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What are the Determinants of Inbound and Outbound Open Innovation Performance?

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Abstract: In this study, a theoretical framework to understand open innovation (OI) was proposed and tested with a questionnaire survey of Japanese manufacturers. The survey revealed that (1) the performance of outbound OI is lower than that of inbound OI and (2) the correlation between inbound and outbound innovation is 0.335, which indicates that they have distinct dimensions. Through structural equation modeling, we confirmed that (1) inbound OI improves R&D performance and that (2) among many variables, the *acquisition/provision window of technology* and *absorptive capacity* positively affect the performance of both inbound and outbound OI. This result indicates that in Japan, performance of OI is determined by the capability and internal systems of firms. (3) Moreover, we confirmed that inbound and outbound OI are determined by different variables.

Keywords: Open innovation; Structural equation model; Absorptive capacity; Trust

1 Introduction

Researchers have investigated open innovation (OI) ever since Chesbrough (2003) proposed this concept. However, OI research has some limitations. First, no comprehensive theoretical framework has been proposed for understanding OI. Second, as Chesbrough et al. (2006) pointed out, most studies in OI employed case studies. However, a few studies employed secondary data. For example, Laursen and Salter (2006) defined external search depth and width, then operationalized them with source of knowledge items in a community innovation survey. Similarly, Spithoven et al. (2010) utilized a CIS survey and examined the effect of knowledge externalities and research cooperation on R&D-related outcomes. The present author developed hypotheses on the determiners of inbound OI performance and tested them with a questionnaire survey on Japanese manufacturers (Hamaoka, 2008). Lichtenthaler (2009) developed a measurement scale for outbound OI strategy and related it to firm-level R&D revenues. Thus, an OI-specific quantitative study that integrates inbound and outbound OI has not yet been conducted. Third, to the best of the author's knowledge, research conducted on OI thus far has focused only on US and EU industries.

Thus, our research has three main purposes.

(1) To develop a theoretical framework for understanding the performance of inbound and outbound OI.

(2) To understand the OI situation through a questionnaire survey of Japanese manufacturers.

(3) To test the proposed theoretical framework through a questionnaire survey.

2 Theoretical Frameworks

The proposed framework for understanding OI is depicted in Fig. 1. As Chesbrough and Crowther (2006) pointed out, there exist both inbound and outbound OI. Our framework relates their performance to antecedents and consequences.

The framework for explaining the performance of inbound and outbound OIintegrates transaction cost theory (Coase, 1937; Williamson, 1975), resource-based view/capability theory (Wernerfelt, 1984; Langlois and Robertson, 1995), and trust theory (Granovetter, 1985). Thorough an extensive survey of the literature, we found more than 40 variables that can affect the OI process (Hamaoka, 2009). We classified them into seven categories: (1) Environmental factors, (2) Organizational factors, (3) Relational factors, (4) Strategy, (5) R&D process, (6) Acquisition/provision window of technology, and (7) Collaboration partners.

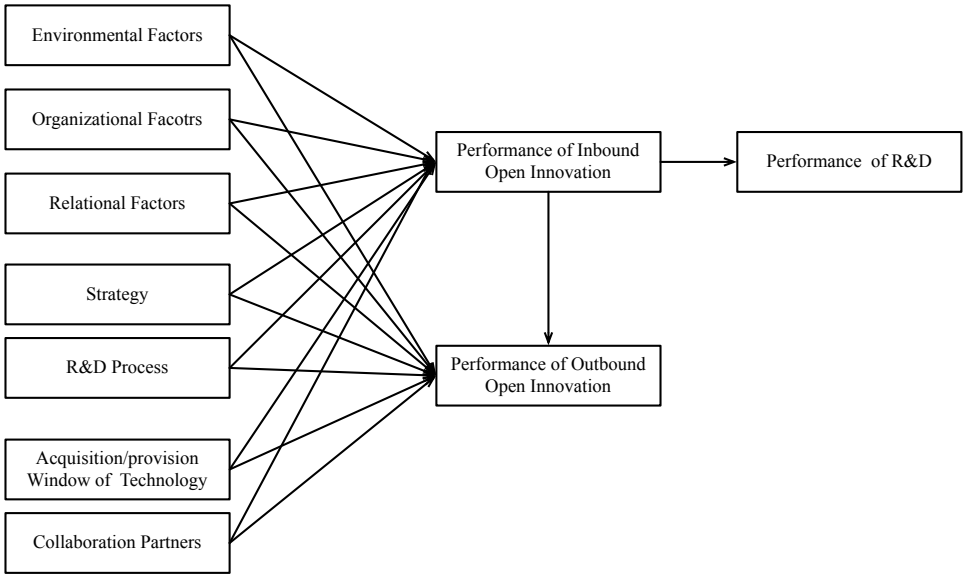


Figure 1 Theoretical Framework.

Main route of OI

By examining German and Japanese firms, Hemmert (2004) found that technology acquisition performance is influenced by institutional factors such as access to R&D personnel and to external sources of knowledge, as well as by legal and administrative environments and the organization of knowledge transfer. Thus, in order to harness OI,

the institutionalization of a formal system or window to acquire external knowledge and to provide internal knowledge is necessary. This leads to the first hypothesis.

$H_{w,io}$: The institutionalization of a knowledge acquisition/provision window is positively related to the performance of inbound and outbound OI.

Consequences of inbound OI

Inbound OI is expected to improve overall R&D performance. This leads to the following hypothesis.

$H_{i,r}$: Performance of inbound OI is positively related to the performance of R&D.

Antecedents of inbound and outbound OI

Factors that affect the performance of inbound and outbound OI are classified into (1) Environmental factors, (2) Organizational factors, (3) Relational factors, (4) Strategy, (5) R&D process, (6) Acquisition/provision window of technology, and (7) Collaboration partners.

Environmental factors

The *appropriability* of technology (Teece, 1986) and *technological uncertainty* (Pisano, 1990) are included as environmental factors. Both have a bidirectional effect. If a technology has high appropriability, it is easy to protect, and thus should have a negative impact on OI. However, appropriability is positively correlated with explicitness of knowledge. For example, a patent-registered chemical formula is strongly protected by patent law. Explicitness of knowledge lowers transaction costs, particularly communication costs.

Similarly, technological uncertainty will raise R&D costs that promote OI. In contrast, it increases communication costs that should have a negative impact on OI. These lead to the following hypothesis without direction of effect.

$H_{e,io}$: The appropriability of technology and technological uncertainty are correlated with performance of inbound and outbound OI.

Organizational Factors

Absorptive capacity (Cohen and Levinthal, 1990), technological competency, and risk-taking organizational culture are included as organizational factors. OI involves not only the acquisition of external knowledge but also the combination of external and internal knowledge. Absorptive capacity (Cohen and Levinthal, 1990) should have a positive impact on OI. Cohen and Levinthal (1990) empirically confirmed that internal R&D

harnesses absorptive capacity.

At the individual level, Andrews and Smith (1996) empirically found that *willingness to take risks* has a positive correlation with the creativity of marketing managers. Among organizational cultural dimensions, Tidd et al. (2001) focused on the creative climate. The OI process is a new approach to firms, and risk taking has a positive impact on the creativity of firms and the creation of innovation. This leads to the following hypothesis.

Hi_o: Absorptive capacity, technological competency, and risk-taking organizational culture have positive correlations with the performance of inbound and outbound OI.

Relational Factors

Chesbrough (2006) described the importance of technology intermediaries such as InnoCentive and NineSigma, implicitly assuming that knowledge or technology is traded in the market with their help. In contrast to such a neoclassical market view, Granovetter (1985) pointed out that embeddedness or a network of economic actors could prevent opportunistic behavior and decrease communication cost. In order to achieve or promote OI, collaboration with external actors is necessary. For Japanese companies, *trust* shapes long-term relationships and cooperative efforts (Clark and Fujimoto, 1991; Sako, 1998). Trust between distributors and manufacturers has a positive effect on the performance of a new product (Doney and Cannon, 1997). Trust between team members reduces coordination cost and enhances the performance of new product development initiatives (Bstieler, 2006). This leads to the following hypothesis.

$H_{r,io}$: Trust in a firm is positively related to the performance of inbound and outbound OI.

Strategy

Chesbrough (2003, 2006) and Chesbrough and Appleyard (2007) highlighted the importance of the business model. In order to build a successful business model, strategy at the firm and technology levels plays a significant role. Here, "strategy" includes technology integration (Iansiti, 1998), core technology development, pro-patent and license-out strategies.

Iansiti (1998) showed that *technological integration* is the key to success for high-tech companies. For a new product development level, it is confirmed that technology-marketing integration contributes to the success of a new product (Song and Parry, 1997). In the case of OI without a strategy, it is easy for internal strength to be lost. A strategy that integrates functional levels among R&D, new product development, production, and marketing, as well as between the firm and functional levels, is the key to a successful OI.

Core technology development strategy (Christensen, 2006) enhances internal technological competence. Of course, without internal technological competence, firms cannot provide their knowledge externally.

For firm-level patent strategy, pro-patent and license-out strategies are also

included. Some companies (e.g., Sharp Co.) do not register their production knowledge of LCDs to prevent spillover of their processing technology. Thus, patenting explicitly reveals knowledge that promotes OI. The license-out strategy promotes outbound OI. This is stated in the following hypothesis.

$H_{s,\ io}$: Technological integration strategy, core technology development strategy, pro-patent strategy, and license-out strategy are positively related to the performance of inbound and outbound OI.

R&D process

R&D and new product development (NPD) are complex processes. Clark and Fujimoto (1991) found that heavyweight project leaders play important roles in integrating the NPD process. By definition, it is necessary to integrate internal knowledge and external knowledge effectively. Project leaders have important roles in the OI process. Takeuchi and Nonaka (1986) and Nonaka and Takeuch (1996) described the NPD process as chaotic. R&D process formalization reduces transaction costs, including communication costs between external and internal entities. This is stated in the following hypothesis.

$H_{p,io}$: Heavyweight project leaders and R&D process formalization are positively related to the performance of inbound and outbound OI.

Collaboration partners

Collaboration with external entities is part of the OI process. OI, particularly inbound OI, seeks external sources of knowledge that complement internal knowledge. Laursen and Salter (2006) focused on the depth and width of the external search and operationalized it by counting knowledge sources in the Eurostat Community Innovation Survey (CIS), which includes suppliers, clients, and competitors. However, Laursen and Salter (2006) neglected the heterogeneity of external entities. In order to achieve innovation, needs information and technology/solution information are necessary (von Hippel, 1994). While customers occasionally innovate (von Hippel, 1988), they have more needs information. In contrast, university and public research institutes require technological information.

The keiretsu, a strong network between parent and subsidiary companies, is a key characteristic of the Japanese firm system. Clark and Fujimoto (1991) considered subsidiaries that participated in the development process of automobiles, which enabled a supply of flexible and high-quality parts at low cost. We add keiretsu as a source of external knowledge. Unlike other industries, industrial groups such as Japan's prodigy group tend to buy within their group rather than from outsiders (Chesbrough et al., 2006). Partnership with keiretsu tends to form a closed network that adversely affects OI performance.

It is also helpful to distinguish between vertical and horizontal collaboration. Vertical collaboration (e.g., firm-supplier, firm-customer) can connect different types of

knowledge, leading to more innovative outcomes. Horizontal collaboration, such as between rival firms, can lead to reductions of R&D costs. Thus, types of collaboration partners affect OI performance in different ways. This leads to the following hypothesis.

$H_{o,\ io}$: Collaboration partners affect the performance of inbound and outbound OIin different ways.

3 Data

Samples

We employed a questionnaire survey in order to understand the OI situation and to test the proposed hypotheses. Since 2007, we have conducted a survey on R&D and a survey on NPD Japanese manufacturers. Open innovation should be more important and easier in basic and applied research than in NPD. Thus, we included questions on OI into the R&D survey. Firms were randomly selected from manufacturers with an R&D department or laboratory that are listed on the Japanese stock exchange. Each year, we sent out approximately 450 questionnaires and received approximately 130 responses[1]. In a period of 5 years, we received 654 responses (including multiple-year responses).

We examined yearly trends in the responses. For some items, trends were significant; in order to eliminate trends, year of survey was introduced into the analysis. We also examined the differences between responding and non-responding firms in terms of sales, number of employees, and industry distribution. We confirmed that there was no non-response bias. Our sample included multiple-year responses. In order to avoid interdependence of the error term, the latest responses were included for analysis. Thus, our sample size was 390 firms.

Measurement Scales

A questionnaire was developed in order to measure constructs. A five-point Likert-type scale was employed for the test. Subjective performance measures have been used in the new product literature and have been shown to be highly correlated with objective

[1] Sample/response/response rate for each year are presented below.

2007: 450/122/27.1%

2008: 419/132/31.5%

2009: 485/127/28.2%

2010: 434/134/30.9%

2011: 451/136/30.2%

Total: 2239/651/29.1%

measures of financial performance (Song and Parry, 1997).

For each construct, a number of questionnaire items were developed. All constructs were measured using multiple-item scales. The wordings and reliabilities of the measures are summarized in Table 1. The Cronbach's alpha index of reliability exceeds 0.6; this indicates that the reliabilities for the constructs are acceptable. The intended constructs were extracted through exploratory factor analysis and then confirmed with confirmatory factor analysis. Thus, we confirmed the internal consistency and discriminant validity of the measurement.

Descriptive Statistics

First, we will provide an overview of OI in Japan. The survey revealed the OI situation in Japan. Only 11.8% of the respondents positively evaluated their acquisition/provision window for open innovation (the sum of two five-point Likert-scale items with three as neutral had a score of higher than four). Although acquisition/provision window performance was not well established, 46.4% of respondents evaluated their inbound OI performance positively. This indicates that they collaborate informally. In contrast, only 20.4% of respondents evaluated their inbound OI performance positively. This indicates that the performance of outbound OI is not well established.

The correlation coefficient between the performance of inbound and outbound OI is 0.335, which indicates a positive relationship. However, it is apparently significantly different from one. This means that the performances of inbound and outbound OI have distinct dimensions.

In sum, the phenomenon of OI is not novel in Japan, but managing inbound and outbound OI, particularly the latter, is difficult.

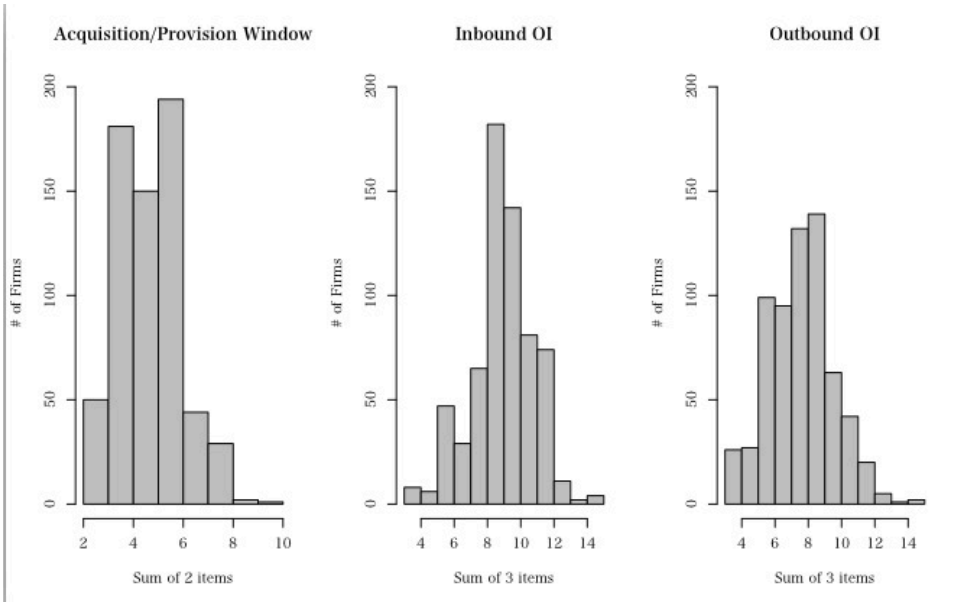


Figure 2 Histogram of the Performance of Inbound and Outbound Open Innovation

4 Results

Estimation

The proposed hypotheses among constructs were examined with the structural equation model by lavaan library (Rosseel, 2011) in R statistical software (R Development Core Team, 2007). Our sample comprised consumer goods (B2C) and industrial goods (B2B) firms. In order to examine the differences between them, we compared a pooled sample analysis with an industry dummy and multi-sample (B2C and B2B) analysis (Byrne, 2001; Kline, 2005). The model fit of the pooled sample analysis was better than that of the two-sample analysis (CFI = 0.725 and RMSEA = 0.062 for the pooled sample analysis; CFI = 0.095 and RMSEA = 0.112 for the two-sample analysis). This implies that our results are the same between consumer goods and industrial goods firms.

Results

Table 2 summarizes the results of the estimation for the pooled analysis. Figure 2 is the estimated path diagram. In order to avoid complexity, the industry dummy was excluded from Figure 2. The numbers on the arrows are path coefficients and asterisks (*) indicate the significance level. Solid and dashed lines represent significant and insignificant paths, respectively, at the 10% significance level.

The main route of OI

The path from the acquisition/provision window to the performance of inbound OI performance is positive and significant at the 10% level (beta = 0.125, $p<0.01$). The path from inbound OI performance to R&D performance is also positive and significant (beta = 0.213,$p<0.01$). Thus, the main process of OI was confirmed.

Antecedents of inbound outbound OI

Environmental factors and organizational factors

Two environmental factors, appropriability of technology and technological uncertainty, are found to be insignificant. In contrast, technological competency is positive and significant for the performance of inbound and outbound OI. Absorptive capacity and risk-taking have significant paths to inbound OI performance. In sum, OI performance is much more strongly affected by organizational factors than environmental factors.

Relational Factors

Trust in the firm has a positive impact on inbound OI performance. This result supports Granovetter's (1985) argument: networking among economic actors reduces transaction cost and promotes inbound OI.

Strategy

Among strategy factors, technological integration and license-out strategy have significant paths to inbound OI performance. The effect of strategy is significant for outbound OI. As mentioned previously, inbound OI is less established in Japan. Thus, the difference in strategy is significant for outbound OI performance.

R&D process

Heavyweight leader is insignificant for inbound and outbound OI. In contrast, R&D process formalization has a positive path to inbound OI, as expected. However, it has a negative path to outbound OI. Process formalization could lead to bureaucracy that impedes innovative processes such as providing own knowledge to external entities.

Collaboration partners

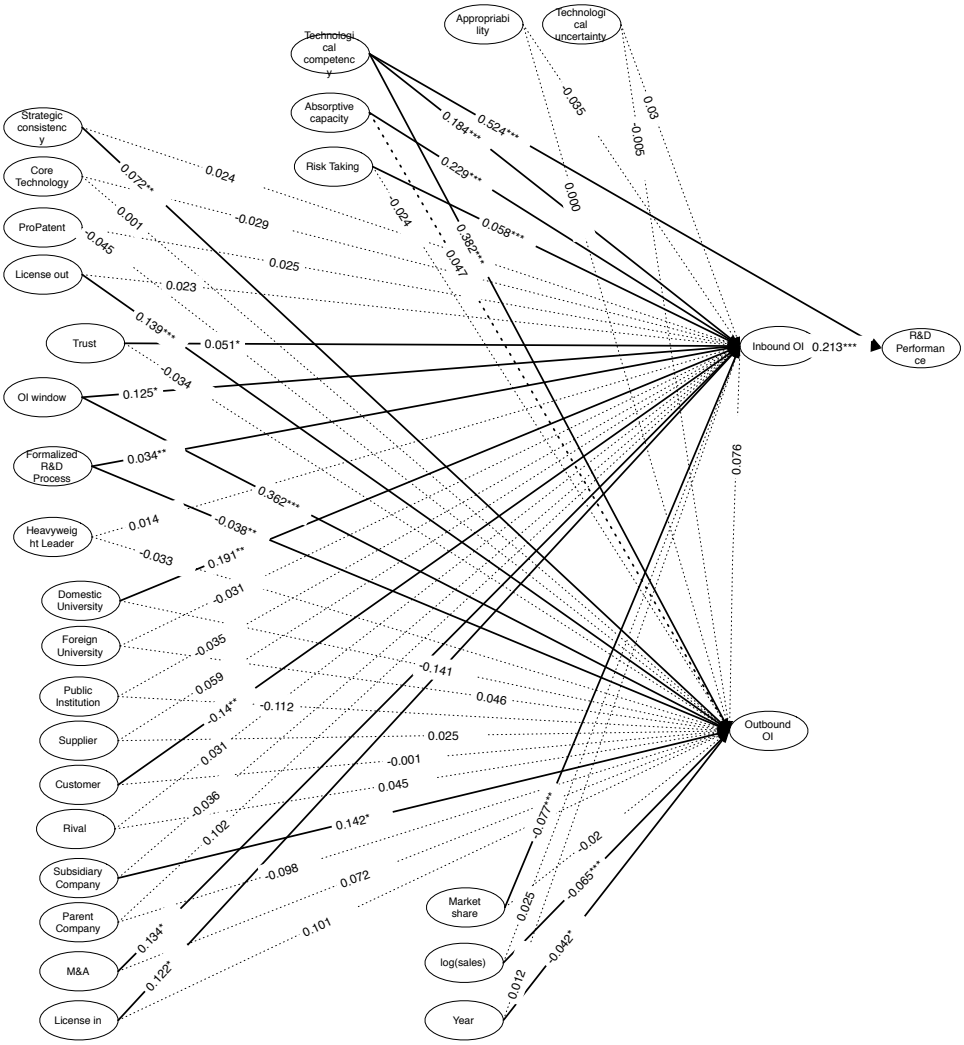
Among listed collaboration partners, domestic university, M&A, and license-in have positive impacts on inbound OI. Interestingly, customers who should have needs information have a negative and significant impact on inbound OI. These results indicate that Japanese manufactures seek technological knowledge for inbound OI. This result may be caused by our sampling frame: our research target is not NPD managers, but R&D managers who seek technological success.

For outbound OI, only subsidiary company is significant. Vertical knowledge provision within keiretsu is successful. Thus, Japanese outbound OI is semi-open innovation.

Control variables

Market position has a negative impact on inbound OI. Thus, weaker firms benefit from inbound OI. Similarly, log(sales) has a negative impact on outbound OI. However, when industry dummies are introduced, only one path—from ceramics to inbound OI—is significant. This implies that researchers on OI tend to focus on high-tech industries; however, our results are common among industries.

Year of survey has a negative and significant coefficient of outbound OI performance. Thus, while open innovation is attracting attention, knowledge provision is becoming limited.



Note: Solid lines indicate significance at the 10% level, at least. Dashed lines indicate insignificance at the 10% level.

Figure 2. Results of Analysis (Path Diagram of the Structural Equation Model)

Table 2. Results of Analysis (Path Coefficients of the Structural Equation Model)

Category	*Factors*	*Performance of Inbound OI*	*Performance of Outbound OI*	*R&D Performance*
Environmental Factors	Appropriability	-0.035	0.000	
	Technological uncertainty	0.03	-0.005	
Organizational Factors	Absorptive capacity	0.229***	0.047	
	Technological competency	0.184***	0.382***	0.524***
	Risk-taking	0.058***	-0.024	
Relational Factors	Trust in a Firm	0.051*	-0.034	
Strategy	Strategic integration	0.024	0.072**	
	Core technology	-0.029	0.001	
	Pro-patent	0.025	-0.045	
	License-out	0.023	0.139***	
R&D process	Heavyweight leader	0.014	-0.033	
	Formalized R&D process	0.034**	-0.038**	
Acquisition/provision window		0.125*	0.362***	
Collaboration Partners	Domestic university	0.191**	-0.141	
	Foreign university	-0.031	0.046	
	Public institution	-0.035	-0.112	
	Rival	0.031	0.045	
	Customer	-0.140**	-0.001	
	Supplier	0.059	0.025	
	Subsidiary company	-0.036	0.142*	
	Parent company	0.102	-0.098	
	License-in	0.122*	0.101	
	M&A	0.134*	0.072	
Industry	Food	0.06	0.073	
	Automotive	-0.015	0.099	
	Pharmaceutical	0.031	0.004	
	Chemical	-0.026	-0.01	
	Ceramics	0.145*	0.044	
	Precision mechanics	-0.012	-0.047	
	Electronics	0.06	-0.014	
	Machinery	0.038	-0.098	
Other variables	Market position (share)	-0.077***	-0.02	
	Log (sales)	0.025	-0.065***	
	Year	0.012	-0.042*	
Performance of Inbound OI		-	0.076	0.213***

Note: Significance levels: ***: 1%; **: 5%; *: 10%.
CFI = 0.725. RMSEA = 0.062.

5 Discussion

In this paper, we proposed a theoretical framework for understanding open innovation (OI) that integrated (1) environmental factors, (2) organizational factors, (3) relational factors, (4) strategy, (5) the R&D process, (6) the acquisition/provision window of technology, and (7) collaboration partners. A questionnaire survey of Japanese manufacturers was conducted in order to understand the OI situation in Japanese firms and to test the proposed hypotheses.

The survey revealed that the performance of outbound OI is lower than that of inbound OI, and the correlation between inbound and outbound innovation is 0.335, which indicates that they have distinct dimensions.

Through structural equation modeling, we confirmed that inbound OI improves R&D performance. Among the proposed hypotheses, two environmental variables—the *appropriability* of technology (Teece, 1986) and *technological uncertainty* (Pisano, 1990)—were found to be insignificant. In contrast, *acquisition/provision window of technology* and *technological competency* positively affect the performance of inbound and outbound OI . This result indicates that in Japan, OI performance is determined by firms' capability and the internal systems of firms rather than transaction costs, which are more influenced by environmental variables. We also confirmed that inbound OI performance is affected by the level of trust in a firm. These results support Granovetter's (1985) argument: networking among economic actors reduces transaction costs and promotes inbound OI.

Further, we confirmed that the performance of inbound and outbound OIare determined by different variables. This indicates that management of inbound and outbound OI requires different capabilities. In particular, outbound OI performance is lower than inbound OI. The former is positively affected by marketing-technology integration and license-out strategy, which are insignificant in inbound OI performance. Establishing a technological strategy is necessary for improving outbound OI.

Our results found that license-in and M&A have positive impacts on inbound OI. This means that Japanese manufactures utilize the market to acquire external knowledge, as in the US. While we do not have a similar quantitative study for the US, trust in firms positively affects inbound OI. This means that relationship-based collaboration is beneficial for Japanese firms. However, international comparison is necessary to confirm our findings.

Our respondents included a variety of industries. We compared pooled data analysis with an industry dummy and two-sample (B2B and B2C) analysis and found that the former fits better. This indicates that our findings are stable among various industries.

Contribution

This study presented a comprehensive theoretical framework for understanding OI. Unlike previous studies, our model identifies external variables, internal factors, and relational factors that influence the performance of inbound and outbound OI. Thus, we

conducted the first questionnaire survey designed to specifically analyze inbound and outbound OI. This research has developed measurement scales for the performance of inbound and outbound OI and their similarities and differences were presented herein.

Practical implications

The current study revealed that inbound and outbound OI have distinct dimensions. Among the many variables, acquisition/provision window for OI has a positive impact on the performance of inbound and outbound OI. Establishing a formal system for OI is key for its success. Absorptive capacity and trust in firms have a positive impact on inbound OI, thereby indicating that at least in Japan, technology is not freely traded in the market. Building firms' capability and being trusted is necessary to improve inbound OI and R&D performance.

Limitation and Future Research

We believe our study contributes to understanding OI. However, further research is required. First, more theoretical consideration is necessary. Technological competency should have a positive correlation with absorptive capacity. Firms with higher absorptive capacity should have better acquisition/provision windows. We neglected the relationships between variables, and theoretical elaboration is necessary to understand OI. Empirically, our research target is R&D managers of Japanese stock-listed manufacturers. R&D seeks more basic research than NPD, and as such, a survey of NPD managers would be helpful in clarifying the OI differences and similarities between R&D and NPD. International comparison would also be meaningful for confirming the generalizability of our findings.

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Appendix. Factors, Measurement Items, and Reliability

Category	*Factor*	*Wording*	*Cronbach's alpha*
Environmental factors	Appropriability	It is important for us to obtain patents for our products. It is easy to obtain a circumventing patent.	0.581
	Technological uncertainty	Technological competition is severe. Technological change is drastic.	0.558
Organizational factors	Technological Resource	We have innovative technology that our competitors do not have. We have more patents than our competitors.	0.661
	Absorptive Capacity	We are good at learning and utilizing external knowledge. We are good at connecting external and internal technology.	0.705
	Risk-taking	We are not afraid of experiencing failures. We can challenge our competitors even after experiencing a failure.	0.762
Relational factors	Trust	Our firm is trusted by customers and suppliers. Our firm is regarded as being fair by customers and suppliers.	0.880
Strategy	Strategy integration	Our R&D strategy is integrated into the firm-level strategy and plan. Basic research, applied research, and product development are well coordinated.	0.713
	Core technology	We focus on a few core technologies.	-
	Pro-patent	We are active in obtaining patents.	-
	License-in	We seek royalties for our patents.	-
Acquisition/Provision window of Technology		We have a formal window/system for accepting technological proposals from other firms. We have a formal window/system for supplying our technology to other firms. We actively monitor technology trends.	0.674
R&D process	Heavyweight Leader	The project leader is responsible for the entire project, from the R&D stage to the launch of a new product. Our project leader has sufficient knowledge of the entire process, from conducting R&D to launching new products.	0.738
	Formalized R&D Process	Our R&D procedure is well documented. Each step of our R&D procedure is clearly defined.	0.880
Acquisition/Provision window of Technology		We have a formal window/system for accepting technological proposals from other firms. We have a formal window/system for supplying our technology to other firms. We actively monitor technology trends.	0.674
Performance	Inbound OI	The introduction of external technology has accelerated our R&D speed. The introduction of external technology has enabled the development of innovative products in our firm. In our firm, the products that incorporate external technology succeed in the market.	0.872
	Outbound OI	Our technology is licensed to other firms, and enables them to develop innovative products. The products of other firms that have licensed our technology succeed in the market. Our revenue from licensing has increased.	0.784
	R&D Performance	Our R&D efficiency is better than that of our competitors. Most of our R&D output is commercialized.	0.769

Note: Each item was measured with a five-point Likert-type scale.