# The hierarchical relationships between CEO characteristics, innovation strategy and firm performance in open innovation

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**Abstract:** Open innovation (OI) has become an important business norm of successful firms; however, its strategic aspects and the role of a key individual, such as a chief executive officer (CEO) in its adoption, have been under-researched. This paper aims to investigate whether OI is relevant to SMEs and how CEO characteristics influence firm performance through OI. The hierarchical relationships between a firm and CEO characteristics are analysed with structural equation modelling (SEM) using data from 401 innovation-oriented SMEs in Korea. The results indicate that: 1) openness can make a greater contribution to firm performance; 2) CEO characteristics are positively associated with openness; 3) government support positively influences both openness and internal R&D. The research suggests that the human elements in SMEs should place a greater emphasis on OI to enhance firm performance and that policy makers should consider developing various programs for key decision makers in SMEs to increase their awareness of OI.

**Keywords:** open innovation; OI; chief executive officer; CEO; small and medium-sized enterprise; SME; structural equation modelling; SEM.

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## 1 Introduction

Open innovation (OI) has become a widely used business strategy across many industries (Gassmann et al., 2010; Mortara and Minshall, 2011; Ahn et al., 2016, 2015). However, while the majority of studies have focused on large multinational corporations (MNCs), less focus has been directed towards small and medium-sized enterprises (SMEs) (Lee et al., 2010; van de Vrande et al., 2009; Hossain, 2015). The paucity of the research and the heterogeneity of SMEs have made it difficult for us to capture the holistic characteristics of OI in SMEs. Because of the heterogeneity of the SME population, not all SMEs directly contribute to social wealth through the creation of new employment (NESTA, 2009; SMEA, 1999). However, it is difficult to deny the importance of highly innovative SMEs due to their roles as contributors to the vibrancy and dynamism of national economies. For this reason, highly innovative SMEs have received much attention from both scholars and governments across the globe (NESTA, 2009; Tidd et al., 2005).

SMEs that attempt to achieve a high level of innovation may have to choose one of the following paths: focusing on internal R&D or opening up their firm boundaries. The former appears to be an easy option for SMEs; however, their limited resources can be a constraint (Narula, 2004; Rothwell and Dodgson, 1994). The latter appears to be risky; however, it may offset SMEs' weaknesses while building on their strengths. Thus, SMEs can be torn between these two strategies; however, the literature has not provided sufficient guidelines in the SME context. This may originate from general attitudes towards internal R&D. In the OI literature, R&D has mainly been examined as a control variable; however, it can play a more important role in the OI process (Spithoven et al., 2012). It may compete with OI adoption, or may indirectly affect firm performance through OI.

Although SMEs recognise the benefits of OI, it is still not easy for them to adopt because they must face the unknown risks that are involved in OI implementation. The upper echelon theory (UET) literature (e.g., Hambrick and Mason, 1984) has shown that a CEO's perception is a vital factor in the innovation strategy of a company. This can be more so in SMEs because in small organisations where decision power is centralised not only does a CEO have considerable influence (Miller and Toulouse, 1986), but "s/he is also right at the epicentre of innovation (Marcati et al., 2008)." In fact, various organisational characteristics of SMEs, such as a high employee turnover rate (Humphreys et al., 2005), long CEO tenure (Teece, 1996) and less shareholder interference (Hambrick, 2007), will increase the impact of CEOs. Moreover, as the distinction between a CEO and an owner is often blurred in SMEs, CEOs are more often involved in everyday business and face-to-face contact with employees than in large firms (Miller and Toulouse, 1986). However, in the OI literature thus far much more attention has been paid to firm organisational characteristics than to human factors (Schroll and Mild, 2012; Ollila and Yström, 2017; Sims and Seidel, 2016). Recently, some scholars have begun to investigate the role of individuals' competences in OI implementation (Chatenier et al., 2010; Salter et al., 2014); however, the role of the most important decision maker, i.e., the CEO, has been under-researched. Despite their immense impact on strategic decision (Thong and Yap, 1995), little is known about how CEO characteristics affect the adoption of OI and how innovative SMEs exploit their CEO characteristics to cope with limited resources and strengthen their knowledge network. Based on UET (Hambrick and Mason, 1984), this paper presumes that CEO

characteristics affect CEO competence and behavioural propensity, which influence innovation strategy and firm performance and investigates this assumption from the perspective of strategic leadership. Accordingly, the paper attempts to answer the questions of how internal R&D and OI are related and how CEO characteristics affect OI.

The remainder of this paper comprises four sections. In the next section, the literature on OI in SMEs and the impact of CEOs is briefly reviewed, and research hypotheses are suggested. The research method and data collection are described in Section 3, and Section 4 presents the results of the analysis and hypotheses tests. Implications and limitations are discussed in the final section of the paper.

## 2 Background and hypotheses

### *2.1 OI in SMEs*

Because a key idea of OI is that knowledge can be transferred across a firm's boundary, both internal and external knowledge can find their way to commercialisation in existing or new markets in the OI paradigm (Chesbrough, 2003). By opening up their boundaries, firms can enjoy various benefits that might not be available in closed innovation. They can exploit the complementary assets of their partners, maximise income by selling unused intellectual property (IP), stimulate growth, save time and costs for innovation, attract potential customers by involving them in production processes, and establish new technology standards by forming concrete partnerships (Chesbrough, 2003; Dahlander and Gann, 2010; West and Gallagher, 2006; Gassmann et al., 2010). However, there are also negative aspects of OI. Firms may have to pay higher transaction costs and face greater risks when they adopt external knowledge and integrate it with internal knowledge (West and Gallagher, 2006). Because not all knowledge is explicit, a firm may have to spend much time in absorbing and understanding tacit knowledge (Narula, 2004). A few notable studies have helped us to understand the general characteristics of OI in SMEs (Wynarczyk et al., 2013; Wynarczyk, 2013). In the research of van de Vrande et al. (2009), who focused solely on SMEs, almost 90% of the samples adopted at least one OI mode. While there have been a few examples of outbound OI modes (e.g., IP licensing-out), the inbound mode has been actively adopted by SMEs (van de Vrande et al., 2009). In particular, customer (or end-user) involvement has been the most frequently observed mode in the empirical studies (Laursen and Salter, 2006; Lee et al., 2010). Firm size was positively associated with OI adoption; however, but no difference in OI adoption has been observed between manufacturing and service firms (Lichtenthaler, 2008; van de Vrande et al., 2009). In terms of OI partners, universities or research institutes have been preferred (Chun and Mun, 2012), while collaborations with large firms have been less popular (Lee et al., 2010). However, the impact of partnership varies according to the collaboration and national contexts (Zeng et al., 2010; Parida et al., 2012; Vrgovic et al., 2012).

There have been various motives towards OI in SMEs and barriers against it (Bigliardi and Galati, 2016; Pullen et al., 2012; Brunswicker and Vanhaverbeke, 2015). In terms of motives, marketing related issues have been identified as the main drivers of OI (Narula, 2004). SMEs have adopted OI to be able to actively react to market changes, to meet customer demand and/or develop new sales channels (Lee et al., 2010; van de Vrande et al., 2009). Poor R&D capacity in SMEs has also made them rely more on

external knowledge (Kim and Park, 2010). To overcome insufficient internal R&D, they have attempted to exploit a wide range of external information sources (Lee et al., 2010; Yoon et al., 2016). Additionally, the enhancement of performance is an important driver of opening a firm boundary (Ebersberger and Herstad, 2013; Ebersberger et al., 2012; Parida et al., 2012; Pullen et al., 2012; Mazzola et al., 2012). With regard to barriers, limited financial resources, difficulties in recruiting highly skilled workers, organisational culture and problems in finding and interacting with external partners are frequently described as hindrances (Lee et al., 2010; van de Vrande et al., 2009). The high cost of patent management may result in infrequent adoption of an outbound OI mode, such as IP-licensing (Spithoven et al., 2012), and limited technology assets to barter may make it difficult for SMEs to establish symmetric relationships with large counterparts (Minshall et al., 2010; Narula, 2004).

OI in SMEs is different from OI in large firms. Although large firms are more widely involved in various OI activities, SMEs are more intensely involved in a few OI activities (Spithoven et al., 2012). Because of their intense engagement, OI can contribute more to a new product or service in SMEs than large firms (Spithoven et al., 2012). In addition, IP protection, despite its infrequency, can play a more important role in SMEs than in large firms (Spithoven et al., 2012).

### *2.2 CEO influence*

CEOs have a strong effect on innovation strategy (Lefebvre and Lefebvre, 1992; Sattayaraksa and Boon-itt, 2016; Kashmiri and Mahajan, 2017). However, as CEOs are typically unable to fully consider all of the aspects of the context within which their firms are placed (Hambrick and Mason, 1984), their limited awareness makes them perceive the business environment based on their own characteristics or past experience, and they then interpret it in their own ways (Ahn et al., 2017b). Consequently, a CEO's personal and cognitive characteristics based on so called 'bounded rationality' (Simon, 1972) can affect a company's strategic choices, such as OI adoption (Hambrick and Mason, 1984).

Because Hambrick and Mason (1984) provided a theoretical background to this view by formulating UET, many attempts have been made to discover the influence of CEO characteristics on firms (Hambrick, 2007). CEO age (Hambrick and Mason, 1984), education (Kitchell, 1997; Papadakis and Bourantas, 1998), career path (Bantel and Jackson, 1989; Lefebvre and Lefebvre, 1992), and tenure (Hambrick and Fukutomi, 1991; Yadav et al., 2007) are frequently examined CEO characteristics. Researchers have also attempted to investigate CEO's personal traits, such as the locus of control (Miller et al., 1982), future aims (Lefebvre and Lefebvre, 1992), aggressiveness (Lefebvre et al., 1997), aspiration for high reputation (Papadakis and Bourantas, 1998), and personal focus and/or interests (Yadav et al., 2007). Recently, Hambrick and Quigley (2014) attempted to measure the overall impact of CEOs on financial profit by analysing 20 year-long longitudinal data.

Findings from these studies suggest the importance of CEOs in the strategy building process. However, while the majority of the UET literature has focused on traditional innovation, such as internal R&D, less focus has been directed towards the effect of CEOs on openness (Ahn et al., 2017b, 2018). Nevertheless, some OI case studies (e.g., Huston and Sakkab, 2006; Mortara and Minshall, forthcoming) have revealed that a CEO can play a pivotal role in encouraging an organisation to adopt OI and overcome the challenges that are involved.

Given the resource limitation, SMEs must rely on key individuals to bridge the knowledge gap between different routines (Macpherson and Holt, 2007). In this process, CEOs' skills that arise from their education and experience will play an important role in providing necessary knowledge stock (Colombo and Grilli, 2005). Additionally, well-managed coordination and strong internal support is vital in addressing the challenges that are involved in interacting with external partners with different cultures and innovation speeds (Kitchell, 1997; Mortara and Minshall, 2011; Mortara and Minshall, 2014). To cope with an organisation's negative prejudice against the exploitation of external knowledge, a high level of risk-taking propensity and a pragmatic attitude is also essential (Chesbrough, 2003; Ahn et al., 2017b). In this context, Chiaroni et al. (2011) emphasised the importance of top management in promoting and championing organisational changes in OI adoption.

## *2.3 Research hypotheses*[1]

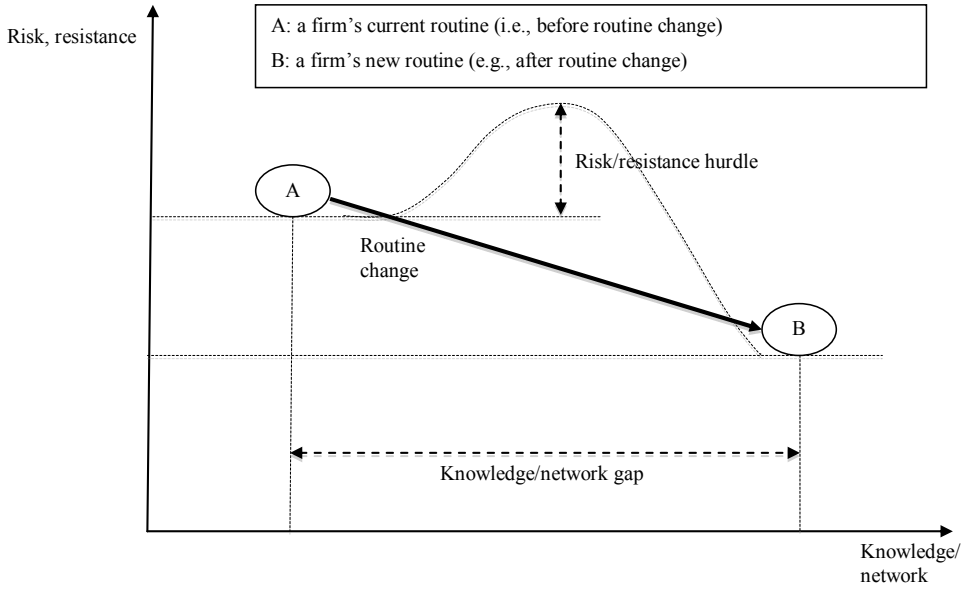
Despite the variety of the CEO characteristics that have been examined in the UET literature, there is no clear guideline as to which CEO characteristics should be included in OI studies (Ahn et al., 2017b). In the literature, some of the demographic and examined psychological characteristics have been selected according to the nature of the research questions and dependent variables (Ahn et al., 2017b). The focus of this study is on investigating the hierarchical relationship between innovation and human characteristics, thus, in this paper, CEO characteristics are selected based on the theoretical foundation that views OI adoption as an organisational routine change. OI is "the purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively[2] [Chesbrough et al., (2006), p.1]." This means that with OI, both internal as well as external knowledge can find its way to commercialisation for existing or new markets by crossing a firm's boundary, which suggests that OI creates a variety of new innovation routes for firms through its various modes. In this respect, OI adoption can be understood as the origin of new organisational routine establishment (Ahn et al., 2018). We find an analogy between OI adoption and an organisational routine change, in the sense that both require new knowledge and/or network building and increase risks and internal resistance during the transition process (Ahn et al., 2018).

As is shown in Figure 1, for a routine change from status 'A' to 'B' (i.e., OI adoption), firms must address the knowledge gap and overcome the 'risk and resistance hurdle' (Ahn et al., 2018). Figure 1 illustrates that the risk level of 'B' is lower than that of 'A'. In practice, the risk and/or resistance level of 'B' can even be the same as that of 'A'; however, it is very much less likely to be higher. This is because, in the end, a newly adopted OI can lower risks and/or resistances by decreasing their levels or bringing in new benefits to offset its possible negative effects (Ahn et al., 2018). In this respect, this risk and/or resistance reduction will play an important driver role in promoting OI adoption (Ahn et al., 2018).

First, OI adoption necessitates knowledge building (Ahn et al., 2018). As knowledge gaps hinder firms from being open (Drechsler and Natter, 2012), they must first develop the relevant capabilities through knowledge building (Lichtenthaler and Lichtenthaler, 2009). However, the type of necessary knowledge in addressing gaps can be different depending on the characteristics of the OI involved (Lichtenthaler and Lichtenthaler,

2009). For example, technological knowledge is necessary to identify and absorb the appropriate external technology (Spithoven et al., 2011), while IP management skills will be more vital when revealing unused IPs through licensing-out (Bianchi et al., 2011).

**Figure 1** OI adoption as a routine change




*Source:* Ahn et al. (2018)

Second, the OI adoption process involves risks (Chesbrough et al., 2006; Mortara et al., 2011). As is shown in Figure 1, risks can be reduced after a routine change. Once firms have adopted OI, this new routine will lower risks by distributing them among external partners or diversifying the firms' innovation strategies (Ahn et al., 2018). This risk reduction is an important driver and incentive of OI adoption. However, at the same time, OI increases the risk level in its adoption process by generating 'the risk hurdle', which is similar to 'activation energy' in a chemical reaction (Ahn et al., 2018). We argue that OI adoption can occur when firms adequately address the increase in risk that will be involved in the OI (Ahn et al., 2018). OI adoption, with its challenges, such as more managerial choices (Nelson and Winter, 1982) and difficulties in finding trustworthy partners (Narula, 2004; Salampasis et al., 2015), will increase uncertainty levels. In in-bound OI firms may pay higher transaction costs because of their limited and/or incomplete information about external knowledge and partners (Narula, 2004). They may also be required to spend a long time and many resources in obtaining external knowledge, and this effort can be greater if much of the knowledge is tacit (Narula, 2004). In out-bound OI, information leakage is a serious risk that leads firms to hesitate to open firm boundaries (Laursen and Salter, 2014). Certainly, sharing information with other innovation actors (e.g., in new product development with suppliers) must be undertaken to access external information. Firms must share at least some aspects of key information to achieve partners' trust and commitment (Salampasis et al., 2014); however, this information sharing can also threaten firms' technology confidentiality (Laursen and Salter, 2014). Therefore, it can be said that OI increases the level of risk

during the adoption process even though, after adoption, it can eventually decrease risks and uncertainties (Ahn et al., 2018).

Third, OI can increase the level of internal resistance while it is being adopted (Ahn et al., 2018). When a firm introduces external information or new partners, it can often face a negative reaction from psychologically biased staff (Burcharth et al., 2014). This means that overcoming the cognitive and cultural differences between different organisations is critical in OI (Nooteboom et al., 2007). For instance, when acquiring external technology, the NIH syndrome, which is rooted in the prejudice against innovation that comes from outside, can hinder the integration of external knowledge (Chesbrough et al., 2006). Similarly, emotional bias, and the so called 'not-shared-here (NSH)' syndrome, can inhibit the external disclosure of information, even when it cannot be used internally (Burcharth et al., 2014).

Lastly, a new routine can expand a firm's network (Ahn et al., 2018). A new routine establishment requires a firm to deviate from the current innovation pattern; thus, in this process, firms must reconfigure their resources and establish new relationships with new stakeholders (Ahn et al., 2018). Once a routine is changed, a firm arrives at a new equilibrium.

Based on this reasoning, as is shown in Figure 1, through a routine transition, the knowledge and/or network gap must be addressed, and risk and resistance hurdles must be overcome (Ahn et al., 2018). Thus, capability-related CEO characteristics, such as 'education' and 'industrial/academic network', are very likely to enable firms to address the necessary knowledge and/or network gap (Ahn et al., 2018). Additionally, attitude-related characteristics are likely to help firms to reduce resistance and take the necessary risks by persuading internal members and mitigating conflicts (Ahn et al., 2018) (see Figure 1).

### *2.3.1 CEO education*

The literature has suggested that educational characteristics contribute positively to a firm's innovation activities (Hambrick, 2007). In light of the high centralisation of authority in SMEs (Miller and Friesen, 1982), CEOs with a deeper knowledge of technology are more likely to engage in R&D activities and make quick decisions on technology issues, such as those that are related to an increase in R&D investment (Kitchell, 1997). Thus, this high involvement of CEOs can lead SMEs to focus on internal R&D, which increases their absorptive capacity, which is a key factor of integrating external knowledge (Ahn et al., 2017b, 2018). Hence:

H1 A CEOs' education will positively influence openness through the medium of internal R&D.

### *2.3.2 CEOs' industrial network*

Hambrick and Mason (1984) suggested that a CEO's former career experience influences a firm's performance and organisational behaviour because a CEO typically favours specific business strategies that are based on former personal experience. This suggests that a CEO's managerial experience plays an important role in increasing a firm's competitiveness and promoting collaborations with other firms. While working in another firm, in particular a large established firm, not only can a CEO accumulate the necessary

managerial knowledge, but she or he can also build close relationships with that large firm. As SMEs are likely to be the weaker partner in an asymmetric relationship with a large counter partner (Minshall et al., 2010), CEOs' personal networks may help SMEs to easily collaborate with large partners. Hence:

H2 A CEO's industrial network will positively influence a firm's degree of openness.

### *2.3.3 CEOs' academic network*

It has been observed in the literature that SMEs prefer collaborations with academic institutions rather than with large firms (Chun and Mun, 2012; Lee et al., 2010; van de Vrande et al., 2009). This may be because SMEs search for partners who can provide necessary complementary assets but who do not simultaneously threaten their business. Given this fact, higher education institutions (HEIs) (i.e., universities and colleges) appear to be SMEs' preferred collaboration partners, and we argue that CEOs' intimacy with academia makes it easy for SMEs to identify trustworthy HEI partners and form strong long-term bonds with them. Hence:

H3 A CEO's academic network will positively influence a firm's degree of openness.

### *2.3.4 CEOs' attitude towards OI*

Even in large firms strong CEO support is an important factor in OI implementation (Mortara and Minshall, 2011). For example, because the CEO of LG household and healthcare had worked in P&G, which is a company that actively adopts OI, the CEO understood exactly the benefits and challenges of OI and could push it forward while overcoming internal resistance, such as the 'not invented here' syndrome (Kim et al., 2008). We find the same phenomenon in information technology (IT) adoption. Thong and Yap (1995) examined the influence of CEOs' attitude towards IT, and they found that CEOs' positive attitude contributed to overcoming the internal resistance of IT adoption. This finding can be extended to OI. Because a CEO is a key decision maker, his or her positive attitude towards OI can promote its adoption, as was the case with IT (Ahn et al., 2017b, 2018).

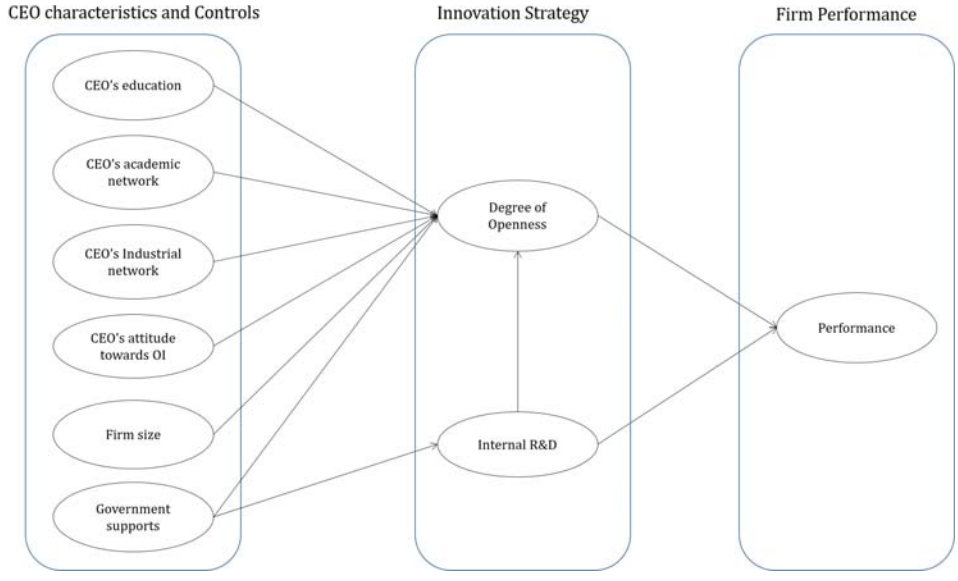
H4 A CEO's attitude towards OI will positively influence a firm's degree of openness.

### *2.3.5 Internal R&D and OI*

In addition to the influence of CEO characteristics on openness, this paper attempts to investigate the hierarchical relationship between innovation strategy and human elements. Thus, as is illustrated in Figure 2, the middle layer 'innovation strategy' was inserted into the model between human elements and firm performance. In the OI literature internal R&D has mainly been examined as a control variable; however, it can play a more important role (Spithoven et al., 2012). Not only can internal R&D affect OI adoption, but it can also compete with OI in relation to firm performance. As strong internal R&D enables a firm to more efficiently absorb external knowledge (Cohen and Levinthal, 1990), intensive R&D is likely to significantly enhance an SME's OI, which may result in better firm performance (Spithoven et al., 2011). Thus, we presume that the degree of openness plays a mediator role on the relationship between internal R&D and a firm's performance. Hence:

H5 Internal R&D will positively influence firm performance through the medium of openness.

**Figure 2** The research model (see online version for colours)




## 3 Method and data

### *3.1 Data collection*

The data were collected through a survey. Multiple databases from the Korean Small and Medium Business Administration (SMBA) and the Korean Ministry of Science, ICT and Future Planning (MSIP) were utilised to increase data reliability. SMBA assesses innovative SMEs, so-called 'INNO-BIZ' firms; MSIP investigates national R&D activity annually, and it has a data pool of innovation-oriented firms with their own corporate R&D centres. In total 5,000 SMEs were contacted for the survey. Structured questionnaires were delivered to CEOs of the firms by e-mail. A total of 88 firms were not reached due to errors in contact details, which yielded a 13.3% response rate. From among those, any missing or partial data was managed by list-wise deletion to conduct bootstrapping. As such, 401 responses were used in the analysis.

### *3.2 Analysis method*

To identify the interrelations between the variables, structural equation modelling (SEM) was employed. SEM is a flexible method that combines 'measurement theory' from psychology and 'multiple regressions' from econometrics (Byrne, 2009), and these multifaceted characteristics provide various methodological benefits to this study. Unobservable variables, such as CEO characteristics, were measured using multiple observable indicators. The relevance of these measurements was tested by confirmatory

factor analysis (CFA). This approach helped us to identify CEO characteristics and to quantify them for further analysis. Furthermore, as multiple dependent variables can be used in SEM, complex hierarchical relationships, such as the mediation effect of OI, can be investigated in the SEM structural model (Byrne, 2009). IBM SPSS AMOS version 20.0 was used as the statistical software package, and the maximum likelihood (ML) method was used for the coefficient estimation. Given that ML assumes normal data distribution, multivariate kurtosis is always of serious concern (Byrne, 2009). Bootstrapping was used to remedy potential non-normality problems.

### *3.3 Measurement*

Small firms are "notorious for their inability and unwillingness to provide desired information (Fiorito and LaForge, 1986)." Not only are SMEs often reluctant to reveal their current status, but neither can we evaluate the accuracy of the reported figures because of difficulty in the SME data interpretation (Covin and Slevin, 1989; Ahn et al., 2015). Low net-income or operating-losses do not necessarily indicate poor management in growth-oriented SMEs (Cooper, 1979). Their financial figures may also be influenced by industrial characteristics (Miller and Toulouse, 1986). Thus, this study attempts to measure firm and CEO characteristics using seven-point Likert scale subjective variables that ask for respondents' opinions rather than for specific numbers (Ahn et al., 2015).

#### *3.3.1 Firm performance*

Firm performance was measured by three manifest variables. The respondents were asked how well the firm had performed over the previous three years in terms of sales, new product development (or related services), and market share compared with average-level competitors in their industry. As the first concern for a CEO is how his or her firm is performing compared with competitors, this subject indicator may be better at excluding potential industrial parameters (Miller and Toulouse, 1986).

#### *3.3.2 Openness*

Openness was measured by two objective indicators [similar to Laursen and Salter's (2006) breadth and depth of openness] and one subjective indicator. The number of OI partners (breadth) refers to the total number of collaboration partners during the last three years, and his or her answers were added and then linear transformed into seven-levels. For OI frequency (depth), the respondents were asked how many times their company had used each the OI mode in the last three years, and this was also rescaled into seven-levels. In addition, a subjective variable, the relative openness of the firm, was employed to exclude potential industry influence.

#### *3.3.3 Internal R&D*

Internal R&D was measured with two manifest variables: R&D intensity and the number of R&D staff. R&D intensity refers to the ratio of R&D investment to sales, and it has been used in many previous studies (e.g., Laursen and Salter, 2006). Internal R&D can also be quantified by measuring the human capital in R&D. In this study, the share of employees who were involved in R&D (i.e., R&D staff ratio) (Muscio, 2007) was used in

the sense that human resources is a crucial factor for R&D in SMEs (Kang and Park, 2012). Relative measures were employed by asking how a firm had performed during the last three years in terms of R&D staff and investment compared with competitors in the same industry.

### *3.3.4 CEO education*

CEO education was measured according to two manifest variables, 'educational match' and 'knowledge depth'. Educational match attempts to measure how relevant one's educational background is to a firm's major business and technology areas. Knowledge depth attempts to assess the extent to which one has expert-level knowledge of such areas.

### *3.3.5 CEOs' network*

'CEOs' industrial network' was established to assess a CEO's personal networking capacity for cooperation with large firms. It was indirectly measured using three manifest variables: the years that she or he had spent in a large firm, his or her prior status within that large firm, and the extent to which she or he maintains an amicable relationship with his or her previous company/companies. 'CEOs' academic network' is chosen to assess a CEO's personal network capacity for collaboration with HEIs. It was indirectly assessed according to three manifest variables: 'study depth', 'hire depth', and 'closeness'. The first attempts to measure the level of the CEO's academic study at the collaboration university (e.g., is he BA, MSc, or PhD). This variable can be useful in the sense that one's academic alumni network is one of the most important factors in networking in Korea (Kim, 2003). 'Hire depth' and 'closeness' attempt to measure the extent to which the CEO hires employees from the collaboration university and the extent to which the CEO maintains an amicable relationship with that university.

### *3.3.6 CEO attitude*

Based on Moore and Benbasat's (1991) scale, two factors, 'voluntariness' and 'relative advantage', were employed to measure a CEO's attitude towards OI (Ahn et al., 2017b). Voluntariness is defined as "the degree to which the use of innovation is perceived as being voluntary or of free will (Moore and Benbasat, 1991)." In this study, voluntariness attempts to identify whether a CEO is an initiator of OI by asking whether OI is adopted and implemented with a top-down approach using two sub-items. Relative advantage is defined as "the degree to which an innovation is perceived as being better than its precursor (Rogers, 1983)", and it asks whether a CEO is aware of OI's advantages using three sub-items.

### *3.3.7 Controls*

Firm size was assessed with the natural logarithm of the total employee number. Government support was measured by one manifest variable that asks the frequency of the firm that receives government support. As these two control variables were measured by only one variable, measurement errors for both firm size and government support[3] were fixed to zero to prevent a negative error variance (Bollen and Long, 1993).

## 4 Results

### 4.1 Descriptive statistics

In our sample, the average number of employees per company was 32.2, and the average firm age was 13.62 years. The sample firms were highly innovation-oriented firms (average R&D intensity 9.33), considering that the total average R&D intensity across the industry was 2.43 in Korea in 2007 (KOITA, 2009). The key descriptive statistics are shown in Tables 1 and 2.

**Table 1** Firm size distribution

| *Employee number* | *Frequency* | *Percentage (%)* |
|---|---|---|
| 1–10 | 70 | 17.5 |
| 11–30 | 150 | 37.7 |
| 31–50 | 44 | 11.0 |
| 51–100 | 41 | 10.2 |
| 101–150 | 24 | 6.0 |
| 151–250 | 35 | 8.7 |
| 251–300 | 36 | 9.0 |

**Table 2** Key descriptive statistics (mean values)

| *Firm age (year)* | *R&D staff ratio (%)* | *R&D intensity (%)* |
|---|---|---|
| 13.62 | 17.33 | 9.33 |

### 4.2 Model assessment

In the structural model, causal relationships are established between latent variables. The structural model shows very satisfactory model fitness. In terms of $\chi^2$, large $\chi^2$ relative to its degree of freedom is of prime concern (Jöreskog and Sörbom, 1993); however, the model shows a good $\chi^2$/degree of freedom ratio (= 2.039), which is reasonable if it is smaller than 3 (Wheaton et al., 1977). Other fit indices also show good figure, which suggests good model specification. The goodness of fit index (GFI) and the adjusted GFI (AGFI) were 0.925 and 0.893, respectively, which are good if they are over 0.9 (Jöreskog and Sörbom, 1993); the Turker-Lewis index (TLI) and the comparative fit index (CFI), both of which reflect model parsimony, were 0.938 and 0.953, respectively; and the standardised root mean square residual (SRMR) was 0.065, which is good if the value is smaller than 0.08 (Hu and Bentler, 1999). In addition, not only did the root mean square error of approximation (RMSEA), which is one of the most informative criteria in covariance structure modelling (Byrne, 2009), meet the recommended level (i.e., reasonable if smaller than 0.8), but its 90% interval at low and high confidence levels (i.e., 0.048 ~ 0.062) also satisfied the cut-off value that was suggested by Browne and Cudeck (1992). The key model fit indices are summarised in Table 3. Most of the paths were statistically significant. In addition to the direct effects, indirect effects were found, as is shown in Table 3. As AMOS does not report the significance levels of indirect effects, bootstrapping was employed to produce two-tailed bootstrapping confidence

(BC) intervals. According to BC, the eight indirect effects were significant at the 0.05 level.

**Table 3** Regression path of the structural model

| *Regression path* | | *Standardised estimate* | *Critical ratio* | *Hypothesis* |
|---|---|---|---|---|
| Direct effects | OPEN → FP | 0.605 | 7.869*** | |
| | RND → FP | –0.062 | –1.062 | |
| | RND → OPEN | 0.166 | 2.828** | |
| | ACAD → OPEN | 0.343 | 4.224*** | H3 |
| | INDUS → OPEN | 0.038 | 0.699 | H2 |
| | EDU → RND | 0.141 | 2.254** | |
| | ATTI → OPEN | 0.216 | 3.776*** | H4 |
| | SIZE → OPEN | 0.196 | 3.683*** | |
| | GOV → OPEN | 0.261 | 4.194*** | |
| | GOV → RND | 0.211 | 3.375*** | |
| Indirect effects | SIZE → OPEN → FP | 0.119† | | |
| | GOV → RND → OPEN | 0.035† | | |
| | GOV → OPEN → FP | 0.158† | | |
| | GOV → RND → OPEN → FP | 0.179† | | |
| | ATTI → OPEN → FP | 0.131† | | |
| | EDU → RND → OPEN | 0.023† | | H1 |
| | ACAD → OPEN → FP | 0.208† | | |
| | RND → OPEN → FP | 0.101† | | H5 |

Notes: $\chi^2(194) = 395.56$, $\frac{\chi^2}{df} = 2.039$, GFI = 0.925, AGFI = 0.893, TLI = 0.938, CFI = 0.953, RMSEA = 0.051, SRMR = 0.065
Significance level: **p < 0.05, ***p < 0.001, †bootstrap confidence p < 0.05
FP = firm performance, RND = internal R&D, OPEN = the degree of openness, EDU = education
ACAD = academic network, INDUS = industrial network, GOV = government support, SIZE = firm size

## 5 Discussion

### *5.1 Findings*

Our findings empirically show that in the context of our research sample, OI is relevant to SMEs. Opening firm boundaries can result in a number of benefits that were perhaps not provided by closed innovation. As is shown in Table 3, the results indicated that opening up firm boundaries plays an important role in enhancing firm performance. In the research model (see Figure 2) we can see that internal R&D competes with openness in the prediction of firm performance. However, contrary to expectation, internal R&D was not significantly associated with firm performance, while openness positively influenced

it. This finding suggests two possible implications: the relevance of OI and the potential 'myth' of R&D expenditure as an indicator of success. Although R&D is regarded as a vital activity in innovation, high investment does not necessarily guarantee better firm performance. Due to the limited resources in SMEs, spending too much on R&D may result in the failure to allocate resources elsewhere and/or poor performance. The fact that the estimate of internal R&D in the prediction of performance was negative and insignificant (i.e., $\beta = -0.062$, $p = 0.307$) supports this interpretation. Laursen and Salter (2006) showed that 'over search' can be detrimental to firms, and their finding can be expanded to R&D. It is difficult to deny the importance of R&D in technological innovation; however, 'over R&D' can harm innovation-oriented SMEs with limited resources. Rather, opening up firm boundaries can be an effective complementary strategy. As the indirect effect of R&D (i.e., 'RND → OPEN → BP') suggests, R&D still positively affects performance through openness. This indirectly supports the importance of R&D and suggests that finding an appropriate balance between R&D and openness may be very important for the performance enhancement of innovative SMEs.

With regard to CEO characteristics, the empirical results showed that three of the four tested characteristics (i.e., education, attitude, and academic network) positively influence openness or internal R&D. First, in terms of CEO education, it was shown that the more knowledge that is related to a firm's business and technology domain a CEO has, the higher its internal R&D will be. This suggests the possibility that a CEO with in-depth knowledge of a firm's core product will emphasise and engage more actively in R&D activities (Ahn et al., 2017b). As the coefficient suggests, CEOs' educational characteristics positively affect R&D and influence the degree of openness indirectly through internal R&D (i.e., EDU → RND → OPEN). Thus, we can conclude that CEO education directly affects internal R&D and indirectly contributes to firm openness.

Second, in terms of CEOs' networks, two, industrial and academic, were examined; however, only the relationship between academic networks and openness was significant. This result may reflect the fact that SMEs prefer horizontal collaborations with higher educational institutions (HEI) to vertical collaborations with large firms (Chun and Mun, 2012). For example, a CEO can establish a strong human resource network with collaboration partner universities by hiring employees from the universities or studying there. Thus, by involving himself in both organisations directly or indirectly, a CEO may be able to find a trustworthy partner and build a stable, long-term partnership. SMEs usually depend more upon entrepreneurial leaders and social and/or informal networks (MacPherson and Holt, 2007), thus, when selecting university partners, education-related networks, such as alumni networks, play an important role in establishing partnerships (Saxenian et al., 2002). In fact, personal relationships are affected by trust, shared values and mutual objectives (Ceci and Iubatti, 2012), and their strengths depend on the duration of the collaboration, the emotional intensity and reciprocal devotion (Granovetter, 1973). Strong personal relationships enable innovation partners to trust each other and foster knowledge exchange by facilitating tacit knowledge acquisition and informal skills (Asheim, 2000; Mellewigt et al., 2007). In this regard, CEOs' personal relationships, which are established through their study, can be effective channels in the consolidation of university-industry links (Cohen et al., 2002; Faulkner and Senker, 1994). As an alumni relationship can be maintained even after the collaboration is officially completed, this type of relationship can strengthen ties (Perkmann and Walsh, 2007).

With regard to industrial networks, contrary to expectation, empirical results suggest that CEOs' prior industrial networks do not contribute to opening firm boundaries. This

may also reflect the fact that large firms are less preferred by SMEs as collaboration partners. Another explanation can be found in socio-cultural contexts. As noted by Edwards et al. (2005), a higher level of understanding of SMEs can be achieved by accommodating the complex connection between an SME and its socio-cultural context. As the samples are all Korean firms, its unique industrial structure – a few large conglomerates and their affiliates dominate almost the whole domestic market by overwhelming SMEs with their broad business portfolio and huge financial resources – might result in poor collaboration between SMEs and large firms (Ahn et al., 2017a). It can also be argued that CEOs' networks with large firms may enable them to develop stable sales channels by acting as large firms' supply chains or by making exclusive contracts, such as original equipment manufacturer (OEM). However, in the alternative model, assuming a regression path between industrial networks and firm performance, the estimate was negative (i.e., $\beta = -0.094$, $p = 0.013$), thus refuting this argument.

Lastly, as in the case of IT adoption, CEOs' attitudes towards OI play an important role in opening firm boundaries. Because OI is a business strategy, a CEO's awareness of the advantages of OI and support of its implementation can significantly affect OI in SMEs. Large firms also occasionally implement OI with a top-down approach (Mortara and Minshall, 2011). Thus, if a CEO perceives OI positively, she or he is likely to become a very strong advocate who will promote its adoption and implementation.

### *5.2 Implications and limitations*

Given the paucity of the prior research on SME OI, we investigated the relevance of OI in innovative SMEs and the influence of CEO characteristics in the context of Korea using large-scale data. There are theoretical and practical implications from the findings.

First, this paper attempted to shed light on an under-researched theme, the role of the key individual in OI. Key individuals' roles have been neglected in the OI literature despite their potential importance (Schroll and Mild, 2012; Wynarczyk et al., 2013; Salter et al., 2014). However, the importance of a micro-foundation in OI in which key individuals' choices and behaviour shape firm-level strategy cannot be underestimated (Salter et al., 2014), particularly in SMEs in which key players, such as CEOs, have a strong influence on firm-level decisions (Hambrick, 2007; Macpherson and Holt, 2007; Eisenhardt and Schoonhoven, 1990). The study raised the issue of the importance of human factors and suggests that more attention be given in the OI literature to the field of strategic leadership.

Second, CEOs in innovation-oriented SMEs should realise the importance of OI in enhancing firm performance. Our findings indicate that openness is a sound antecedent of good firm performance in SMEs, and, in fact, it plays a greater role than R&D. As R&D is a key factor in innovation, CEOs can be misled by giving it too much attention. However, when CEOs recognise the importance of OI adequately, their positive attitude will encourage firms to adopt OI proactively, which will result in improved performance. In addition, CEOs should be aware that their efforts in building close academic networks through employment or study can contribute to successful OI.

Our findings also suggest that policy makers should recognise that CEOs, who are at the epicentre of innovation activities (Marcati et al., 2008), can play an important trigger role in promoting and propagating OI in innovation-oriented SMEs. Direct support such as R&D grants can be helpful in the promotion of OI; however, decision makers should

bear in mind that enhancing CEOs' awareness of OI or supporting their network building can be a good policy. For example, specialised education programs that enable CEOs to deepen their knowledge of OI, giving subsidies to CEOs in innovative SMEs to study at the OI partner university, or giving tax incentives for SMEs to employ highly skilled R&D staff from the OI partner university should be considered.

Despite the findings and implications, it cannot be denied that this paper suffers from some research limitation. First, because this research first attempted to link the two fields of literature, OI and strategic leadership, the tested CEO characteristics are mainly borrowed from the strategic leadership literature. If future research aims to investigate the role of CEO characteristic in depth, many variables, such as "the degree of homogeneity in human resource composition", "the ratio of recruitment from the collaboration university" and "the use of a CEO's alumni network", can be examined using a quantitative method. Further theoretical research that attempts to analyse the mechanism of OI adoption or in-depth case studies that focus solely on the impact of human factors can be helpful in developing the CEO variables that may have been overlooked in the literature. Second, panel data collection and longitudinal analysis is required to examine any possible dynamics or delay effects. The results show a negative relationship between internal R&D and firm performance. This may be originated from a delay effect of R&D (i.e., there is a time gap between R&D and performance); however, it was not possible to examine this issue using cross-sectional data. Additionally, the negative relationship may be the result of 'over R&D'; however, it was not possible to test this square term effect in the SEM analysis focusing on mediation effects. Future research based on longitudinal data and advanced econometric analysis will allow us to examine the hierarchal relationship between CEO traits, internal R&D, openness and performance.

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## Notes

1 This section is developed based on the work of Ahn et al. (2018, 2017b).

2 Chesbrough and Bogers (2014) recently defined OI as a distributed innovation process based on purposively managed knowledge flows across organisational boundaries using pecuniary and non-pecuniary mechanisms in line with the organisation's business model. However, as this paper does not focus on non-pecuniary mechanisms, the concept that was suggested in 2006 was employed.

3 It encompasses all types of government support, such as subsidies, tax incentives, loans, and/or grants.