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Open Innovation Projects in SMEs as an Engine for Sustainable Growth

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Abstract: Most innovation activities that are inevitable for sustainable growth are coordinated via research and development (R&D) projects, which can differ widely in terms of both project and open innovation characteristics, even when conducted within the same firm. Therefore, it is important to consider the peculiarities of R&D projects when evaluating the performance of open innovation strategies, as well as to explore how the benefits and costs of open innovation are shaped by cross-level interactions. This study identifies the differences between successful and unsuccessful open innovation projects, in both firm-level and project-level terms. We focus on small and medium enterprises (SMEs), which usually lack the full set of internal resources and competences required to effectively develop, produce, and commercialize their innovations, and thus must adopt open innovation approaches more actively for sustainability. Adopting an empirical approach, we conducted a survey of 517 Korean SMEs and analyzed 241 successful and unsuccessful open innovation projects in depth. By combining measurements at the firm and project levels, this study provides new insight into the intra-organizational challenges of implementing open innovation projects, which are not only helpful to strategic decision-makers in SMEs, but also to those who make policies for them.

Keywords: open innovation; comparative analysis; multi-level analysis; SME; project; sustainable growth

1. Introduction

The last two decades have seen fundamental changes in how firms undertake innovation activities for sustainable growth, among which is the tremendous increase in the use of external networks [1,2]. The concept of "open innovation" (OI), in which innovative ideas and knowledge flow freely, both inwardly and outwardly [3–5], has become a central issue in innovation management. Innovation scholars have embraced this concept, and scholarly attention has shifted away from closed innovation to OI, in order to examine the potential advantages of the former over the latter [6]. The concept of OI has spawned conferences (e.g., the 2008 International Society of Professional Innovation Management Conference, the 2009 European Conference on Management of Technology, and the 2015 World Open Innovation Forum), journals (e.g., *Industry and Innovation* 2008, *R&D Management* 2010, *International Small Business Journal* 2013, *Research Policy* 2014, and *European Journal of Innovation* 2017), numerous books, and hundreds of papers.

Previous studies on OI can be classified into several categories according to the units of analysis. For example, Chesbrough and Bogers (2014) suggested a list of possible units of analysis that may

offer a more fine-grained framework for OI research: (1) intra-organizational; (2) organizational; (3) extra-organizational; (4) inter-organizational; (5) industry; (6) regional innovation system; and (7) society [7]. Among these levels of analysis, this research focuses on the intra-organizational level, particularly on the project level. More research on this area of analysis is required for a comprehensive understanding of OI performance because innovation, which is inevitable for sustainability, is typically conducted via innovation projects [8]. Such projects can differ widely, in terms of both project characteristics (e.g., the type of technology being developed) and OI characteristics (e.g., the type of collaboration mode used), even when conducted within the same firm. Kim *et al.* (2015) showed that project-level openness could be affected by team and task characteristics such as team size, learning distance, strategic importance, technology and market uncertainty, and relevance to the main business [9]. There may be significant heterogeneity with respect to OI performance and patterns across innovation projects. Therefore, we must consider the peculiarities of R&D projects when evaluating the performance of OI strategies [10]. Such a project-level analysis of OI performance is necessary to advance the research and provide practical guidelines for OI adoption in a firm by indicating the types of innovation projects that can benefit the most from OI, thus suggesting customized OI strategies for each type of innovation project, or by identifying the antecedents of OI at the project level. However, despite the massive interest in OI, scant attention has been paid to project-level analyses, with a few exceptions (e.g., [9,11]).

To address this lack of project-level analyses, this study addresses the differences between successful and unsuccessful OI projects, which distinguish this study from the existing work (e.g., [9]). We attempted to explore the various factors that can affect the success of OI projects at both the firm and project levels. The factors at the firm level include basic firm profiles, such as firm size, degree of R&D, the characteristics of business models (BMs), and attitudes toward OI. The factors at the project level include the characteristics of partnerships, partners, collaboration items, and collaboration results. The research question is whether there are significant differences in these factors between successful and unsuccessful OI projects. This exploratory analysis will drive more in-depth research into the variations of intra-organizational level OI studies and can be a basis for future prospective studies. In particular, we focus on small and medium enterprises (SMEs), unlike the previous study on OI projects conducted by Du *et al.* (2014), which was done in the context of a large multinational firm [11]. SMEs usually lack the full set of internal resources and competences required to effectively develop, produce, and commercialize their innovations [12], and thus can potentially benefit from OI for their sustainable growth. Adopting an empirical approach, we conducted a survey of 517 Korean SMEs and in-depth analyses of 241 successful and unsuccessful OI projects. By combining measurements at the firm and project levels and addressing the OI issues at SMEs, the research results are expected to show how different SMEs may have to work in different ways to ensure the best possible success of OI at the project level, thus ultimately contributing to their sustainable growth. Hence, this study provides new insight into the intra-organizational challenges of implementing OI projects that are not only helpful to strategic decision-makers in SMEs, but also to those who make policies for them.

The rest of this paper is organized as follows. Section 2 briefly discusses OI in SMEs and reviews OI performance. Section 3 presents the study's research methodology, and the findings are explained in Section 4. Finally, Section 5 offers some conclusions and future research directions.

2. Literature Review

2.1. Open Innovation in SMEs for Their Sustainable Management

Most OI studies have analyzed large companies, while offering scant research on OI in SMEs [13]. The findings on OI in large companies cannot be readily generalized to SMEs because the ways in which SMEs implement innovation differ from those of large companies [14]. Quite recently, a research strand of SMEs has emerged from the recognition of OI studies in the SME context (e.g., [12,15,16]. Theyel (2014) discussed the strong interrelationships among OI practices, along with the varied impacts

of OI practices on innovation performance in SMEs [17]. Roper (2014) suggested the potential for R&D centers to act as catalysts for OI and emphasized that the focus of the R&D being conducted must be relevant to the needs of smaller firms [18]. The need for SMEs to collaborate with external partners in order to supplement and complement their internal resources has dominated much of the academic debate [19,20]. However, recent studies have argued that SMEs draw intensively on external collaborations to access the innovation inputs they lack [9,12]. Studies on OI performance in SMEs [21–23] have also noted that OI affects SMEs' strategies and capabilities. For example, SMEs can enter international markets through external collaborations [24] or learn new technologies from partners [25], but their lack of external partnerships negatively impacts innovation [26]. Similarly, Fukugawa (2006) indicated that networking is a means of accelerating innovation and providing access to expertise and resources for SMEs [20]: external resources provide SMEs with the stimulus and capacity to innovate more effectively and efficiently, contributing to sustainable growth in SMEs.

Therefore, OI can help SMEs to offset the size-related advantages of larger firms; thus, OI is of paramount importance to their sustainability [19]. Issues regarding the introduction and management of OI—specifically, how to enhance OI performance—are central to OI studies, particularly as they relate to SMEs. Many factors affect SME OI performance, particularly OI project performance. We classify the factors into two categories. The first consists of factors at the firm level. External networking is essential to many SMEs that target business-to-business (B2B) or global markets. Recognition of, or experience with, previous OI projects can also exert either a positive or negative influence on the performance of a new OI project. The second category consists of factors at the project level. Project performance is affected by the characteristics of each R&D project, such as the type of technologies being developed, the available resources, and the ways in which the projects are managed. A firm can use only internal R&D for an innovation project, generally implying intensive networking with external partners. Collaborative innovation projects are possible even in firms that prefer internal R&D. Ways of managing these OI projects will differ across projects, even within firms, which affects their performance. We assume that both successful and unsuccessful OI projects show different patterns in their underlying firm- and project-level factors. We aim to identify those differences.

2.2. SME Openness and Performance at the Firm Level

Studies have indicated that the differences between successful and unsuccessful projects can be affected by firm-level factors, such as their profiles, business models (BMs), and attitudes toward OI. The profiles are the most basic information to consider as firm-level characteristics and were considered as major firm-level factors. The BMs are regarded as the most significant factors affecting technology opportunity discovery activities in SMEs, which are highly related to their OI practices [27], and thus were taken into account in this study. Finally, No and Lee (2015) argued that perceptual factors are valid for OI in SMEs [28]; thus, we also explored attitudes toward OI.

2.2.1. Size and R&D

We expect SME OI project performance to be influenced by the company's size and the intensity of its R&D activities. First, many studies on innovation have focused on the relationships between size and performance. Smaller companies command fewer resources, perform less R&D, and generally face more uncertainties in technologies and markets, as well as barriers to innovation. Thus, their external networks are more likely to respond to the risks that arise from the development and use of new technologies, while reducing uncertainties [14,29]. Hypothesis 1: A smaller company will produce more successful stories on the benefits of OI projects.

On the other hand, SMEs must invest resources to absorb knowledge spillover [30] because this comes at a cost to the recipient [31]. Among these resources, one of the most critical for creating new knowledge and absorptive capacity is internal R&D investment. Hung and Chou (2013) found that internal R&D positively moderates the effects of inbound OI on firm performance [32], thus implying that greater benefits from inbound OI can be expected from greater internal R&D investment. They

also found that internal R&D and outbound OI had complementary effects on firm performance, thus implying that SMEs may reinforce the benefits of outbound OI from greater internal R&D investment. Hypothesis 2: SMEs with greater R&D intensity are likely to be more successful in their OI projects.

2.2.2. Business Model

The characteristics of SME BMs are worth considering. A BM represents the firm's underlying core logic and strategic choices for creating and capturing value within a value network [33]. It shows how a company makes money by specifying where it is positioned in the value chain; therefore, the necessity and effects of external collaboration depend on the firm's BM. The concept of "BM components" is used to identify BM characteristics. BM components have been defined in many different ways. Among these, Shafer *et al.* (2005) have suggested a relatively simple but generally applicable set of four components [33]: strategic choices, value network, create value, and capture value. We have adopted these components while redefining them in the context of OI in SMEs; the set now consists of a target market (as a basis for SME strategic choices), supply chain management (SCM) position (as a position in SME value networks), competitive strategy (as an approach to creating value), and target product (as a method of capturing value). We expect that a particular type of BM offers the best fit for OI in terms of needs and effectiveness. More specifically, SMEs with B2B–manufacturing (Mfg) market transactions (SCM position) will have a strong motivation to innovate, which is essential to survive in a market. Hypothesis 3: SMEs with a SCM position of B2B–Mfg market transactions will be more likely to operate successful OI projects.

2.2.3. Recognition and Experiences of OI

Employee attitudes are important for the successful implementation of OI [34]. However, the few studies on employee attitudes toward external collaboration have produced inconsistent results. Though some have reported positive tendencies toward knowledge insourcing [35], most others have found that employees are unwilling to collaborate [12,36]. Companies that begin to interact with external partners tend to face organizational and cultural issues; negative attitudes to knowledge sharing are the most prevalent and act as the main barrier to the implementation of OI approaches.

An attitude is a "psychological tendency to evaluate an identifiable object with some degree of favor and disfavor" [37], and thus represents a "learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object" [38]. Burcharth *et al.* (2014) argued that three facts need to be considered when interpreting attitudes: "they are learned", "they may be favorable or unfavorable," and "they represent a predisposition" [34]. Because attitudes are learned, previous experiences with implementing OI strategies may affect attitudes. Each SME can adopt OI strategies for its own purposes and with its own expectations, and these can condition not only their benefits but also their difficulties. As a firm cultivates more of these experiences over time, its attitudes toward OI are formed. Because attitudes represent a predisposition and may be favorable or unfavorable, a firm's recognition of the importance of OI strategies (a predisposition) is significantly related to its favorable or unfavorable attitudes.

In examining the OI strategies that affect the experiences and recognition of OI implementation, the literature has stressed the use of the collaboration modes through which firms open up their innovation processes to collaborators. Bianchi *et al.* (2011) claimed that the commonly used practices for inbound OI include in-licensing, minority equity investments, research funding, joint ventures, R&D contracts, purchasing technical and scientific services, and non-equity alliances, whereas the typical practices for outbound OI include licensing-out, spinning out new ventures, joint ventures for technology commercialization, offering technical and scientific services, selling innovation projects, corporate venturing investments, and non-equity alliances [39]. Through these practices, firms also establish relationships with various heterogeneous actors: their collaboration partners [40–42]. SMEs that adopt more diverse modes of OI practices would likely use them more intensively and rate them as more important, on average, and they may have more favorable attitudes toward OI. They may

adopt OI more aggressively and ultimately may operate successful OI projects. Thus, it is expected that the recognition of the utility and importance of OI practices and partners, along with their overall experiences of OI, will determine SMEs' attitudes to both OI and OI project performance. The following hypotheses can be introduced. Hypothesis 4: SMEs that have introduced OI practices more widely and intensively, on average, will be more likely to conduct successful OI projects.

Hypothesis 5: Those having experienced more benefits will be more likely to conduct successful OI projects.

2.3. Project-Level Factors that Affect SME Open Innovation Performance

The literature suggests that the project-level characteristics of partnerships and partners, collaboration items, and expected project outputs determine the success or failure of OI projects. Collaboration is working with others (partners) to do a task (collaboration items) and to achieve shared goals (expected project outputs) via a particular mode or method (partnerships). Thus, these four factors were determined as major factors to investigate at the project level.

2.3.1. Partnerships

One method of exploring new possibilities in R&D is to establish partnerships, as suggested in the OI literature [3,43]. R&D partnerships in the context of OI have primarily been examined at the firm level, but they are worth analyzing at the project level, where they serve as a means of accessing and leveraging external, complementary project resources. Bianchi *et al.* (2011) argued that the collaboration modes selected by a firm vary substantially across R&D phases (e.g., basic research, applied research, development, and launch) [39] because each phase has distinct characteristics in terms of investment level, degree of risk and uncertainty, and requirements for exploring new or exploiting existing knowledge [44]. Bellantuono *et al.* (2013) suggested that it is necessary to identify which OI practices best fit a specific innovation project that a firm is carrying out when a number of modes exist for it to open its innovation process [45]. Accordingly, they suggested five context variables—"knowledge owned by the recipient to address the innovation problem", "knowledge owned by the recipient to define the innovation problem and evaluate solutions", the "knowledge source's interest and easiness of participation in the innovation project", the "recipient's collaborative architecture", and the "criticality of the knowledge supply"—and nine innovation practice variables—"access mode", "degree of formality", "incentives", "interaction mode", "information flow", "locus of control", "coordination mode", "output" and "coordination form"—in order to match them. Hence, collaboration modes and R&D phases at the project level are expected to be related to OI strategies and performance. According to Lee *et al.* (2010), SMEs may be reluctant to reveal sensitive technological information during collaboration [14]. Instead, they may prefer to facilitate the innovation process by collaborating with others at the commercialization stage. Hypothesis 6: Less successful OI projects are expected in the form of collaborative R&D.

Hypothesis 7: Less successful OI projects are expected at the front-end of R&D.

2.3.2. Partners

The types of partners with which SMEs enter into relationships also vary greatly by R&D project type. The most common partner taxonomy divides them into customers; suppliers; competitors; consultants; private R&D institutes; universities; and other higher education, government, and public research organizations [40]. Zeng *et al.* (2010) found significant positive relationships between three cooperation types—inter-firm cooperation, cooperation with intermediary institutions, and cooperation with research organizations—and SME innovation performance [46]. Among these, inter-firm cooperation has the most significant positive impact on SME innovation performance. Thus, partner type may affect OI performance. Hypothesis 8: In particular, it is expected that inter-firm cooperation OI projects are more likely to be successful than cooperation with intermediary institutions and cooperation with research organizations.

Partner selection may be critical for successful collaboration. Schilling (2008) suggested that a firm needs to review "resource fit" and "strategic fit" during partner selection. Resource fit is the degree to which potential partners have resources that can be effectively integrated into a strategy that creates value; such resources may be either complementary or supplementary. Strategic fit is the degree to which partners have compatible objectives and styles [47]. Firms need to assess how collaborating with a partner is likely to impact the firm, in terms of its external opportunities and threats, internal strengths and weaknesses, potential for sustainable competitive advantage, and ability to achieve its strategic aims. Taking a future perspective is essential for partner selection, as collaboration is not only for current businesses but also for future businesses. Hypothesis 9: We expect that OI projects will produce successful results when partners are selected by accounting for their future potential.

Therefore, it is relatively easy to assess the capabilities and potential impacts of collaborating with long-term partners. Love *et al.* (2011) claimed that it is necessary to accurately analyze the typology and sources of knowledge necessary for the intended innovation before starting an OI process [48]. Selecting a partner with which the firm has had a long-term relationship helps enhance the performance of OI projects. In addition, these long-term relationships help SMEs form trust with partners because trust is the bedrock of such relationships. In general, SMEs tend to adopt an OI strategy to avoid risk when there is uncertainty; however, collaboration partners may also be more opportunistic when there is uncertainty [9]. Robertson and Gatignon (1998) claimed that in a highly uncertain environment, collaboration partners experience difficulties with agreeing on projected scenarios, thus making them passive about collaboration [49]. This is particularly true when the transaction costs required to prevent opportunistic behavior significantly outweigh the benefits of the reduced risk that could stem from collaboration. Hypothesis 10: Trust based on a long-term relationship may significantly reduce the risk of opportunistic behavior, thus retaining the value of collaborative innovation when there is uncertainty and hence producing more successful OI projects.

Finally, the location of partners should also be emphasized in collaboration. The notion of "innovation interaction" occurs in many studies on the regional clustering of industries (e.g., regional networks and industrial districts [50]. Regional clusters allow firms to engage in greater collaboration for innovation projects, suggesting that it is more advantageous for SMEs to collaborate with geographically close partners. Hypothesis 11: Successful OI projects are likely to be in the form of regional clusters.

2.3.3. Item: Newness of Projects

Multiple OI benefits have been identified, such as better adaptation to dynamic market environments, shared resources and risks among partners, and higher commercial returns [51]. Among the most significant is that OI helps SMEs reduce risks by resolving uncertainties. Therefore, the effects of an OI approach are expected to be related to the level of the collaboration's degree of uncertainty, which increases according to the project's newness. It should be noted here that, although innovation implies doing something different or doing the same thing in a different way, newness is not only applied to the global or market context, but also to the firm context [52]. Hypothesis 12: More successful stories of OI projects are expected from collaborations with high degrees of newness.

2.3.4. Outcome: Patent Appropriability

The literature on OI has emphasized the need for collaborative R&D, as a method of facilitating the synergistic blending of external and internal ideas for innovation [53–55]. However, the more firms collaborate with external partners, the more difficult it becomes to retain exclusive possession of the collaboration outcomes [56,57]. This phenomenon—in which creating innovation benefits from openness, yet commercializing it requires appropriability—is called the "paradox of openness" [58]. The challenges in the appropriation of innovation outputs are being increasingly acknowledged. Issues with regard to the creation and co-ownership of intellectual property (IP) as outcomes of OI require more in-depth analysis. Recognizing this need, Belderbos *et al.* (2014) explored the value creation

and appropriation implications of R&D collaboration, particularly with regard to the co-ownership of IP [53]. They classified collaboration partners into three types—intra-industry, inter-industry, and university partners—and analyzed the characteristics of co-owned patents for each of the three partners. Their findings indicated that co-owned patents generally tend to have higher patent value but receive fewer self-citations, thus placing constraints on the future exploitation of the relevant technologies. Moreover, these value-appropriation challenges are more evident in intra-industry co-patenting, possibly because partners are more likely to have overlapping exploitation domains. Consequently, value-appropriability is significant for successful OI performance, and successful OI projects are expected to maintain the appropriability of innovation outputs. Hypothesis 13: OI projects are more successful when their degree of control over the technology's appropriability is stronger.

3. Methodology

3.1. Research Framework

Figure 1 presents the overall research framework. First, a survey questionnaire for empirical research was designed and the relevant data were collected. Using these data, we analyze SME utility, while recognizing the importance of various OI practices. This exploratory analysis is intended to determine the respondent perceptions of OI and identify the OI practices of SMEs. OI practices are defined as the "processes" that managers start when deciding when, how, with whom, with what purpose, and in what ways they should cooperate with external partners [22]. These are collective efforts for a firm to open up its innovation processes and are considered at the firm level in this research. In this research, the OI modes used to implement OI were adopted to define the types of OI practices. The next step is an in-depth analysis of SME OI projects. One of the key differences between an OI project and an OI practice is that a "project" is a planned series of "activities" that leads specific outcomes being completed for the firm. The in-depth analysis aims to identify the differences in the firm-level and project-level factors, indicating the characteristics of an OI project and the characteristics of a firm operating the project.

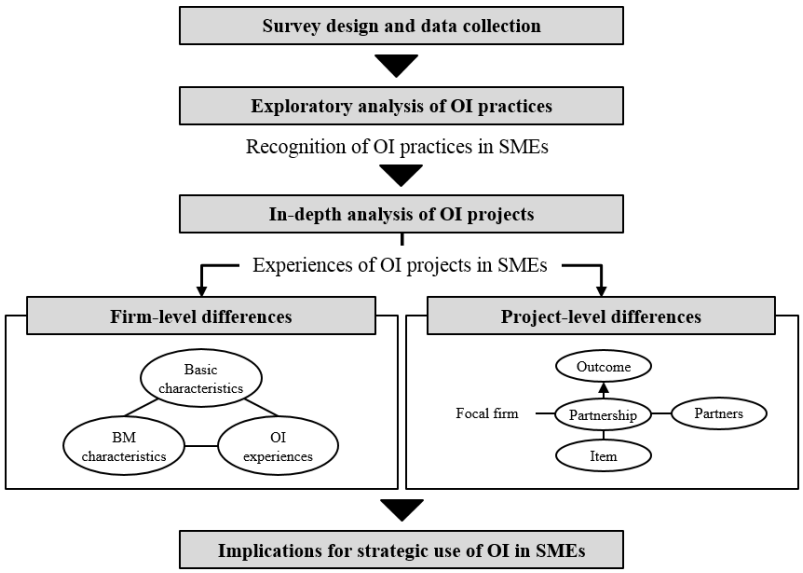

Figure 1. Overall research framework.

Our survey asked respondents to describe whether they had any experiences of successful collaboration with external parties, whether they had conducted an innovation project (e.g., a new product, service, or technology development project) during the last three years, and the characteristics of their most successful project. Among the 517 responding firms, 83 reported that they had conducted

a successful OI project in the last three years. Firms with no successful experiences (158 cases) were asked to describe their least successful project. Finally, firms that had no experience with external collaboration during the last three years (276 cases) were removed from the database. Appendix 1 shows the characteristics of firms with successful experiences, unsuccessful experiences, and no experiences of OI projects with regard to their size, manufacturing sector, and target markets and products. Relatively small firms in the manufacturing sector that produce "parts" were likely to be included in the excluded set. The questionnaire stated that collaboration with external partners includes both inbound and outbound strategies. This in-depth analysis focuses on a comparative analysis between successful and unsuccessful projects, in terms of their firm- and project-level differences. Therefore, we basically adopted an unpaired two-sample t-test method for nominal (interval) values. This method is most commonly applied to examine whether two sets of independent data are significantly different from each other. On the other hand, a chi-squared test was used for the categorical variables. This method is used to check for significant differences between the expected frequencies and the observed frequencies in one or more categories.

Combining the research findings generated valuable insight into the types of SMEs that are most likely to produce successful OI projects and the types of collaboration projects that are most likely to be successful, which are essential to establishing an OI strategy for SMEs.

3.2. Data Collection

The survey data were collected from Korean firms with more than ten and fewer than 300 employees in the manufacturing, software (SW) development, and R&D service sectors. We restricted our data to these three sectors because these industries are more prone to engaging in OI and are thus appropriate for OI studies. Gassmann (2006) claimed that OI is more prevalent in industries characterized by globalization, technology intensity, technology fusion, new business models, and knowledge leveraging [59]. Chesbrough and Crowther (2006) also mentioned that OI concepts have primarily been regarded as relevant to high-technology industries [51]. According to the Korean Innovation Survey 2009, manufacturing firms conduct innovation activities more actively than service industries [60]. The statistics of Dutch enterprises also indicated that manufacturing firms are more technology-intensive, invest more in R&D, and operate in larger regions than service firms, on average [12]. However, unlike traditional service sectors, the SW development and R&D service sectors are not only technology-intensive but also highly collaborative in nature; thus, they are worth considering for our analysis and were included as a target sector.

We randomly selected 5000 SMEs from a list of Korean firms published in 2010, using proportionate stratified sampling by region, in an attempt to eliminate the collaboration effect by region. As a result, our sample included SMEs from all provinces except one: Jeju Island, in which few manufacturing SMEs are located. The survey was conducted over one month, from 30 September to 29 October 2011, by a professional survey agency, InsightKorea; data for 517 SMEs were collected. The average number of firm employees was 41.06. The average size of the R&D staff was 9.19, with 11.25% R&D intensity. A total of 77.8% of responding firms were in the manufacturing sector, 11.8% were in the SW development sector, and 10.4% were in the R&D service sector. A wide range of sub-sectors was found among the responding firms from the manufacturing sector, covering all 20 sub-sectors, such as foods and beverages, textile products, pulp and papers, chemicals and allied products, nonmetallic mineral products, primary metals, and so on. Regarding the firm size, the data consisted of 398 SMEs (77.0%) with less than 50 employees, 72 SMEs (13.9%) with more than 50 and less than 100 employees, and 47 SMEs (9.1%) with more than 100 and less than 300 employees. As to the R&D intensity, our sample has 207 SMEs (40.0%) with less than 1%, 111 SMEs (21.7%) with 1% and less than 5%, 159 SMEs (30.8%) with more than 5% and less than 30%, and 36 SMEs (7.0%) with more than 30%. Based on these distributions, we concluded that our data are not biased. Only 16.1% of the firms had experienced successful collaborations with external partners during the last three years, whereas 30.6% only had unsuccessful experiences. The remaining 53.3% had no experience collaborating with external partners.

Regarding the firms with collaboration experiences, their average number of firm employees was 50.00. The average size of their R&D staff was 14.13 employees, with 16.94% R&D intensity. A total of 66.38% of them were in the manufacturing sector, while 17.0% were in the SW development sector and 16.6% were in the R&D service sector, revealing that we could observe more firms with collaboration experiences in the SW development and R&D service sectors than in the manufacturing sector.

Most of the respondents were from management teams (72.0%). The other respondents were from R&D teams (10.1%), planning teams (6.8%), and other teams such as marketing, production, and general affairs teams (11.2%). Accordingly, more than half of the respondents were manager (51.1%), while the remainders were researchers/staffs (44.7%) and CEO/directors (4.2%). The respondents in these positions were eligible for our survey.

3.3. Survey Design and Measurements

The survey questionnaire contained three parts. The first consisted of questions on basic company profiles and BM. The company profiles included company size, measured as the number of employees and total sales, and the degree of R&D, measured as the size of the R&D staff and R&D intensity. We asked the respondents to describe the characteristics of BM components as a categorical value (see Table 1). The BM components and their values were identified by Cho *et al.* (2016) [26].

Table 1. Measurements for firm characteristics: basic company profiles and BM.

Category	Sub-Category	Characteristics	Scale
Company profiles	Size	Number of employees; Total sales	Numeric
	Degree of R&D	Number of R&D staff; R&D intensity	Numeric
BM components	Target market	Domestic-specific regions; Domestic—the entire country; Global	Categorical
	SCM position	B2B–manufacturing market transaction; B2B–manufacturing long-term contracts; B2B–services; B2G; B2C	Categorical
	Competitive strategy	Differentiation; Cost leadership; Focus	Categorical
	Target product	Materials or intermediary products; Final products; Services	Categorical

The second part is related to the SME perception of OI strategies and the results of adopting OI (see Table 2). Among the various OI practices, some are for adopting and exploiting science-based knowledge, whereas others are for market-based knowledge [61]. Studies have shown that both types are significant but play different roles in innovation [62,63]. Thus, we considered both when defining OI practices. The literature also divides OI into two processes—inbound and outbound OI [3]; we considered both when defining OI practices. More specifically, van de Vrande (2009) suggested eight OI modes: venturing, licensing IP to other firms, customer involvement, employee involvement, network usage in innovation processes, participation in other firms, outsourcing R&D, and licensing IP from other firms [12]. Abulrub and Lee (2012) summarized 13 types of OI modes: purchasing, licensing-in, joint venture, joint development, contract R&D, venture capital, mergers and acquisitions (M&A), customer involvement and external networking, selling, licensing-out, spin-off, and open source [64]. Bianchi *et al.* (2011) identified six OI modes, focusing on the bio-pharmaceutical industry:

alliances, purchase of scientific services, in-licensing, alliances, supply of scientific services, and out-licensing [39]. Cosh and Zhang (2012) suggested five informal activities—(1) engaging directly with lead users/early adopters; (2) exchanging ideas through websites and competitions; (3) participating in innovation networks/hubs; (4) participating in open-source software; and (5) sharing facilities with others—and ten formal activities to accelerate innovation—(1) licensing externally developed technologies; (2) joint R&D; (3) joint university research; (4) participating in research consortia; (5) joint marketing/co-branding; (6) joint production of goods or services; (7) joint purchasing of materials or inputs; (8) outsourcing or contracting out R&D projects; (9) providing contract research to others; and (10) joint ventures, acquisitions, and incubations [15]. Based on these findings, we defined 19 OI practices that SMEs use to open up their innovation processes to collaborators, thus encompassing the broadest possible range (see Appendix 2).

Table 2. Measurements for firm characteristics: OI practices and experiences.

Category	Sub-Category	Characteristics	Scale
OI practices	Degree of use	Inbound R&D (User/customer involvement; Using external experts; Using collective intelligence; Using informal human networks; Using formal human networks; Inward technology transfer; M & A; Joint R&D; R&D consortia; Outsourcing: R&D); Inbound commercialization (Co-marketing and co-branding; Co-production; Joint purchasing; Outsourcing: other than R&D; Investment from external sources); Outbound (Outward technology transfer; Organizing a venture business; Joint venturing; Open platform)	Five-point Likert
	Change in the degree of use		Three-point Likert
	Recognized importance		Three-point Likert
OI experiences	Benefits	Reduced time for R&D; Increased efficiency in R&D investment; Source technology acquisition; Increased number of available technology alternatives; New market creation and discovery; Increased efficiency of internal decision-making processes; Improved reputation as an innovator	Binary
	Difficulties	Not-invented-here syndrome; Administrative burden for collaboration; Additional time and cost for collaboration; Lacking knowledge of administration and law; Lacking technological capabilities for collaboration; Lacking knowledge about collaboration items and potential partners; Uncertainty about the capability and reliability of partners; Conflicts with partners because of different operation policies and organizational cultures; Communication difficulties because of geographical distance; Communication difficulties because of different technological knowledge; Communication difficulties because of different language; Conflict risks linked to IP for co-created innovation; Conflict risks linked to different collaboration purposes	Binary

Notes: Five-point Likert scale to measure "degree of use": 5 for very high; 4 for high; 3 for moderate; 2 for low; and 1 for very low. Three-point Likert scale to measure "change in the degree of use": 3 for an increase in the last three years; 2 for no change in the last three years; 1 for a decrease in the last three years. Three-point Likert scale to measure "recognized importance": 3 for important; 2 for undecided; and 1 for not important.

For each practice, we asked about its degree of use, changes in its degree of use, and the recognition of its importance using Likert-type scales. Here, it should be noted that different scales were adopted

for different category values. To increase the reliability of the data collected, we decided to use three-point Likert scales for "change in the degree of use" and "recognized importance" during the pilot survey. The Likert scale was transformed into a one-to-ten scale for consistency as well as ease of interpretation. The timespans for the data collection were set to the last three years. Finally, we reviewed the possible benefits and difficulties (*i.e.*, OI experiences) described in the literature [15] but modified for this research into simpler variables, considering that the survey target is SMEs, and asked respondents whether they had experienced the benefits and difficulties when adopting OI strategies; a binary scale is used for these items.

The third part asks questions on the characteristics of the respondents' OI projects, in terms of partnerships, partners, collaboration items, and collaboration results (see Table 3). For the partnerships, collaboration modes and phases of R&D process were investigated. We employed the collaboration mode categories suggested by Shilling (2008)—strategic alliances, licensing, outsourcing, collective research organizations, and joint ventures—while modifying them to suit SMEs [46]. This produced five modes: networking for intelligence and consulting, licensing, outsourcing, collaborative R&D, and others (e.g., joint ventures). We used the "chain-linked" innovation process model to define the phases of the R&D process, which consists of market discovery, overall design, detailed design and test, redesign and production, and sales and marketing. We merged the first two phases and renamed them to make it easier for SMEs to understand their exact function and to make them more applicable to SMEs. The respondents were asked to select the mode and phase upon which their open activities were most focused using a categorical scale. Second, for the collaboration partners, we considered their type, selection criteria, relationships, and location. We identified 11 partners using the OECD (2008) [40] and four-partner selection criteria using Schilling (2008) [47]. Categorical scales were applied to these two variables. With regard to relationships with partners, we asked the SMEs whether they and their partners had "long-term relationships." To investigate partner location, we divided the locations into three categories: regional cluster, national but not regional cluster, and abroad. Third, for the items, we addressed their degree of newness. The respondents were requested to check one of the three categories that best described their collaboration item: new to the market, new to the firm, and existing but improved. Finally, for outcomes, the degree of the collaboration results' appropriability was measured. The respondents were asked to select from among co-owned patents, exclusively self-owned patents, exclusively partner-owned patents, and no patents obtained.

Table 3. Measurements for project characteristics: partnership, partner, item, and outcome.

Category	Sub-Category	Characteristics	Scale
Partnership	Collaboration modes	Networking for intelligence and consulting; Licensing; Outsourcing; Collaborative R&D; Others	Categorical
	Phases of R&D process	Market discovery/planning; Development/test; Production; Sales/distribution/marketing/services	Categorical
Partner	Type	Clients and customers; Suppliers; Competitors; Affiliates; Complementary companies (IT-support business and business services); Government-funded research centers; Non-government-funded research centers; Universities; Non-profit organizations	Categorical

Table 3. *Cont.*

Category	Sub-Category	Characteristics	Scale
Partner	Selection criteria	Strategic fit—vision; Strategic fit—future potential; Resource fit—current capabilities; Resource fit—past performance;	Binary
	Relationships	Long-term	Binary
	Location	Regional clusters; Nation—not regional clusters; Abroad	Categorical
Item	Degree of newness	New to the market; New to the firm; Existing, but improved	Categorical
Outcome	Degree of appropriability	Co-owned; Exclusively self-owned; Exclusively partner-owned; No patents obtained; Others	Categorical

The survey questionnaire was pretested to examine its reliability and validity. We asked five examiners, including potential survey respondents and OI professionals, to review the questionnaire. The first test was conducted with two professionals in OI. They examined the structure of questionnaire and the questions in the questionnaire in its suitability for survey. Then, the second test was carried out with three managers in SMEs. They reviewed the descriptions in the questionnaire and notified us if any misleading or unclear questionnaire items existed. For each question, we also asked the rationales for their answers for each question to check the questions in the questionnaire actually measure what we wanted to measure. This feedback was used to create a final set of questionnaire items for the main survey. In addition, we conducted a Cronbach alpha analysis to identify the reliability of the Likert-scale variables found that all scales achieved 0.8 or higher. The Cronbach alpha analysis results are summarized in Appendix 3. SPSS 18.0 was used to analyze the data.

4. Results and Discussion

4.1. Exploratory Analysis of OI Practices in SMEs

The results of the exploratory analysis are indicated in Table 4, which shows that OI practices that were recognized as important tended to be used more frequently, and that most were related to inbound OI for R&D, thus absorbing innovative ideas and technological knowledge from external sources. These are the OI practices that are relatively easy for SMEs to adopt, considering the transaction costs and potential risks anticipated from general OI practices; thus, SMEs value these practices highly. On the other hand, we observed no remarkable increasing or decreasing trend in the degree of use across different OI practices. Furthermore, no dominant OI practice seemed to attract the attention of SMEs or exhibit broad adoption as a new opportunity for innovation, despite recent interest in the OI paradigm.

Among the 19 practices, the most notable were user/customer involvement and using informal human networks, for which all three index values were high, as were those for core OI practices in SMEs. As SMEs tend to concentrate on B2B or niche markets, user and customer-involved innovation will play a significant role in sustainable SME growth. Using informal human networks is related to intelligence gathering via informal channels, such as the personal networks of CEOs and employees. These channels are regarded as important assets for SME OI practices, since they assist in the collection of valuable information at a relatively low cost. Moreover, using formal human networks is valuable,

although doing so costs more than using informal ones. Because important resources may be limited in SMEs, SMEs will likely prefer informal networks to formal ones. Nevertheless, formal human networks are used more frequently than other OI practices. Regardless of the potential costs, SMEs are eager to collect information from external sources in order to respond quickly to opportunities for—and threats to—innovation. Interestingly, outward technology transfer is the OI practice characterized by increasing use, thus showing the highest value for change in the degree of use. With the increase of stronger and more active technology transfers between firms, SMEs, in addition to large enterprises, have tended to adopt technology out-licensing or aggressive selling as a means of commercializing technology. Another noticeable OI practice is using external experts, which exhibits a relatively high value in terms of recognized importance. Because many SMEs are struggling to secure manpower, they have realized the importance of using external experts to compensate for manpower shortages.

Table 4. Degrees of utility and recognized importance of OI practices in SMEs.

Category	OI Practices	Degree of Use	Change in the Degree of Use	Recognized Importance
Inbound—R&D	User/customer involvement	**5.20**	**6.90**	**6.00**
	Using external experts	4.68	6.76	5.58
	Using collective intelligence	4.16	6.45	5.24
	Using informal human networks	**5.12**	**6.83**	**5.54**
	Using formal human networks	**4.90**	6.82	**5.54**
Inbound —Commercialization	Inward technology transfer	4.14	6.62	5.06
	M & A	3.24	6.67	4.52
	Joint R&D	4.54	6.82	5.14
	R&D consortium	4.06	6.68	4.96
	Co-marketing and co-branding	3.58	6.46	4.84
	Co-production	3.66	6.57	4.80
	Joint purchasing	3.36	6.30	4.86
	Outsourcing: R&D	3.86	6.51	4.78
	Outsourcing: other than R&D	3.40	6.30	4.62
	Investment from external sources	3.54	6.52	4.88
Outbound	Outward technology transfer	3.52	***6.90***	4.64
	Organizing a venture business	3.26	6.76	4.02
	Joint venturing	2.98	6.45	3.86
	Open platform	3.24	6.35	4.04
	Average	3.92	6.61	4.89

Notes: The Likert scale was transformed into a one-to-ten scale. The three largest values are indicated in bold.

Based on the analysis results, we classified the 19 OI practices into several types, as listed in Table 5. Theoretically, eight types can be defined using the binary values (*i.e.*, higher or lower than the average) of three variables. However, the 19 OI practices are mapped to four types, focusing on two in particular.

First, core-and-critical consists of the OI practices with high values for all three variables. Most are related to inbound unilateral OI activities done to absorb external knowledge during technology

planning and development processes, although a few are concerned with more active interactive collaboration activities, such as joint R&D and R&D consortia. The inbound mode has been far more popular in industry than the outbound mode [6], possibly because many firms are in a better position to use technology than to create it, or prefer to use external resources to reduce costs, which the inbound mode facilitates.

Second, not-for-SMEs has characteristics opposite to those of the first type, exhibiting relatively low values for all three variables. Although collaborative marketing, branding, production, and purchasing have been suggested as ways to increase commercialization efficiency, these collaboration modes require relatively high transaction costs, making them inappropriate for SMEs. Outsourcing and joint venturing are seldom applicable to SMEs, possibly because of their limited financial resources. An open platform implies high risk and high return, and can be useful in a few industry sectors, such as the software industry, making it suitable for most SMEs.

Third, the potentially valuable type consists of OI practices regarded as important and used frequently, but that show decreasing usage. The use of collective intelligence and inward technology transfer belong to this type. These practices are highlighted through the introduction of the OI paradigm, and SMEs also seem to have pursued them. However, the decreasing usage trend indicates that SMEs may find it difficult to adopt them. The applicability of this type must be strengthened by developing a more practical model for SMEs or through government support.

Finally, the potentially usable type consists of OI practices that are not important or used frequently, but show signs of increasing usage. This includes M & A, outward technology transfer, and organizing a venture business, which mostly relate to the active exploitation of technology. Their increasing usage signifies that, despite not having been explicitly recognized by SMEs, these OI practices in various outbound modes are potentially usable by SMEs. It seems that the outbound mode can be implemented only after the inbound mode has been institutionalized. Thus, this type of OI practices is expected to begin to be adopted by those who have institutionalized the first or third types—the inbound OI practices.

Table 5. Classification of OI practices for SMEs.

Types	Degree of Use	Change in the Degree of Use	Recognized Importance	OI Practices
Core-and-critical	High	High	High	User/customer involvement; Using external experts; Using informal human networks; Using formal human networks; Joint R&D; R&D consortia
Potentially valuable	High	Low	High	Using collective intelligence; Inward technology transfer
Potentially usable	Low	High	Low	M & A; Outward technology transfer; Organizing a venture business
Not-for-SMEs	Low	Low	Low	Co-marketing and co-branding; Co-production; Joint purchasing; Outsourcing: R&D; Outsourcing: other than R&D; Investment from external sources; Joint venturing; Open platform

4.2. In-Depth Analysis of OI Projects in SMEs

This section presents a comparative analysis of firms that have had experiences with successful and unsuccessful OI projects at the firm and project levels. This study emphasizes that even the same variable can take different values at different levels. For example, when "user/customer involvement" in projects is clear and wide across an organization, very little "user/customer involvement" can be

reported for a particular project. In this case, the variable "degree of user/customer involvement" will have a high value at the firm level but a low value at the project level. We focused on a single project to investigate the firm- and project-level characteristics of OI projects; therefore, success was only defined at the project level.

4.2.1. Firm Level

The firm level differences between successful and unsuccessful OI projects are analyzed according to four dimensions: basic company profiles, BM, OI practices, and OI experiences in general.

First, although the two groups showed insignificant differences in size, firms with experiences of successful OI projects were more likely to be active in R&D (see Table 6), rejecting Hypothesis 1 and accepting Hypothesis 2. The size of the R&D staff and R&D intensity were greater in the successful group (statistically significant at significance levels of 0.1 and 0.05, respectively). It seems that a major share of the successful cases came from R&D-focused collaboration in SMEs because of their superior R&D capabilities.

Table 6. Firm-level comparative analysis results: size and R&D.

Company Profiles	Variables	Success	Fail	*p*-Value
Size	Number of employees (people)	57.42	45.48	0.176
	Total sales (Korean won)	1,570,478	1,463,235	0.856
Degree of R&D	Size of R&D staff (people)	19.02	11.56	0.064 *
	R&D intensity (%)	26.70	11.81	0.049 **

Notes: ** $p < 0.05$; * $p < 0.1$.

Second, the two groups follow different business models (significant at 0.1). The successful group tended to target a global market rather than a domestic one, and to focus on B2B business in the manufacturing sector using short-term market transactions, rather than on long-term agreements with customers or clients. They naturally pursued a differentiated strategy to sustain their competitive advantage in market transactions. The findings show that a particular type of BM offers the best fit for OI in terms of needs and effectiveness (see Table 7). More specifically, at a significance level of 0.05, SMEs with an SCM position of B2B–Mfg long-term contract were less likely to operate successful OI projects, while those with an SCM position of B2B–Mfg market transaction were more likely to operate successful OI projects, accepting Hypothesis 3.

Table 7. Firm-level comparative analysis results: BM.

BM Components	Options	Success	Fail	*p*-Value
Target market	Domestic—specific regions	13.3%	20.3%	0.084 *
	Domestic—the entire country	67.5%	69.6%	
	Global	19.3%	10.1%	
SCM position	B2B–Mfg market transaction	49.4%	39.9%	0.022 **
	B2B–Mfg long-term contract	9.6%	24.7%	
	B2B–Service	21.7%	24.7%	
	B2G	12.0%	8.2%	
	B2C	7.2%	2.5%	
Competitive strategy	Differentiation	77.5%	63.9%	0.094 *
	Cost leadership	6.3%	12.3%	
	Focus	16.3%	23.9%	
Target product	Materials or intermediary products	77.5%	63.9%	0.910
	Final products	6.3%	12.3%	
	Services	16.3%	23.9%	

Notes: ** $p < 0.05$; * $p < 0.1$.

Third, the successful group generally produced values for both degree of use and perceived importance of OI practices that were higher than those of the other group, regardless of OI practice type. Interestingly, whereas this difference was significant for only four types of OI practice in perceived importance, it was significant for 11 types of degree of use (see Table 8). Thus, the SMEs that introduced OI practices more widely and intensively, on average, were more likely to operate successful OI projects, accepting Hypothesis 4.

Table 8. Firm-level comparative analysis results: degree of use and perceived importance of OI practices.

OI practices	Degree of use			Perceived importance		
	Success	Fail	*p*-Value	Success	Fail	*p*-Value
User/customer involvement	3.43	3.01	0.001 **	3.87	3.44	0.004 **
Using external experts	3.28	2.89	0.013 **	3.61	3.35	0.075 *
Using collective intelligence	2.73	2.40	0.021 **	3.33	3.08	0.103
Using informal human networks	3.27	3.01	0.075 *	3.36	3.19	0.190
Using formal human networks	3.33	3.02	0.028 **	3.45	3.28	0.238
Inward technology transfer	2.65	2.44	0.191	3.16	2.87	0.065 *
M&A	1.77	1.85	0.590	2.59	2.56	0.834
Joint R&D	3.47	2.82	0.000 **	3.31	3.08	0.110
R&D consortium	3.04	2.38	0.000 **	3.13	2.93	0.174
Co-marketing and co-branding	2.41	2.08	0.036 **	2.92	2.80	0.450
Co-production	2.35	2.07	0.090 *	2.72	2.73	0.974
Joint purchasing	1.99	1.83	0.276	2.82	2.69	0.413
Outsourcing: R&D	2.49	2.34	0.316	2.86	2.87	0.900
Outsourcing: other than R&D	2.27	1.94	0.024 **	2.82	2.64	0.222
Investment from external sources	2.27	2.01	0.136	2.90	2.80	0.519
Outward technology transfer	2.24	1.95	0.085 *	2.89	2.58	0.066 *
Organizing a venture business	1.96	1.86	0.499	2.40	2.26	0.387
Joint venturing	1.69	1.68	0.943	2.29	2.18	0.469
Open platform	1.99	1.81	0.258	2.43	2.23	0.236

Notes: ** $p < 0.05$; * $p < 0.1$.

Finally, Table 9 shows the differences in OI experiences between the two groups. Regarding the benefit of OI practices, only three out of six items were significantly different (at the 0.1 level). Similarly, as a consequence of OI adoption, 36.1% and 22.8% of the successful and unsuccessful groups, respectively, benefited from the reduced time for R&D, and 47% and 33.5% of the successful and unsuccessful groups, respectively, benefited from the increased efficiency of their R&D investments. Of all of the potential benefits of OI strategies, those directly related to R&D were recognized significantly more highly than the others, and were also recognized more highly by SMEs with successful experiences of OI projects than by those with unsuccessful experiences. On the other hand, the SMEs that benefited from new markets being created and discovered accounted for 28.9% and 18.5% of the successful and unsuccessful groups, respectively. Only approximately 20% of the SMEs responded that they identified new market opportunities using external resources, with this effect being more evident in the successful group. The greatest difficulties facing SMEs were the additional time and cost required for external collaboration. Given their limited resources, it is not easy for SMEs to invest sufficient time and funds when collaboration results are uncertain; however, such investments are essential to successful collaboration. Nevertheless, no significant differences concerning OI difficulties were observed between the two groups, except one: SMEs faced similar risks and burdens when adopting OI strategies, but their method for overcoming such risks and burdens determined the success or failure of their OI projects. The only significant difficulty (significant at 0.1) was the uncertainty with regard to their partners' capability and reliability, which was observed more frequently in the unsuccessful group. Hence, one of the essential prerequisites for successful external

collaboration is building trust in collaboration partners and being confident in their capabilities and reliability. Summarizing these results, we found that SMEs that have experienced more benefits were more likely to operate successful OI projects, again accepting Hypothesis 5.

Table 9. Firm-level comparative analysis results: OI experiences.

Experiences		Success	Fail	*p*-Value
Benefits	**Reduced time for R&D**	47.0%	33.5%	0.041 **
	Increased efficiency of R&D investment	36.1%	22.8%	0.027 **
	New market creation and discovery	28.9%	18.4%	0.060 *
	Source technology acquisition	33.7%	24.1%	0.109
	Increased number of available technology alternatives	25.3%	23.4%	0.745
	Increased efficiency in internal decision-making processes	18.1%	22.2%	0.458
	Improved reputation as an innovator	9.6%	13.3%	0.408
Difficulties	**Uncertainty in partner capability and reliability**	18.1%	28.5%	0.076 *
	Additional time and cost for collaboration	48.2%	53.2%	0.463
	Administrative burdens of collaboration	21.7%	20.3%	0.794
	Conflicts with partners because of different operations policies and organizational cultures	20.5%	22.2%	0.765
	Lacking knowledge of administration and law	21.7%	15.2%	0.206
	Difficulties in communication because of different technical knowledge	19.3%	18.4%	0.861
	Lacking information about collaboration items and potential partners	18.1%	17.7%	0.946
	Lacking the technological capabilities for collaboration	18.1%	17.1%	0.848
	Communication difficulties because of geographical distance	16.9%	12.0%	0.299
	Conflict risks linked to IP for co-created innovation	14.5%	10.8%	0.402
	Conflict risks linked to different collaboration purposes	8.4%	11.4%	0.474
	Communication difficulties because of different language	8.4%	7.6%	0.818
	"Not-invented-here" syndrome	6.0%	6.3%	0.926

Notes: ** $p < 0.05$; * $p < 0.1$.

4.2.2. Project Level

The project-level differences between successful and unsuccessful OI projects were investigated from four perspectives—partnership, partners, collaboration items, and collaboration outcomes.

From the partnership perspective (see Table 10), the successful and unsuccessful projects exhibited significant differences in collaboration mode (at a 0.05 level): successful projects tended to adopt relatively active and interactive collaboration modes (e.g., collaborative R&D), whereas the unsuccessful projects used passive and bilateral modes (e.g., networking for intelligence and consulting). Hypothesis 6 is therefore rejected. We also found that 11% of the unsuccessful projects included collaboration modes other than the dominant four. Applying any type of OI practice to SMEs requires significant effort. Contrary to our expectations, we found no significant differences in R&D phases between the successful and unsuccessful projects, rejecting Hypothesis 7. It is not when to collaborate but how that has the strongest impact on project success.

Table 10. Project-level comparative analysis results: partnership.

Partnership	Options	Success	Fail	*p*-Value
Collaboration modes	Networking for intelligence and consulting	33.7%	44.9%	0.018 **
	Licensing	13.3%	10.8%	
	Outsourcing	10.8%	10.8%	
	Collaborative R&D	42.2%	26.6%	
	Others (Venturing, *etc.*)	0.0%	11.0%	
Phases of R&D process	Market discovery and planning	10.8%	12.0%	0.495
	Development and test	71.1%	62.0%	
	Production	9.6%	12.0%	
	Sales, distribution, marketing, and services	8.4%	13.9%	

Notes: ** $p < 0.05$; * $p < 0.1$.

Second, the characteristics of the collaboration partners in the two groups showed few significant differences, rejecting Hypothesis 8; however, differences in partner selection criteria and location were only significant at the significance level of 0.1 (see Table 11). With regard to partner types, the findings confirmed that SMEs collaborated with partners not only within but also outside their value chains. Furthermore, no dominant partner type was observed more frequently in successful OI projects than in unsuccessful ones, conflicting with our expectation that vertical and horizontal cooperation with customers, suppliers, and others would play a more active role in SME innovation than horizontal cooperation with research institutions, universities, government agencies, and others [46]. Instead, we found that the successful OI project group had a relatively high share of government-funded research centers as partners, although the differences in partner type were generally not significant. In Korea, government-funded research centers are responsible for supporting SMEs and have coordinated a number of collaboration programs. The Korean SMEs that have utilized these programs properly seem to have produced outstanding results; our results reflect these characteristics of Korea's national innovation system. Regarding partner selection, successful OI projects tended to rely on the strategic and vision fit, whereas unsuccessful ones emphasized potential partners' past performance, partially supporting Hypothesis 9. In addition, more success stories came from collaborations with long-term partners than from newly established ones, consistent with our expectations regarding Hypothesis 10, though weakly supported. As for partner location, 53.0% of the partners in successful OI projects were located outside of regional clusters, whereas 61.5% of those in unsuccessful OI projects were located in regional clusters, contrary to our expectation in Hypothesis 11. In our findings, whether the company and its innovation partners were close to each other was irrelevant; rather, it was common for partners in successful projects to be far from each other, contrary to our expectation. These results led us to conclude that geographical proximity no longer influences the success of collaborative projects because of advances in transportation and telecommunication technologies. At the same time, when a firm decides to work with a geographically distant partner, it is usually a case of desperation; therefore, a more active collaboration is envisaged to enhance the possibilities of success.

Table 11. Project-level comparative analysis results: partner.

Partner	Options	Success	Fail	*p*-Value
Type	Clients and customers	17.1%	16.7%	0.249
	Suppliers	14.6%	13.5%	
	Competitors	6.1%	10.9%	
	Government-funded research centers	20.7%	9.6%	
	Universities	12.2%	17.9%	
	Complementary companies	13.4%	19.2%	
	Affiliates	8.5%	6.4%	
	Others	7.3%	5.8%	
Selection criteria	Strategic fit—vision	47.0%	38.5%	0.081 *
	Strategic fit—future potential	18.1%	19.2%	
	Resource fit—current capabilities	27.7%	27.6%	
	Resource fit—past performance	7.2%	14.7%	
Relationships	Long-term relationships	60.2%	48.4%	0.090 *
	Newly established relationships	39.8%	51.6%	
Location	Nation—regional clusters	47.0%	61.5%	0.319
	Nation—not regional clusters	44.6%	33.3%	
	Abroad	8.4%	5.1%	

Notes: ** $p < 0.05$; * $p < 0.1$.

Finally, the differences in the characteristics of collaboration items and outcomes between successful and unsuccessful projects were found to be significant at the 0.05 level, accepting both Hypotheses 12 and 13 (see Table 12). The largest portion of successful OI projects (45.8%) focused on the development of new-to-the-world items, whereas most of the unsuccessful OI projects (47.1%) targeted new-to-the-firm items. These findings suggest that SMEs have a greater possibility of achieving superior performance by using external resources when conducting more innovative projects. Moreover, we found that a larger share of successful projects (73.5%) produced intellectual properties (IPs), the ownership of which was acquired either exclusively or partially. On the contrary, no IP was obtained in the largest portion of unsuccessful projects (45.3%), or the IP obtained was owned exclusively by partners (11.3%). These results imply that successful SME projects tend to pursue collaborative R&D but also contribute sufficiently to IP generation, with exclusive ownership. Gambardella and Panioco (2014) claimed that the party with key assets (*i.e.*, a major contributor) enjoys a bargaining power that discourages other collaboration parties from investing and extracts more value from the collaboration by assuming the power to make decisions during the collaborative R&D processes [65].

Table 12. Project-level comparative analysis results: collaboration items and outcomes.

Item and Outcome	Options	Success	Fail	*p*-Value
Item (Degree of newness)	New to the market	45.8%	24.2%	0.003 **
	New to the firm	31.3%	47.1%	
	Existing but improved	22.9%	28.7%	
Outcome (Degree of appropriability)	Patent obtained and exclusively self-owned	42.2%	28.7%	0.005 **
	Patent obtained and exclusively partner-owned	6.0%	11.3%	
	Patent obtained and co-owned	25.3%	14.7%	
	No patents obtained	26.5%	45.3%	

Notes: ** $p < 0.05$; * $p < 0.1$.

4.3. Discussion and Practical Implications

Under the circumstances of fierce competition within a market and quickly changing technologies, business as usual is clearly not an option for SMEs to ensure sustainable growth. SMEs have to create value by seeking new business opportunities from external networks and seizing opportunities by collaborating with external partners. Adopting an OI approach can be a useful strategy for SMEs to adapt to the changes in the market and respond quickly to consumers' demands and technological advances, thus helping them survive and thrive in economic turmoil, and enabling long-run sustainability. SMEs can benefit from OI by sharing innovation-related risks, but adopting an OI approach can present numerous challenges, including how to manage intellectual property. Accordingly, it is worth investigating OI projects in SMEs in the context of sustainability.

Our findings indicate that several issues must be discussed concerning the application of OI strategies to SMEs. First, OI strategies, particularly for SMEs, have recently been proposed, both in theory and practice. Nevertheless, discussion has been limited to the few OI practices that SMEs believe are useful and thus use, notwithstanding the various attempts to identify OI models for SMEs. We observed no clear increasing or decreasing trend in the use of OI practices over the last three years at the macro level, and only marginal differences in the trends across practices. Thus, OI strategies still enjoy limited recognition and use in most SMEs. For example, most core-and-critical OI practices are associated with intelligence activities to acquire high-quality information quickly when needed though networking and collaboration activities during R&D. On the other hand, most activities that concern using external resources during technology commercialization and marketing (e.g., co-manufacturing, co-sales, or outsourcing are regarded as relatively insignificant, and are thus unused). Du *et al.* (2014) found that collaboration projects are more financially successful when focused on acquiring external technological knowledge, but found no significant effects in market-oriented collaborations [61]. They also claimed that the financial performance of R&D projects with OI partnerships are affected by how they are managed: appropriate management produced better performance, and science-based partnerships are positively correlated with project performance for loosely managed projects, whereas market-based partnerships are only correlated with project performance for structured formal project management. Because SMEs can apply little formal project management, their collaborative projects are likely to be loosely managed; SMEs tend to obtain more performance from science-based partnerships than from market-based partnerships, and prefer the former to the latter. However, SMEs that lack technology commercialization and market-based partnerships can overcome these limitations if their collaboration projects are well managed, as suggested by the recent literature on OI in SMEs (e.g., [14]); SMEs are neither familiar with using external sources for technology commercialization through market-based partnerships nor used to effective coordination and tight project management. Further discussion is required to increase the performance of market-based and science-based partnerships.

Second, although not all SMEs enjoy the benefits of OI strategies, we expect that a few firm-level characteristics best fit the effective application of OI strategies. Our findings indicate that the types of SMEs that have experienced successful OI projects are (1) SMEs with R&D capabilities; (2) B2B firms that target a broad market in the manufacturing sector and offer a differentiated product or service; (3) SMEs that have introduced OI practices more intensively, on average; and (4) SMEs that have ever experienced benefits from OI, such as reduced time for R&D, increased efficiency in R&D investment, or new market creation and discovery. These research findings provide insight into how to develop programs to support OI in SMEs at the government level and determine their main beneficiaries. Factors such as R&D intensity, the suitability of BM for OI, and past experience of OI practices, in terms of diversity and intensity, can be used as criteria for government-funded OI projects. In addition, SMEs that had experienced more benefits were more likely to conduct successful OI projects. Advertising best practices or success stories of OI practices will help SMEs to experience the advantages of OI indirectly and initiate OI projects more actively.

Third, not only firm characteristics but also project characteristics are related to the performance of OI projects in SMEs. Because no SME can maintain an independent department for OI, OI activities

in SMEs are likely to be designed and managed mainly at the project level. We observed that successful OI projects were likely to target new-to-the-world products or services, in which sufficient resources are contributed to claim ownership of the collaboration outputs. Collaboration for highly innovative technologies reduces the cost and risk of R&D, and improves the satisfaction of the collaboration's participants. In particular, when selecting collaboration partners, strategic fit and trust seemed to be more important than the geographical proximity or past performance of potential partners. Starting a new partnership is always risky, hence the need to facilitate OI via an intermediary that can analyze the characteristics of potential partners, provide the relevant information to the client, and support match-making between companies. Here, government-funded research centers emerge as potential partners. These organizations possess the advanced technical skills required for collaborative R&D, are trustworthy—because they rarely bring their technologies to markets alone—and have produced excellent results when collaborating with SMEs. Our research findings should help project managers in SMEs to establish OI strategies through their valuable insight into how to start and manage OI projects. According to our findings, an OI approach is appropriate for collaborative R&D projects targeting novel technologies, which enables R&D costs and risks to be shared among collaborators. It may be significant to check whether the projects can produce intellectual properties and the focal firm is expected to be an owner of the intellectual properties.

Here, an interesting finding is that SMEs with positive experiences from OI practices, and not those with diverse uses of OI practices at the firm level, are more likely to manage their OI projects more successfully at the project level. This means that encouraging SMEs to adopt one or a few OI practices and having them experience the potential benefits of OI could be the basis for continuous adoption of OI and further successful operation of OI projects. Here, with regard to the OI practices that should be adopted (*i.e.*, collaboration modes) for successful OI, we do not expect them to be a "one-size-fits-all" solution for SMEs. Therefore, we analyzed the differences in collaboration modes according to industry type, firm size, and R&D intensity for successful OI projects. Table 13 shows SMEs that have used different strategies to achieve success with OI projects. Coinciding with our findings from the in-depth analysis, collaborative R&D was the most frequently adopted strategy, regardless of the SME's characteristics, with the exception of the group with R&D intensity less than 5%. Networking for intelligence and consulting was prevalent in successful OI projects when the firm size was small and the R&D intensity low. Relatively large SMEs and those in the software sector successfully adopted licensing and outsourcing. These observations lead to the conclusion that all SMEs, regardless of size, R&D intensity, and industry, can achieve success in OI with different modes of collaboration, which requires future research with a large set of empirical observations.

Table 13. Collaboration modes of successful OI projects.

Collaboration Mode	Size (Employees)			R&D Intensity			Industry		
	(0, 20)	**(20, 50)**	**(50, ∞)**	**(0, 5)**	**(5, 20)**	**(20, 100)**	**Mfg.**	**Software**	**R&D Service**
Networking for intelligence and consulting	**41.2% (14)**	**36.0% (9)**	20.8% (5)	**50.0% (14)**	**27.3% (9)**	22.7% (5)	**44.9% (22)**	7.7% (1)	23.8% (5)
Licensing	0.0% (5)	20.0% (0)	**25.0% (6)**	17.9% (5)	9.1% (3)	13.6% (3)	6.1% (3)	**30.8% (4)**	19.0% (4)
Outsourcing	5.9% (2)	4.0% (1)	**25.0% (6)**	10.7% (3)	12.1% (4)	9.1% (2)	10.2% (5)	15.4% (2)	9.5% (2)
Collaborative R&D	**52.9% (18)**	**40.0% (10)**	**29.2% (7)**	21.4% (6)	**51.5% (17)**	**54.5% (12)**	**38.8% (19)**	**46.2% (6)**	**47.6% (10)**
Total	100% (34)	100% (25)	100% (24)	100% (28)	100% (33)	100% (22)	100% (49)	100% (13)	100% (21)

Notes: (A, B) indicates a value greater than or equal to A and smaller than B. Text in bold indicates values greater than 25%.

5. Conclusions and Limitations

The OI paradigm considers R&D as an open system in which firms benefit from a variety of collaborative activities with external partners that enables a firm's sustainable management. However, we lack a firm understanding of OI activities at the project level, where the R&D activities in SMEs are actually performed. Moreover, the relationships between OI strategies and performance are not well understood in the context of SMEs, despite the popularity of the paradigm. Therefore, this study investigated the project-level characteristics of OI activities as factors associated with OI performance for sustainable growth. To this end, we conducted a comparative analysis of successful and unsuccessful OI projects, in both firm-level and project-level terms. The research findings at the project level revealed statistically significant differences between the two groups in terms of collaboration mode, partner selection criteria and type of relationships, the innovativeness of the collaboration items, and the appropriability of collaboration outcomes. The firm-level analysis suggests that SMEs with a record of successful OI projects differ from those with a history of unsuccessful projects, in terms of R&D capabilities, BM characteristics, and experiences with OI practices in general.

This study's theoretical contribution adds to the growing OI literature by using multi-level perspectives to analyze OI practices. We examined the relationships between firm and project aspects and the success of SMEs' open innovation projects, considering both firm and project-level characteristics. The need to develop these multi-level perspectives on OI—including individuals, groups/projects, business units, ecosystems/communities, firms, regions, and national innovation systems—has been described in the literature [10]; our research is one of the earliest attempts to meet this need. We contribute to a better understanding of the OI practices recognized and managed within SMEs by investigating not only successful but also unsuccessful cases of OI projects. Our results are valuable sources of knowledge that can help to identify the factors that may affect the performance of OI projects in SMEs, thus informing the strategic activities intended to foster OI adoption or promotion, and ultimately to enable sustainable management. As firms and governments increasingly seek to re-align their strategy and policy frameworks with OI, it is becoming increasingly important to identify the conditions under which SMEs engage in open relationships and generate successful OI projects.

Amid its meaningful contributions, this research is also subject to a few limitations. First, its findings are difficult to generalize. The survey respondents were restricted to three industry sectors (manufacturing, R&D service, and SW), which may have affected the research findings, in which more successful stories originated from R&D-centered collaboration modes. However, more successful stories can come from other collaboration modes such as crowdsourcing in other industries [66] Moreover, Korean SMEs tend to pursue closed innovation and are slightly subordinate to a few large enterprises. These distinguishing features of Korean SMEs may have affected our research findings as well. Hence, further analysis is required to increase the study's external validity, possibly by referencing the research conducted in other countries and industry sectors. Second, this research only used simple techniques, such as t-tests and chi-square tests, which are appropriate for exploratory analysis and the purposes of this research (*i.e.*, to compare successful and unsuccessful OI projects). However, meaningful implications could flow from applying an elaborate model (e.g., a regression model) to our data. A project-level analysis that uses an elaborate model would also help to extract the best practices of successful OI models, which could then inform OI adoption strategies. Thirdly, this research is based on SME attitudes to OI. For example, SMEs judged whether their OI projects were successful according to their own criteria. Different SMEs must have used different criteria, which may have produced a subjectivity gap in the results. Further work is required to reduce this gap and gather more objective data. Fourth, a comparative analysis of different industries is necessary to explore the firm- and project-level characteristics of open innovation. In this research, the data explored three different industries—manufacturing, SW development, and R&D services—but most of the responding firms were in the manufacturing sector; accordingly, we could not obtain meaningful insight from the comparative analysis. Future research needs to focus on the differences in open innovation characteristics between industries. Finally, a research method should be designed to take

selection biases into account. In this study, we asked a firm if it possessed a successful case of an OI project in the last three years. If yes, we asked more about the project; otherwise, we collected data on the firm's unsuccessful OI projects. Although this research only focused on a single project, this approach may lead to a selection bias. For example, there may be a firm with only one greatly successful project but a number of minor unsuccessful projects. As our target firms were SMEs and therefore may only have had limited opportunities to collaborative with others, the selection bias problem might have been avoided in this research. Nevertheless, more meaningful insight can be obtained by controlling the success and failure of OI projects at the firm level. Determining the success and failure of OI projects not only at the project level but also at the firm level is necessary to improve the reliability of analysis, which should be considered in a future research design.

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Appendix

Appendix 1. Comparative Analysis of Firms with Successful Experience, Unsuccessful Experience, and No Experience of OI Projects

Table A1. Comparative analysis of firms in our databases (%).

Categories		Successful Experience of OI Projects (A)	Unsuccessful Experience of OI Projects (B)	No experience of OI Projects (C)	Total
		16.1	30.6	53.4	100
Size	Less than 50	14.1	28.6	57.3	100
	50–99 *	19.4	37.5	43.1	100
	100–299 *	27.7	36.2	36.2	100
Industry	Manufacturing	12.2	27.6	60.2	100
	SW development *	21.3	45.9	32.8	100
	R&D service *	38.9	35.2	25.9	100
Target market	Domestic	14.9	31.5	53.7	100
	Global *	24.2	24.2	51.5	100
Target product	Parts	13.2	24.2	62.6	100
	Products	18.3	34.5	47.2	100
	Services *	18.5	43.2	38.3	100
	Others *	15.0	10.0	75.0	100

* Statistically significant differences at a significance level of 0.05 identified compared with the share of three categories (A, B and C) in the total cases.

Appendix 2. Identification of OI Practices

OI practices were identified from previous studies on OI; however, we extended the modes of collaboration at the commercialization phase, referencing Cosh and Zhang (2012) [15]. Accordingly, the types of alliances in SMEs were divided into five groups: joint R&D, R&D consortium, co-marketing and co-branding, co-production, and joint purchasing. In addition, the types of outsourcing were divided into two groups: R&D and other than R&D, unlike the previous studies focusing mostly on R&D. SMEs may also need to outsource business services, considering their lack of resources in the relevant areas.

Table A2. OI practices identified from the previous studies.

OI Practices	Van de Vrande (2009) [12]	Abulrub and Lee (2012) [65]	Bianchi *et al.* (2011) [39]	Cosh and Zhang (2012) [15]
User/customer involvement	Customer involvement	Customer involvement		Engaging directly with lead users/early adopters
Using external experts	Network usage in innovation processes, employee involvement	External networking		Exchanging ideas through websites and competitions
Using collective intelligence				
Using informal human networks				Participating in innovation networks/hubs
Using formal human networks				
M & A		M&A		
Inward technology transfer	Licensing IP from other firms	Licensing-in	In-licensing	Licensing in externally developed technologies
Joint R&D	Participation in other firms	Joint development, contract R&D	Alliances	Joint R&D, joint university research
R&D consortium				Participating in research consortia
Co-marketing and co-branding				Joint marketing/co-branding
Co-production				Joint production of goods or services
Joint purchasing				Joint purchasing of materials or inputs
Outsourcing: R&D	Outsourcing R&D	Purchasing	Purchase of scientific services	Outsourcing or contracting out R&D projects
Outsourcing: other than R&D				
Investment from external sources		Venture capital		
Outward technology transfer	Licensing IP to other firms	Selling; Licensing-out	Supplying scientific services; Out-licensing	Providing contract research to others
Organizing a venture business	Venturing	Spin-off		Joint ventures, acquisitions, and incubations
Joint venturing		Joint venture		
Open platform		Open source		Participating in open source software, sharing facilities with others

Appendix 3. Results of Reliability Test on Survey Items

A Cronbach's alpha analysis was conducted on the datasets of 517 firms. A Cronbach's alpha level of 0.05 for all statistical tests was used.

Table A3. Cronbach's alpha values for exploratory analysis variables.

Category		In-Bound		Out-Bound (4 Items)
		R&D (10 Items)	Commercialization (5 Items)	
OI practices	Degree of use	0.913	0.863	0.873
	Change in the degree of use	0.848	0.858	0.827
	Recognized importance	0.951	0.923	0.907

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