *Concept from customer*, *Concept from supplier*, *Concept from university*, and *Joint conceptualization*. Table 6 shows the AMEs of non-core field projects for all firms as well as the results estimated for the large- and small-firm subsamples considering the five types of information sources in the conceptualization stage.[4] For demand pull projects (i.e., projects using the customer as an information source), the probability of selecting a bilateral contract increases by 0.086 for non-core business projects ($p < 0.05$) compared to core business projects. By contrast, the coefficient of internal sourcing is negative (AME = -0.111, $p < 0.05$), indicating that internal sourcing is more likely to be used for core business projects (compared to non-core business projects). The non-core projects amplify the incentive to use bilateral contracts in demand pull projects, thus these results support H4a.

'Insert Table 6 here'

When we divide the entire sample into large and small subsamples, results consistent with H4a are found for small firms. With respect to the AME of bilateral contracts in SMALL, in the case of projects based on customer information, the AME of *non-core field* projects using a bilateral contract (0.137; $p < 0.05$) is greater than the AME of *non-core field* projects using a bilateral contract (0.079; $p < 0.1$) in model (6) of Table 4. Thus, it would appear that for the NPD projects of small firms, market knowledge provided by customers is important when the product concept originated with the customer; that is, in cases where the project is in a non-core business field, bilateral contracts are more preferred than in the core business project to fulfill a lack of market knowledge. As for LARGE, the AME of bilateral contracts is statistically insignificant (0.008; $p = 0.881$). As discussed in regard to H2, for a resource-rich firm, some projects may be non-core to a particular group within the firm, but that may not be the case for the entire firm. Therefore, H4a is partially supported, depending on firm size.

We find different results with respect to projects based on customer information versus supplier information, even though both are related to a firm's business transactions. For projects based on supplier information, a firm is more likely to choose a unilateral contract in a core business field as compared to a non-core field, as shown by the negative AME in ALL (AME = -0.196, $p < 0.01$). In a core business field, where the firm has sufficient market knowledge, it is more efficient to source external knowledge using a unilateral contract when the firm undertakes an NPD project that entails process innovation that uses supplier technology. The reason for this is that the supplier's technological knowledge is embedded in a part of the product or that machinery provided by the supplier incorporates that knowledge, either of which makes the knowledge transfer easier.

As for technology push projects (i.e., using a university as the information source), if we consider ALL samples, although the unilateral contract probability increases for non-core business projects (i.e., the sign of coefficient is positive), which is consistent with H4b, the indicated increase is statistically insignificant ($p = 0.237$). This outcome is due to the large standard error (0.197), which might be explained by the greater heterogeneity found in projects based on university information (Motohashi, 2005). When the sample is split into LARGE and SMALL subsamples, the result supporting H4b for the large firms is obtained (AME = 0.723, $p < 0.01$). The implication is that, for an NPD project based on university information, a large firm will prefer unilateral contracting if the project is in a non-core business field versus a core field because extensive technology adjustments to accommodate a specific business domain are not required. However, the estimates for university sourced-projects for the LARGE firm subsample are too large, and hence not valid, due to there being too few observations involving technology push and non-core business projects.

DISCUSSION AND CONCLUSION

In this study, we use a novel dataset on NPD projects among Japanese firms as the basis for empirical analyses aimed at advancing our understanding of how firms source external technology and combine it with their own knowledge and resources to develop new products. We consider the make-buy decision that involves three alternative sources: bilateral contract-based alliances (i.e., joint venture, joint R&D), unilateral contract-based alliances (i.e., licensing, commissioned R&D), and internal sourcing (i.e., completely in-house development). Applying the theory of strategic alliances proposed by Grant and Baden-Fuller (2004) that is built on the knowledge-based view, the first alternative involves cooperation with a partner to broaden the firm's knowledge base in a knowledge acquisition approach, whereas the second involves the straightforward process of sourcing a partner's specialized knowledge in a knowledge accessing approach.

We show the choice of technology sourcing in NPD projects through the lens of efficient knowledge management, arriving at several important conclusions. First, a firm uses external technology sourcing to resolve the incongruity between knowledge domains and product domains when the firm develops new products in a non-core field. Second, a large firm with combinative capabilities is more likely to undertake unilateral contracting for an NPD project in a non-core business field (versus a core field) as this allows the firm to efficiently resolve the incongruity between knowledge domains and product domains. By contrast, a small firm will prefer bilateral contracts for NPD projects in non-core business fields in order to acquire explicit and tacit knowledge through an alliance.

Third, a firm with an NPD project based on an idea coming from a university (i.e., a technology push project) favors unilateral contracting because the firm intends to leverage specialized knowledge but not broaden its in-house knowledge base through learning (though the result also implies the heterogeneity of projects in which universities are involved). Forth, the relationship between technology sourcing type and projects in non-core business areas depends on the source of the new product concept. For instance, when the concept for the NPD project comes from customers (i.e., it is a demand pull project), the firm is likely to choose bilateral contracting when it is in a non-core business field to make up for its lack of market knowledge in that field.

Theoretical implication

This study develops the make-buy decision and alliance formation with the knowledge-based view. The study described here not only tests the technology make-buy decision; it also tests the impact on the choice of the type of alliance the firm will use, bilateral or unilateral, when the buy decision is made in order to confirm certain regularities regarding the type of project—such as "core field" vs. "non-core field" and "technology push" vs. "demand pull"—predicted by efficient knowledge management. Our results contribute to addressing the complex process of external technology sourcing by taking a knowledge-based view, focusing on new product development processes that combine internal and external knowledge (Grant and Baden-Fuller, 2004). We extend that theory by treating market and technological knowledge separately, and empirically test the regularities in technology sourcing mechanisms according to the type of new product being developed.

Managerial implications

Our findings can serve as useful inputs to managers when making decisions regarding external technology sourcing for a new product development project. First, types of external technology sourcing, which are unilateral one and bilateral one, have difference in knowledge management, thus firms should select an appropriate type of external sourcing in NPD projects with respect to the types of the projects. Second, our finding shows that the firms tend to source external knowledge when internal knowledge does not cover the knowledge domain required the projects. While firms with enough managerial resources that integrate internal knowledge with external knowledge conduct unilateral alliance, firms without resources make bilateral alliances. Third, this study provides how likely firms choose internal sourcing, bilateral alliance, and unilateral alliance in demand pull projects and technology push projects. Elements of knowledge such as tacit or codified knowledge are related to technology sourcing. According to our result, firms are likely to use unilateral alliances in the technology push projects to leverage the specialized knowledge but no desire to broaden its in-house knowledge. Furthermore, in cases of demand pull project firms engaged in non-core business field projects are more likely to make bilateral alliances to broaden the knowledge through interaction. Thus, our empirical findings suggest one insight that external technology sourcing in NPD projects is referred as an issue on pursuing efficiency of knowledge utilization.

LIMITATIONS AND FUTURE RESEARCH

One of the more notable empirical findings is that differences in such regularities are related to the size of the firm, producing several contrasting results between large and small firms. We used the firm's number of employees, admittedly a rather crude measure, to specify our firm-size variables. Further detailed analysis with data of finer granularity would be recommended. For example, theories of the knowledge-based view are built on the distinction between, within, and across firm-knowledge flows. However, the reality is more complex. There are additional variations such as an intra-firm case without inter-department knowledge flows. In this paper, we argue that one business department (i.e., an observation unit in our survey) within a large firm might be benefited by having other departments within the firm, whereas small firms are less likely to be multi-divisional. Our dataset is too crude to investigate the efficacy of knowledge flows between internal and external elements in such intermediate cases.

Another opportunity for further study is to make a more explicit link between technology and market knowledge. Danneels (2002) presents a framework that features a matrix of exploitation-exploration and technology-market domain, and explains the evolution of a firm's new product development process by using partial exploration (e.g., market exploration with existing technology exploitation or vice versa) to expand (explore) both market and technology resources. However, Danneels (2002) does not explicitly treat the possibility of external resources. Our survey samples include NPD cases of technology push and non-core business, suggesting the possibility of jumping into a "pure exploration strategy" (using the Danneels quadrant) from external technology sourcing. New theoretical developments based on empirical studies (either by means of case or quantitative studies with a new survey) show promise in an era of open innovation.

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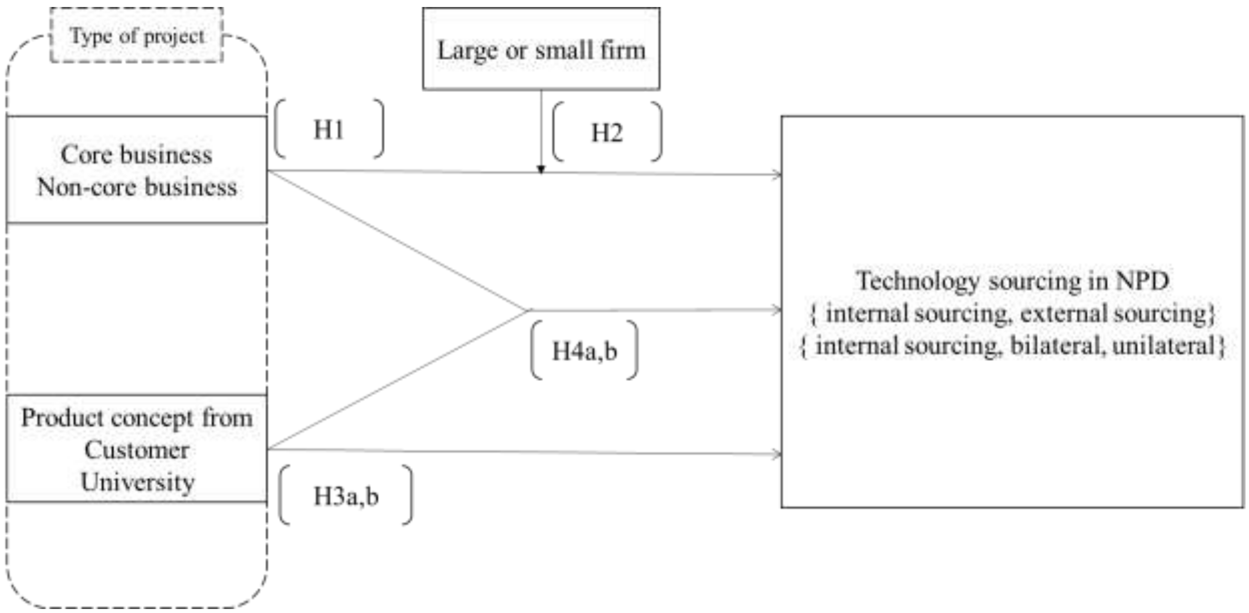
Tables and Figures

Figure1. Conceptual Framework



H1: *Prob*(external sourcing| Non-core, Z) > *Prob*(external sourcing| Core, Z)

H2: *Prob*(unilateral| Non-core, Z) > *Prob*(unilateral| Core, Z) in Large firms

Prob(bilateral| Non-core, Z) > *Prob*(bilateral| Core, Z) in Small firms

H3a: *Prob*(bilateral| Customer, Z) > *Prob*(bilateral| j, Z), j represents the other types.

H3b: *Prob*(unilateral| University, Z) > *Prob*(unilateral| k, Z), k represents the other types.

H4a: *Prob*(bilateral| Non-core, Customer, Z) > *Prob*(bilateral| Core, Customer, Z)

H4b: *Prob*(unilateral| Non-core, University, Z) > *Prob*(unilateral| Core, University, Z)

Prob(j| ·) is the probability choosing the alternative j, and Z represents the other variables.

Table 1. Descriptive statistics

	ALL		LARGE		SMALL	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Internal sourcing	0.62	0.49	0.63	0.48	0.62	0.49
Bilateral	0.18	0.39	0.19	0.39	0.17	0.38
Unilateral	0.20	0.40	0.18	0.39	0.21	0.41
Non-core field	0.22	0.42	0.20	0.40	0.25	0.43
Concept from customer	0.54	0.50	0.58	0.49	0.50	0.50
Concept from supplier	0.12	0.33	0.11	0.31	0.14	0.35
Concept from university	0.03	0.18	0.03	0.16	0.04	0.20
Joint conceptualization	0.18	0.38	0.16	0.37	0.20	0.40
Patented product	0.45	0.50	0.59	0.49	0.32	0.47
Single specific customer	0.10	0.30	0.08	0.28	0.11	0.32
Multi specific customer	0.29	0.45	0.33	0.47	0.25	0.43
R&D intensity ≥ 5%	0.17	0.38	0.21	0.40	0.14	0.34
New bus. unit	0.19	0.39	0.14	0.34	0.24	0.42
Supplier in group	0.23	0.42	0.23	0.42	0.23	0.42
Customer in group	0.21	0.40	0.18	0.38	0.23	0.42
Firm employee	5.17	1.49	6.28	1.21	4.07	0.71
Firm age	3.55	0.89	3.69	0.90	3.40	0.85
N	994		497		497	

Table 2. Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	Internal sourcing	1.00																
2.	Bilateral	-0.60	1.00															
3.	Unilateral	-0.63	-0.23	1.00														
4.	Non-core field	-0.11	0.08	0.05	1.00													
5.	Concept from customer	0.05	0.01	-0.07	-0.04	1.00												
6.	Concept from supplier	-0.01	-0.04	0.05	0.04	-0.41	1.00											
7.	Concept from university	-0.13	0.06	0.11	0.01	-0.20	-0.07	1.00										
8.	Joint conceptualization	-0.09	0.09	0.02	0.05	-0.51	0.81	-0.09	1.00									
9.	Patented product	-0.10	0.08	0.05	-0.03	0.08	-0.11	0.08	-0.05	1.00								
10.	Single specific customer	-0.11	0.10	0.04	0.04	0.11	-0.04	-0.02	-0.08	-0.05	1.00							
11.	Multi specific customer	-0.02	0.04	-0.02	0.02	0.07	0.01	-0.04	0.00	0.15	-0.21	1.00						
12.	R&D intensity ≥ 5%	-0.07	0.03	0.06	0.01	0.03	-0.05	0.05	0.03	0.19	0.00	0.02	1.00					
13.	New bus. unit	-0.06	0.02	0.06	0.14	-0.06	0.00	0.06	0.01	-0.07	0.02	-0.01	0.00	1.00				
14.	Supplier in group	-0.03	-0.04	0.07	0.02	-0.05	0.05	0.01	0.04	-0.01	-0.01	0.02	-0.02	-0.06	1.00			
15.	Customer in group	-0.03	-0.05	0.09	0.02	-0.04	0.02	-0.02	0.04	-0.06	0.06	-0.01	-0.03	-0.06	0.53	1.00		
16.	Firm employee	0.01	0.01	-0.02	-0.04	0.12	-0.05	-0.02	-0.04	0.34	-0.04	0.12	0.09	-0.15	-0.02	-0.09	1.00	
17.	Firm age	-0.01	0.05	-0.04	0.01	0.08	0.02	0.00	0.03	0.06	0.00	0.03	0.00	-0.07	-0.10	-0.08	0.29	1.00

Note: The number of observations is 994.

Table 3. Average marginal effects from a probit model of external technology sourcing

	(1) All	(2) LARGE	(3) SMALL
	External sourcing	External sourcing	External sourcing
Non-core field	0.091**	0.164***	0.009
	(0.038)	(0.055)	(0.049)
Concept from customer	0.033	-0.021	0.107**
	(0.036)	(0.050)	(0.048)
Concept from supplier	0.074	0.062	0.118*
	(0.052)	(0.080)	(0.070)
Concept from university	0.373***	0.502***	0.300***
	(0.084)	(0.104)	(0.112)
Joint conceptualization	0.325***	0.265***	0.358***
	(0.070)	(0.101)	(0.097)
Patented product	0.092***	0.041	0.129***
	(0.035)	(0.048)	(0.049)
Single specific customer	0.162***	0.192**	0.153**
	(0.054)	(0.084)	(0.070)
Multi specific customer	0.027	0.039	-0.004
	(0.034)	(0.046)	(0.050)
R&D intensity ≥ 5%	0.038	-0.044	0.180***
	(0.042)	(0.052)	(0.067)
New business unit	0.049	-0.040	0.131**
	(0.039)	(0.058)	(0.051)
Supplier in group	0.041	0.050	0.017
	(0.041)	(0.061)	(0.057)
Customer in group	0.014	0.049	-0.035
	(0.043)	(0.067)	(0.055)
Firm employee	-0.009	-0.003	-0.021
	(0.011)	(0.018)	(0.029)
Firm age	0.016	0.031	0.013
	(0.018)	(0.026)	(0.025)
Industry dummy	YES	YES	YES
Log pseudo likelihood	-598.344	-288.106	-290.190
Pseudo R-squared	0.093	0.123	0.124
Wald Chi-square	119.317 [0.000]	70.762 [0.000]	82.009 [0.000]
N	994	497	497

Note: The average marginal effect of factor levels is the discrete change from the base level/ the reference group. Values in parentheses are standard errors by the delta method, values in bracket indicate p-values. The dummy variables of new product categories and a constant are dropped from the table. LARGE refers to the group consisting of the respondents with more than 136 employees of the median value, SMALL is the group of the respondents with less than 136 employees.

Table 4. Average marginal effects from a multinomial logit model of external technology sourcing

	(4) ALL			(5) LARGE			(6) SMALL		
	Internal sourcing	Bilateral	Unilateral	Internal sourcing	Bilateral	Unilateral	Internal sourcing	Bilateral	Unilateral
Non-core field	-0.091**	0.072**	0.019	-0.162***	0.060	0.102**	-0.010	0.079*	-0.070*
	(0.038)	(0.032)	(0.032)	(0.055)	(0.045)	(0.047)	(0.050)	(0.043)	(0.040)
Concept from customer	-0.033	0.065**	-0.032	0.015	0.021	-0.036	-0.106**	0.123***	-0.017
	(0.036)	(0.026)	(0.030)	(0.049)	(0.037)	(0.041)	(0.048)	(0.034)	(0.042)
Concept from supplier	-0.071	0.032	0.039	-0.061	0.045	0.016	-0.114	0.046	0.068
	(0.053)	(0.035)	(0.047)	(0.079)	(0.059)	(0.065)	(0.072)	(0.043)	(0.067)
Concept from university	-0.371***	0.187**	0.184**	-0.507***	0.372***	0.135	-0.287**	0.069	0.218*
	(0.087)	(0.087)	(0.090)	(0.102)	(0.139)	(0.133)	(0.117)	(0.078)	(0.119)
Joint conceptualization	-0.342***	0.440***	-0.098**	-0.286***	0.385***	-0.098	-0.378***	0.498***	-0.120*
	(0.069)	(0.071)	(0.047)	(0.093)	(0.092)	(0.064)	(0.092)	(0.094)	(0.064)
Patented product	-0.091***	0.026	0.065**	-0.037	-0.003	0.039	-0.129***	0.025	0.103**
	(0.035)	(0.028)	(0.030)	(0.048)	(0.041)	(0.037)	(0.050)	(0.039)	(0.044)
Single specific customer	-0.161***	0.110**	0.051	-0.192**	0.095	0.096	-0.149**	0.110*	0.040
	(0.053)	(0.048)	(0.048)	(0.082)	(0.067)	(0.079)	(0.069)	(0.064)	(0.060)
Multi specific customer	-0.032	0.036	-0.004	-0.041	0.058	-0.017	0.007	-0.009	0.002
	(0.034)	(0.027)	(0.029)	(0.045)	(0.036)	(0.036)	(0.050)	(0.036)	(0.042)
R&D intensity ≥ 5%	-0.041	-0.030	0.070*	0.044	-0.056	0.012	-0.192***	0.002	0.190***
	(0.042)	(0.029)	(0.038)	(0.052)	(0.036)	(0.045)	(0.068)	(0.045)	(0.067)
New business unit	-0.050	0.005	0.046	0.036	-0.040	0.005	-0.129**	0.046	0.083*
	(0.039)	(0.032)	(0.034)	(0.059)	(0.047)	(0.049)	(0.051)	(0.042)	(0.046)
Supplier in group	-0.036	0.000	0.036	-0.043	-0.010	0.053	-0.008	0.011	-0.003
	(0.041)	(0.033)	(0.034)	(0.063)	(0.047)	(0.049)	(0.058)	(0.044)	(0.051)
Customer in group	-0.013	-0.053*	0.066*	-0.038	-0.102**	0.140**	0.032	-0.012	-0.020
	(0.043)	(0.030)	(0.038)	(0.066)	(0.043)	(0.058)	(0.056)	(0.042)	(0.050)
Firm employee	0.009	-0.009	0.001	0.007	-0.026*	0.018	0.019	-0.013	-0.005
	(0.011)	(0.009)	(0.010)	(0.019)	(0.015)	(0.015)	(0.029)	(0.022)	(0.024)
Firm age	-0.017	0.022	-0.004	-0.038	0.047*	-0.009	-0.010	0.009	0.001
	(0.019)	(0.015)	(0.016)	(0.027)	(0.024)	(0.019)	(0.025)	(0.018)	(0.023)
Industry dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Log pseudo likelihood	-827.235			-383.473			-399.767		
Pseudo R-squared	0.102			0.162			0.136		
Wald Chi-square	193.617 [0.000]			130.616 [0.000]			136.426 [0.000]		
N	994			497			497		

Note: The base category is *Internal sourcing*. Values are the average marginal effects of the independent variables on the probability choosing the alternative. The average marginal effect of factor levels is the discrete change from the base level/ the reference group. Values in parentheses are standard errors by the delta method, values in bracket indicate p-values. The dummy variables of new product categories and a constant are dropped from the table.

Table 5. Predicted probabilities for a type of information source and difference in probabilities

	Internal sourcing	Bilateral	Unilateral
Customer	0.646 (0.020)	0.178 (0.016)	0.177 (0.016)
Supplier	0.608 (0.044)	0.144 (0.030)	0.248 (0.039)
University	0.307 (0.082)	0.300 (0.084)	0.393 (0.087)
Joint conceptualization	0.337 (0.063)	0.552 (0.068)	0.111 (0.040)
Others (reference)	0.679 (0.029)	0.112 (0.020)	0.209 (0.025)
(a) Difference			
Customer - Supplier		0.033 (0.034)	
Customer - University		-0.122 (0.085)	
Customer - Joint concept		-0.374*** (0.070)	
Customer - Others		0.065** (0.026)	
(b) Difference			
University - Customer			0.217** (0.088)
University - Supplier			0.145 (0.095)
University - Joint concept			0.282*** (0.095)
University - Others			0.184** (0.090)

Note: Values in the first part are the average predicted probability choosing the alternative when the information source of a NPD project is the focal category. Values in the second part, or (a) Difference, are the difference between the average predicted probabilities evaluated at customer information and the counterpart, and values in the third part, or (b) Difference, are the difference between the average predicted probabilities evaluated at university information and the counterpart. Values in parentheses are standard errors by the delta method. Parameters estimated in model (4) of Table 3 are used.

Table 6. Average marginal effects for non-core filed (vs. core field) at a type of information source

	ALL			LARGE			SMALL		
	Internal sourcing	Bilateral	Unilateral	Internal sourcing	Bilateral	Unilateral	Internal sourcing	Bilateral	Unilateral
Customer	-0.111**	0.086**	0.025	-0.109	0.008	0.101	-0.074	0.137**	-0.062
	(0.052)	(0.044)	(0.044)	(0.072)	(0.054)	(0.064)	(0.074)	(0.067)	(0.059)
Supplier	0.164*	0.033	-0.196***	0.013	0.063	-0.076	0.257**	0.060	-0.317***
	(0.088)	(0.070)	(0.066)	(0.149)	(0.121)	(0.110)	(0.110)	(0.092)	(0.078)
University	0.009	-0.243*	0.234	-0.170	-0.553***	0.723***	-0.067	-0.018	0.085
	(0.182)	(0.144)	(0.197)	(0.108)	(0.146)	(0.132)	(0.213)	(0.164)	(0.219)
Joint conceptualization	-0.120	0.005	0.115	-0.014	-0.066	0.080	-0.124	0.016	0.109
	(0.131)	(0.146)	(0.091)	(0.203)	(0.215)	(0.106)	(0.182)	(0.188)	(0.110)
Others	-0.192**	0.130**	0.062	-0.406***	0.269**	0.137	0.010	0.028	-0.038
	(0.075)	(0.061)	(0.062)	(0.103)	(0.110)	(0.098)	(0.091)	(0.059)	(0.079)
N	994	994	994	479	479	479	479	479	479

Note: Values are the average marginal effects of non-core field on the probability choosing the alternative at a type of information source. Values in parentheses are standard errors by the delta method.

FOOTNOTES:

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[1] Recent studies on customer co-creation deal with business-to-consumer (B2C) rather than business-to-business (B2B) because customer co-creation in B2C is open to discussion while studies on B2B have been well-developed (Gemser and Perks, 2015).

[2] Since we conducted the survey by business units, out of 994 responses, there are 115 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.

[3] As for Table IV, in the model for all firms, we cannot reject the hypotheses that the coefficients of the full model and the restricted model without *Bilateral* are the same ($\chi^2(35) = 14.23$, p = 0.99) and that the coefficients of the full model and the restricted model without *Unilateral* are the same ($\chi^2(35) = 25.62$, p = 0.88). Similarly, according to the test of the full model against the restricted model without *Bilateral* in the model for large firms, we cannot reject the hypothesis ($\chi^2(32) = 13.35$, p = 0.99); moreover, the test of the full model against the restricted model without *Unilateral* shows that the hypothesis is not rejected ($\chi^2(32) = 15.38$, p = 0.99). For small firms, we also cannot reject the hypotheses; ($\chi^2(34) = 12.68$, p = 0.99) and ($\chi^2(34) = 15.78$, p = 0.99). We also conducted tests of the models in Table 5 and 6. We used the Stata "suest" post-estimation command for the tests.

[4] We do not report the average marginal effects of the other variables when adding an interaction term because the model with the interaction term works for decomposing the effect of a non-core project, making the other variable values almost the same as the values in Table 4.

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