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Article

An Investigation into the Performance of an Ambidextrously Balanced Innovator and Its Relatedness to Open Innovation

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Abstract: This study investigated the relationship between open innovation and the radicalness of innovation. The balance between radical and incremental innovation is an essential part of the ambidextrous use of explorative and exploitative strategies, and this study assumed that open innovation is usually interlinked with explorative strategies and is thus related to radical innovation performance. Accordingly, following an empirical investigation, we demonstrate that the balance of open innovation firms is slightly skewed toward explorative radical innovation. Using the Korean version of the community innovation survey, we show that the relative radicalness that is projected on innovation output exhibits an inverted-U curve. Furthermore, the curve shifts based on the level of inbound open innovation. Our results suggest that there is an ambidextrous balance between radical and incremental innovation while implementing open innovation. In addition, the research results imply that firms placing greater weight on explorative radical innovations need to consider in-depth open innovation strategies.

Keywords: radical innovation; inbound open innovation; ambidextrous organization

1. Introduction

A cautious approach to the exploitation of current markets with improved technologies always hampers a firm's desire to explore technological frontiers with radical innovation. This tension between exploration and exploitation leads to managerial challenges [1], and it is likely to influence the strategic organization type, as documented by Miles and Snow [2].

In another dimension, the innovation performance of firms has been continuously questioned under the condition of open innovation [3–8]. The effect of open innovation on firm performance has been intensively discussed and debated in the case of small and medium enterprises [9]. However, only a few studies have explored the connection between open and radical innovation in terms of firm performance. Rather, firm innovation performance is usually investigated using the input variable of the research and development investment, and sometimes with moderating conditions, such as entrepreneurial orientation [10], strategic orientation [11,12], and external linkages [9].

The body of literature regarding strategic orientation often refers to organizational ambidexterity, whereby a firm balances explorative and exploitative strategies; this is a concept that remains critical. A seminal work by March [1] clearly designated the importance of strategic orientation in management [13]. The dichotomy of explorative vs. exploitative strategies can even be applied to the types of strategic alliances [14]. A recent study dealt with in-bound open innovation and its impact on ambidextrous innovation performance [15], and its results were in line with the tradition of dealing with both strategic ambidexterity and external linkages.

This study investigated the most essential form of explorative innovation, radical innovation, with a particular focus on the balance between radical and incremental innovation. A firm's technological innovation strategy should include a focus on radical vs. incremental innovation, as well as long- and short-term plans [16,17]. Based on the Korean innovation survey, our study demonstrates the importance of balancing radical and incremental innovations, even in small- and medium-sized firms. In fact, the optimal balance point is in the middle and it is not static, but certain moderating factors can affected (shifted) it. We determined the dynamic balance point under an open innovation environment by analyzing the innovation performance curves of the relative radical/incremental innovators.

2. Literature Review and Hypothesis

2.1. Ambidextrous Innovator: The Importance of Balance between Radical vs. Incremental Innovation

Tushman and Smith [18] tried to interpret radical innovation as a way of targeting the new and novel development of markets and, in parallel, incremental innovation was defined as targeting current customer needs. As radical innovation is accompanied by risk, its overemphasis can jeopardize a company's cash flow. Although some studies have argued that a trade-off exists between explorative and exploitative learning, in effect, the relationship between the two can be best summarized as being two sides of the same coin. The virtue of radical innovation seems to be apparent as novel products and services cause disruptions in the market and, in some cases, even create new industrial sectors. Incremental innovations, which provide marginal improvements to extant solutions, also greatly affect firms and consumers by lowering the prices of goods [19]. However, too much incremental innovation may cause a company to fall into the trap of seeking immediate short-term profit and could dampen its future competitiveness. An excessive focus on radical innovation can be also dangerous. Radical innovation usually requires deep pockets. Massive investment without commercial success occurs occasionally, and the risk of radical innovation is apparent, since the length of breakthrough-type radical innovation projects is often typically ten or more years [20]. Accordingly, the management skills that are required for radical innovation differ from those for incremental innovation [21], which causes a managerial challenge.

Hence, a company that can manage both explorative radical innovation and exploitative incremental innovation exhibits ambidextrous organizational capability. The superiority of ambidextrous organizations has been empirically proven [22,23]. Under favorable environment conditions, such as when a dominant design emerges [24] and when technological dynamics are complex and rapidly changing [25], radical innovation may play significant roles in industrial development. Jansen et al. [26] indicated that exploitative innovation (i.e., a general form of incremental innovation) becomes effective under financial pressure and severe competitive situations. Bento [27] also emphasized the importance of using both explorative and exploitative knowledge to operate properly in a collaborative and integrative work environment.

The balance seems to be dynamic, as the initial stage of the industrial life cycle might encourage radical product innovation, and the mature industrial stage might stimulate cost-saving incremental process innovations [18,28]. As an industry evolves from the initial ferment stage to the mature stage of the industrial cycle, firms also need to switch their management activities to achieve a tighter grip on administrative routines than entrepreneurial challenges [29]. Raisch et al. [30] also emphasized that ambidextrous organizations are the result of a dynamic combination of internal and external knowledge processes and argued that the static vs. dynamic framework may provide a better understanding of ambidextrous capabilities. In fact, some studies have posited that having a balance between exploration and exploitation could be an essential component in dynamic capabilities [31]. Hence, managing the balance between radical and incremental innovation is crucial when companies need to expand their knowledge base through strategic alliances [13].

2.2. Ambidextrous and Balanced Innovation and Its Relation to Open Innovation

To respond to the challenge of managing radical innovation, firms tend to deepen technological collaborations with diverse partners. Han [32] implied that open innovation inherently involves the "quest of the unknown" territory of the knowledge frontier, alluding to a hidden connection to explorative innovation. Lausen and Salter [33] empirically tested the influence of open innovation on radical innovation. Their analysis of a United Kingdom (UK) firm survey indicated that the depth (intense linkages) of open innovation could positively affect the radical innovation in a curvilinear manner (a slightly inverse U curve). A recent study questioned the interrelatedness of seemingly separate radical and open innovation [15]. Ardito et al. [15] posited that inward open innovation could affect ambidextrous innovation performance. They used a similar dependent variable to Lausen and Salter to investigate this [33], but they used the multiplicative scale of novel product market share and incrementally modified the product market share. Half of the radical innovation product and half of the incremental innovation market made a maximum ambidextrous value of $0.5 \times 0.5 = 0.25$, and they found that knowledge sourcing from both suppliers and customers contributes to ambidextrous innovation performance; in other words, inbound open innovation contributes to the balance of radical and incremental innovation.

In a previous study, Hwang [23] showed that balanced ambidextrous firms exhibited higher performance in patenting activities. He followed the framework of Choo and Chinaprayoon [34] in the search for an inverted-U curve, but measured the innovation performance in terms of patent applications rather than the number of new product developments. He used a small and medium enterprise data sample from the Korean innovation survey and found that the inverted-U curve (x-axis radicalness of innovation, y-axis number of patent applications) was only notable and statistically significant in the case of innovative firms (firms with venture certificates). The inverted-U curve was not apparent in ordinary small and medium enterprises. Yun and Park [7] indicated a higher performance in accordance with the level of open innovation, and measured firm performance in terms of the number of new product developments. Recently, Ardito et al. [15] presented a strong argument that open innovation facilitates balance (ambidextrous) innovation output, though the causality between open and balanced innovation was not clearly proven. Combining these research results, expecting a strong inverted-U curve for the innovation performance of firms in the case of open innovation is plausible.

Hypothesis 1. *Relative radicalness has an inverted-U shape relationship with the innovation output in the case of open innovation.*

When firms perform open innovation, the balance between incremental and radical innovation becomes critical. Of the broad range of studies on the balance between exploration and exploitation, few have questioned whether the effect of balance on the innovation output differs by shifting toward more explorative radical R&D (or exploitative incremental improvements). One exception was a study by Choo and Chinaprayoon [34], who first presented the inverted-U curve between relative exploitation and firm performance (product and process innovations). Subsequently, they investigated the shifting effect of foreign direct investment (FDI) on the balance between exploration and exploitation. The results showed that a high level of FDI shifts the inverted-U curve toward exploitation. In a subsequent explanation, they presumed that FDI could include wide knowledge absorption to facilitate additional modified innovations in developing countries, like Thailand, thereby increasing both the number of products and process innovations. If we interpret the high level of FDI as representing more intense external linkages and as a form of open innovation, then this contradicts earlier research results [33]. As described above, Lausen and Salter's study [33] showed that open innovation with a wide and deep search of external innovation sources could facilitate radical innovation. According to their paper, the breadth of open innovation (the number of different information sources for innovation, regardless of importance/intensity) did not contribute to radical innovation, and what really counted was the depth of open innovation (the number of intensively engaged external information sources). We argue that open innovation shifts the optimal balancing point between radical and incremental innovation (the zenith of the inverted-U curve) toward radicalness. A separate study of listed firms in a German-speaking area also concluded that linkages exist between open innovation and radical innovation [35]. We presumed that the FDI is related to exploitative innovation, because developing countries that are learning from multinational firm linkages tend to focus on modification and more efficient production, which is slightly different from the normal purpose of open innovation. The current research utilized the Korean innovation survey, and it was expected that our results would be closer to the European cases. Therefore, it is plausible to set the research hypothesis in line with European research results, placing emphasis on explorative radical innovation.

Hypothesis 2. *The balance between incremental and radical innovation may shift toward radicalness in the case of open innovation (skewed inverted–U curve).*

3. Data and Methodology

3.1. Data Source

The dataset is briefly introduced in this section. The 2005 Korean innovation survey (KIS) data from the manufacturing sector were used to obtain a continuous measure of the relative radicalness of innovation activities, as later series of Korean innovation surveys have only included dichotomous values that are related to radical/incremental innovations. In the 2005 KIS, 2399 small and medium enterprises (SMEs) responded, and a final sample size of 680 enterprises with multiple (three or more) product innovations was selected. SMEs suffer from having scarce resources, allowing for the importance and impacts of open innovation to be more greatly perceived than if large enterprises were used [36,37].

3.2. Independent Variable

The radicalness of innovation (the relative number of radical vs. incremental innovations) was measured as the number of new product developments over the total number of product developments:

$$\text{radicalness} = \frac{n_n(\textit{new product developments})}{n_n(\textit{new product developments})+n_i(\textit{improved product developments})} \quad (1)$$

Open innovation has been questioned while using both dichotomous and interval values (ranging from zero to nine different external sources). This study followed the method of Lausen and Salter [33] to yield the depth and the breadth of open innovation. However, the variables were mainly extracted from "sources of technological acquisition" and "technological collaboration", instead of from the "information sources" section. Although it did not include outbound open innovation, a previous study utilized external sourcing and collaboration [6]. If firms expressed the external linkages as being very important (4–5 on a Likert scale) technological sources and collaborations, the open innovation depth became positive. The maximum depth was nine, as there were nine difference sources and partners. The breath only counted the number of different sources and collaborations; thus, the value was equal to or greater than the depth of the open innovation. If a firm engaged in very shallow partnerships with external sources, the breadth would be a high number, but the depth would be a low number.

In addition to the major two independent variables, research and development investment was also used. A binary factor that indicated whether a firm was certified as an innovative firm was also included as a control variable. Other typical control variables were included: log (firm size: number of employees), firm age, and industry dummy. Table 1 presents a summary of these variables. For the multicollinearity check, we determined the largest variance inflation factor (VIF = 1.309), which was well below the recommended criteria of 10. In Table 1, the dichotomous (2) open innovation variable's average mean was 0.64, which indicated that 64% of the tested SMEs were engaging in open innovation. However, the open innovation depth mean value was only around one (maximum nine), due to almost half of the sample not engaging in a deeper level of open innovation. As for the other variables (9), the number of patent applications was correlated with the size and R&D investment, as expected.

Table 1. Basic statistics of variables.

	Mean	StdD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Innov Firm Cert.	0.47	0.50	1								
(2) OpenInnov	0.64	0.48	0.182 **	1							
(3) Age	17.23	11.71	−0.109 **	−0.008	1						
(4) Size	107.41	77.25	0.034	0.096 *	0.407 **	1					
(5) R&D invest (B KRW)	1.19	2.94	0.167 **	0.107 **	0.028	0.209 **	1				
(6) Radical	0.37	0.34	−0.011	−0.007	−0.059	−0.044	−0.027	1			
(7) OpenIDepth	1.09	1.75	0.181 **	0.468 **	−0.003	0.109 **	0.114 **	0.034	1		
(8) OpenIBreadth	2.66	3.15	−0.034	−0.055	0.011	0.011	−0.049	−0.037	−0.041	1	
(9) Product Patent(app.)	6.78	16.06	0.062	−0.064	−0.016	0.200 **	0.130 *	0.049	−0.006	−0.028	1

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, about the abbreviations of variables, please see Table 2.

3.3. Dependent Variable and Adopted Methods

The current section presents two kinds of dependent variable that are used, depending on the adopted regression methods. The first dependent variable is detailed in Section 3.3.1 with the associated regression method, and the second dependent variable is subsequently explained in Section 3.3.2 with the different regression method. Table 2 presents the summary of variables.

Table 2. Summary of variables.

	Analysis: Effect of Open Innovation Attributes and Radicalness on Patenting Performance	**Analysis: Effect of Open Innovation Attributes on Ambidexterity (Median Radicalness)**	**Sources**
Model (Method)	Negative Binomial Regression	Logistic Regression	
Dependent Variable	Number of Patent Applications (in product innovation during previous three-year period)	Binary of Radicalness (median 50%)	
Independent Variables	Age	←	Age of firm calculated from the Korean innovation survey (KIS) founding year
	Ln_Size	←	Log of firm size, Log(number of employees): the number extracted from KIS
	Industrial dummy	←	Following [23], four categories according to level of high-technology: original value 2 digits Korea Standard industry code in KIS
	R&D investment	←	The value in billion Korean won: KIS
	Innovative firm certificate		Binary: government certificate of innovative firms: KIS
	Radicalness		Calculated from the ratio of radical product innovation: KIS
	OpenI.Depth	←	The depth of open innovation similar to [32] but extracted from two questions of the KIS: the source of technological acquisition and the partner type of technological collaboration. The diversity of the partner type is nine, thus ranging from 0 to 9.
	OpenI.Breadth	←	The breadth of open innovation, similar to [32], extracted from two questions from the KIS: the source of technological acquisition and on the partner type of technological collaboration The diversity of partner type is nine, thus ranging from 0 to 9.
	Open Innov.	←	Binary: equivalent to OpenI.Breadth > 0

3.3.1. Patent Applications

The dependent variable, innovation performance, can be either financial or non-financial [33,34]. In the current study, we focused on non-financial performance, which could include the share of new product sales [33], the number of new product innovations [7,34], or the number of patents [23]. We took patent applications as a proxy variable for innovation output. Process innovation was excluded due to the research results from Hwang [23], who reported that process innovation patent applications do not feature an inverted-U curve.

The number of patent applications was used as a proxy measure for the innovation output. Although this is considered as an intermediate output, it has been frequently used in previous research [23,38,39]. The method to measure the number of patent applications vary, but two methods are the most popular: Poisson and negative binominal regression. Negative binominal regression is preferred, due to over-dispersion [33,40]; therefore, we adopted this method for the regression. In addition, to identify the shifting effect of the inverted-U curve, the interaction term between two variables (e.g., radicalness * open innovation depth) is presented in the regression results, along with the graphs [33].

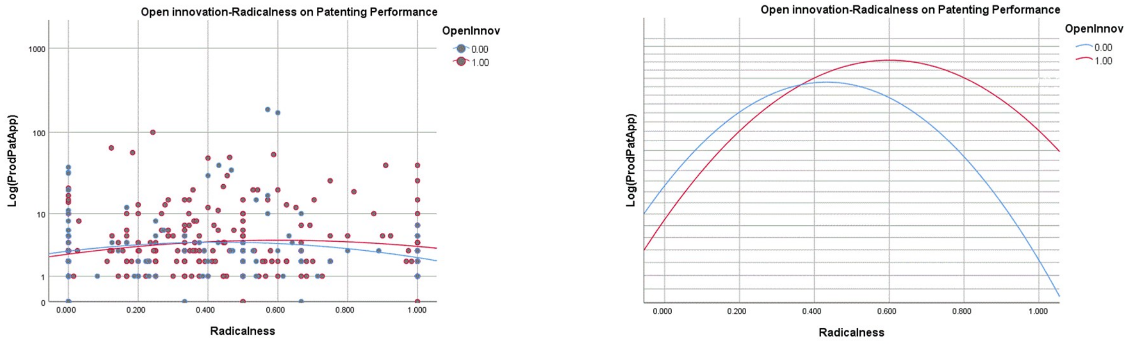
3.3.2. Binary Variable of "Radicalness"

A dichotomous variable was created for additional logistic regression analysis. The 50% median range of "radicalness" spanned from above zero to 0.667; in fact, due to duplicated values in 0.667, the exactly middle 52% of the population was assigned a value of "one", and the other two extremes were assigned a value of "zero". The value of "one" indicated a balanced case of ambidextrous innovation.

4. Results and Discussion

As seen in Figure 1, the inverted-U curve was apparent, regardless of whether or not the firm had performed open innovation. The prominence of the inverted-U curve of open innovators against solo innovators was not clear; the inverted-U curve (observed in Model 2a of Table 2) was ambiguous, as the coefficient of "radicalness ^{2}" was negative but not statistically significant. If the condition was more strictly confined to serious open innovators (here, we mean "serious" open innovators as those with positive open innovation depth—firms replied with at least one of the technological acquisitions or collaborations with external partners as highly useful), then the inverted-U curve seemed to be more evident. The squared term of radicalness, "radicalness ^{2}", as shown in Model 2b, Table 3, had a negative coefficient and it was statistically significant, which implied that serious open innovators (with positive open innovation depth) with a good balance between radical and incremental innovations performed better in terms of patent applications. In sum, Hypothesis 1 was only partially supported as the simple "open innovation" situation did not show a statistically concave inverted-U curve, but the inverted-U curve was apparent in the "open innovation depth" situation. However, in the comprehensive Model 3 of Table 3, the multiplicative term between "open innovation depth" and "radicalness ^{2}" was not significant.

Table 3 presents the overall regression results. The first column, Model 1, includes the open innovation dummy, where the interaction term between the "radicalness" variable and the dichotomous "open innovation" variable is positive and statistically significant. This proves that there was a shift in the optimal balance between radical and incremental innovation. Figure 1b shows the shift toward radicalness. In addition to Model 1, the soundness of this finding was once again supported by Model 2a, where the coefficient of "radicalness" was positive and statistically significant at the 5% level. We selected another subsample, Model 2b, for firms with a positive open innovation depth. Model 2b also identified the coefficient of "radicalness" as being positive and statistically significant, and Figure 2b presents the graphical result of this. To summarize, a serious open innovation firm (positive open innovation depth) with high performance in applying patents tended to focus on radical innovation slightly more than incremental innovation. In sum, Hypothesis 2 was supported. We could see a shifting balance toward radicalness. The direction of the inverted-U curve shift toward radicalness was in contrast to the case of a previous Thai study [34], where the external linkage (FDI, though it is not tantamount to open innovation) caused a shift toward exploitation.



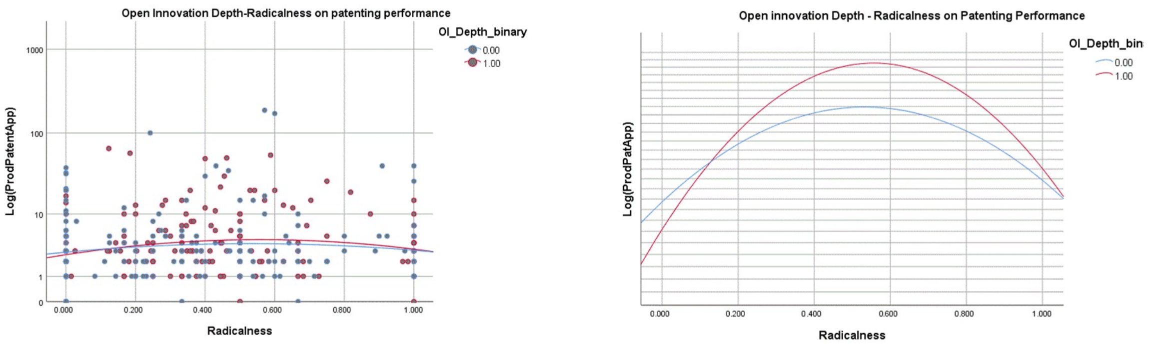
(**a**) (**b**)

Figure 1. Inverted-U curve of patent application performance: open vs. non-open innovation firms: (**a**) Log (Patent Application)-Radicalness; and, (**b**) simplified with fitting curve.

Table 3. Negative binomial regression on the number of patent applications–inbound open innovation firms.

Coefficient (Wald Chi_Square)	Model 1	Model 2a	Model 2b	Model 3
	Total Sample	Subsample	Subsample	Total Sample
		OpenInnov = 1	OpenI.Depth > 0	
Constant	1.249 *** (7.482)	1.424 *** (7.907)	0.268 (0.198)	0.849 * (3.733)
Industry dummy	−0.438 * (2.988)	−0.731 ** (6.192)	0.526 (2.277)	−0.362 (2.028)
Innovative firm certified (1/0)	0.158 (1.264)	0.129 (0.606)	0.105 (0.279)	0.178 (1.584)
Age	−0.008 (1.530)	−0.001 (0.035)	−0.006 (0.488)	−0.010 (2.467)
Ln_size	0.182 ** (4.760)	0.067 (0.487)	0.111 (0.944)	0.204 ** (5.744)
R&D investment	0.009 *** (9.126)	0.007 ** (4.706)	0.003 (1.541)	0.008 *** (7.799)
Radicalness	0.645 (1.020)	1.439 ** (3.904)	2.727 *** (9.937)	0.954 (2.124)
Radicalness	−1.180 * (3.570)	−0.963 (1.700)	−2.262 ** (6.436)	−0.883 (1.945)
Open Innovation (1/0)	−0.654 *** (9.755)			
OpenInnov * Radical	1.041 ** (5.658)			
OpenI.Depth				−0.069 (1.684)
OpenI.Breadth				−0.018 (0.331)
OpenI.Depth * Radicalness				0.113 (1.094)
OpenI.Breadth * Radicalness				0.013 (0.045)
Likelihood-ratio of chi (df)	56.36 (11)	29.44 (9)	24.07 (9)	47.97 (13)
Pr > L.R. chi	0.000	0.001	0.004	0.000
Sample size N	680	434	309	680

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.



(**a**) (**b**)

Figure 2. Inverted-U curve of patent application performance: positive open innovation depth vs. zero open innovation depth: (**a**) Log (Patent Application)-Radicalness; (**b**) simplified with fitting curve.

However, it was not clear whether "open innovation depth" caused a higher patenting performance. In Model 3 of Table 3, the most comprehensive model, except for control variables, like R&D investment and Log (size), no variable appeared to be statistically significant. Therefore, we concluded that Hypothesis 1 was only weakly supported.

We implemented another regression to reinforce our argument. The dependent variable was "balanced or not" in terms of ambidextrous innovation. Table 4 presents the logistic regression on the dichotomous dependent variable "ambidextrously balanced" firms (half of the firm population in the middle had a value of one; both extreme cases, zero and above 0.667 "radicalness", were assigned as zero). We clearly observed that "open innovation depth" had explanatory power with statistical significance in the regression on the dependent variable "median radicalness: ambidextrous and balanced innovation performance". In Model 1, as shown in Table 4, the independent variable "open innovation" was not statistically significant, but in Model 3 of Table 4, "open innovation depth" was significant at the 5% level. The variable "open innovation breadth" was not statistically significant. Although not presented in this research paper, we implemented a separate multinomial logit analysis. The dependent variable was segmented into five intervals, as follows: (0) zero radicalness as reference segment; (1) $0 <$ radicalness ≤ 0.25; (2) $0.25 <$ radicalness ≤ 0.5; (3) $0.5 <$ radicalness ≤ 0.75; and, (4) $0.75 <$ radicalness ≤ 1. The results of this segmentation supported the link of "open innovation depth" with segment (2) $0.25 <$ radicalness ≤ 0.5 and was somewhat weakly linked to segment (3) $0.5 <$ radicalness ≤ 0.75. "Open innovation breadth" was not significant as an explanatory variable. This is consistent with recent research results [15], though, to measure "radicalness" in the previous research, the radical product market share was used instead. The previous research [15] indicated that external knowledge sources, such as supplier, customer, and competitor are important for ambidextrous performance. Our research adopted a much more stringent definition of inbound open innovation (collaboration or knowledge acquisition), but still produced a similar result, highlighting the importance of inbound open innovation for ambidextrous innovation performance. In addition, our research emphasized the "depth" of open innovation contrasting to the "breadth". To the best of our knowledge, our research is one of first endeavor to reveal "skewed" performance of ambidextrous innovators in conjunction with open innovation. Furthermore, in Model 3 of Table 4 the coefficient of the squared term "open innovation depth ^{2}" is negative and statistically significant, which is in line with the decreasing return of "open innovation depth", as reported by Lausen and Salter [33].

Table 4. Logistic regression on the ambidextrous innovation performance.

	Model 1	Model 2	Model 3
Constant	−0.648 (1.747)	−0.868 * (3.121)	−0.867 * (3.036)
Industry dummy	−0.448 (2.459)	−0.412 (2.058)	−0.395 (1.883)
Age	0.009 (1.335)	0.009 (1.174)	0.009 (1.143)
Ln_size	0.171 (2.372)	0.173 (2.407)	0.161 (2.056)
R&D investment	0.005 (2.151)	0.005 (1.940)	0.004 (1.550)
Open Innovation (1/0)	−0.251 (2.070)		
OpenI.Depth		0.119 ** (5.808)	0.290 ** (6.377)
OpenI.Breadth		−0.010 (0.157)	−0.050 (0.258)
OpenI.Depth			−0.027 * (2.746)
OpenI.Breadth			0.005 (0.190)
Log Likelihood	−411.91	−406.92	−405.476

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

When considering exploitative incremental innovation built on an existing knowledge base and explorative radical innovation hinged on creating or expanding a knowledge base, the collaboration with external partners or new technology acquisition may contribute to the ambitious expansion of an SME's knowledge base. The relation between in-depth open innovation and radical innovation was once confirmed again in the case of SMEs.

5. Conclusions

5.1. Concluding Remarks

As we discussed in previous sections, in Model 2b, Hypothesis 1 was weakly supported (the coefficient of "radicalness ^{2}"was negative and significant in Model 2b, but not clear in Models 2a and 3). The inverted-U curve was prominent in the case of serious open innovation (positive open innovation depth). However, in general, there was no indication as to whether this inverted-U curve was clearer than the other non-open-innovators' patenting performance curves.

Hypothesis 2 was supported, since we witnessed that inbound open innovation causes a shift of the inverted-U curve toward "radical" innovations. Additional analysis regarding the relationship between open and radical innovation in Table 4 showed that "open innovation depth" was critical to ambidextrous innovation performance.

Our study has deepened the understanding of explorative open innovation with empirical data. Even though both explorative and exploitative external linkages contribute to a firm's knowledge base, firms utilize inbound open innovation more frequently for the purpose of expanding their knowledge base and/or implementing explorative strategies. When considering that few studies have explored the attributes of open innovation with empirical analyses of small and medium enterprises (SMEs), these research results extend our understanding of open innovation. This study contributes to strategic management literature on ambidextrous organizations by clearly revealing the impact of open innovation on the performance of ambidextrous innovators and, unlike previous research on open innovation, our research results highlight the inherent connection to radical innovation. The implications for the strategic balance between ambidextrous (explorative and exploitative) innovations can be related to contingent and dynamic balancing. This research confirms that the depth of inbound open innovation shifts the balance between the explorative radical and exploitative incremental innovations. This study reaffirms the importance of achieving balance when seriously engaged in open innovation. Balance, but with slightly more weight on radical innovation and performing inbound open innovation, can generate great results regarding innovation output (patenting performance). In the case of shallow open innovation, we found that balance did not improve the patenting performance. To further the contribution of the current study, the study of dynamic balancing could be extended to dynamic capability literature [41].

Regarding policy implication, we suggest that a research consortium, as a platform of in-depth open innovation, could help to achieve breakthrough technological development. In addition, the design of a collaborative research consortium might encourage the participation of diverse actors, but it is more important to emphasize the commitment of each participant rather than the number and types of diverse participants.

5.2. Limitations and Future Research

First, the limitations of this research mainly come from the inability to reveal the causality between "openness" and "radicalness" in product innovations, as they are interrelated. We imply that open innovation, as a tool of exploring new knowledge dimension, may affect radicalness. However, the causality has not been clearly explained.

Second, this study also has a weakness regarding the measurement of radicalness. This research adopted a proxy variable from past innovation portfolios of the ratio between the number of radical innovations and the number of incremental innovations. We used this proxy as the strategic orientation for radical innovation to measure another type of innovation performance (patent applications), as seen in Table 2. The relative radicalness could have been improved if the survey had provided the R&D budget ratio for explorative innovations. In addition, the study only selected product innovation without an analysis on process innovation. Though this was based on the results of previous research [23], another study [34] included process innovation. Additionally, for future research, to check robustness, the dependent variables could also be expanded to include the number of innovations, the financial outputs that were improved by innovations, and the market share of radical new products.

Finally, this research only included inbound open innovations. If a proper survey was adapted, it would be possible to discern the impact of inbound open innovations from outbound open innovation.

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