

Understanding the human side of openness: the fit between open innovation modes and CEO characteristics

Joon Mo Ahn ¹, Tim Minshall ² and Letizia Mortara ³

¹Graduate School of Management of Technology (MOT), Sogang University, 35 Baekbeom-ro, Mapo-gu, Seoul 04107, South Korea. jmahn@sogang.ac.kr

²Centre for Technology Management, Institute for Manufacturing, University of Cambridge, 17 Charles Babbage Road, Cambridge CB3 0FS, United Kingdom. thwm100@cam.ac.uk

³Centre for Technology Management, Institute for Manufacturing, University of Cambridge, 17 Charles Babbage Road, Cambridge CB3 0FS, United Kingdom. lm367@cam.ac.uk

In small- and medium-sized enterprises (SMEs), where typically the decision-making process is highly centralised, important decisions, such as open innovation (OI) adoption, will be strongly influenced by the characteristics of their Chief Executive Officers (CEOs). Pointing the attention to the strategic leadership and human elements, this paper sheds light on the micro-foundation of OI by emphasising the role that the personal traits of key individuals in innovation. OI adoption could result in the enactment of several OI modes – each representing an opportunity of potential change (of market, of technology or/and of the organisation) – and this paper attempts to examine the relationships between the CEO characteristics and each of the OI modes. Our analysis, using Korean SME data, shows that CEOs' positive attitude, entrepreneurial orientation (EO), patience and education can play important roles in facilitating OI in SMEs. However, this paper also observed that the effects of CEO characteristics on OI adoption were differently configured according to the nature of each OI mode, for example, CEOs' patience and EO had different impacts depending on the degree of uncertainty in the OI mode. This suggest that OI must be understood as a wide innovation spectrum, and, to increase opportunities for successful OI adoption, CEOs have to attempt to compensate for characteristics they may lack by recruiting appropriate complementary top managements. The research has practical implications for CEOs and policy makers who are interested in enhancing competitiveness of SMEs.

1. Introduction

Open innovation (OI) has become a major theme within the innovation literature, and work is

being undertaken to understand its features, implications and challenges (West et al., 2014). Firms across industries have adopted OI to cope with a rapidly changing business environment (Mortara and

Minshall, 2011), and OI has been recognised as an effective approach for achieving corporate renewal and gaining a competitive edge (Vanhaverbeke and Cloudt, 2014). As OI implementation goes beyond the operationalisation of innovation processes, it cannot be separated from firm strategy. Not only does OI change the ways companies manage knowledge, but it also transforms the business model or interaction patterns with markets. However, the strategic aspect of OI, particularly in small and medium-sized enterprises (SMEs), has not yet been sufficiently understood (Vanhaverbeke and Roijakkers, 2014; Alexy et al., 2016).

The challenges are multiple: first, OI is not a single innovation activity. Rather it embraces various innovation modes (Spithoven et al., 2013). All OI modes (e.g., licensing-in or spin-off) share a single concept, that is, the fact that knowledge flows across permeable firm boundaries (Tucci et al., 2016), but each mode distinguishes itself in terms of knowledge flow direction and types of changes (e.g., technological or organisational change) involved in its adoption process (Ahn et al., 2015). This multifaceted characteristic has fragmented the understanding of OI and occasionally resulted in confusion and disputes between scholars (e.g., Trott and Hartmann, 2009; Groen and Linton, 2010). Given the variety of modes encompassed by the term OI, it is reasonable to hypothesise that each one is linked to different strategies and approaches and OI cannot be understood as the mere sum of individual modes. Instead, we have to recognise different characteristics of each OI mode. Yet, with the exception of a few papers, most studies have investigated OI modes in isolation.

Second, the research investigating the determinants of OI has focused on contingent factors (Dahlander and Gann, 2010). It has broadly examined organisational level elements (e.g., internal R&D expenditure) or environmental factors (e.g., market turbulence) (Hung and Chou, 2013), but little attention has been paid to the role of human elements (Schroll and Mild, 2012; Wynarczyk et al., 2013), which are known to have a deep effect on strategy and innovation management (Gavetti and Levinthal, 2004). However, this effect is expected to be particularly strong for SMEs, which are more likely to lack resources and a structured management system compared to larger firms and hence depend more strongly upon strategic leadership (Humphreys et al., 2005; Lubatkin et al., 2006). According to the Upper Echelon Theory (UET), which underpins the understanding of the linkage between the most powerful actor, the Chief Executive Officer (CEO), and his/her firm's strategic decisions (Hambrick and Mason, 1984), the CEOs' influence would outweigh environmental or institutional factors

in an organisation where a high level of CEO managerial discretion and job demands exist (Hambrick, 2007). In SMEs, owing to a simple organisational hierarchy, CEOs are more frequently involved in the everyday business (from the strategic to the tactical and operational details) and respond more quickly than their counterparts in large firms (Lubatkin et al., 2006). This enables the critical impact of Hambrick's two moderators – the CEO's managerial discretion and his/her job's demands – in the understanding of SMEs' strategic and operational innovation (Lubatkin et al., 2006; Papadakis, 2006).

Recognising the above limitations in the literature, this paper attempts to investigate the human side of openness, focusing on the linkage between the choice of OI modes and CEOs' characteristics in SMEs. To this end, survey data were collected from 306 Korean manufacturing and innovation-oriented SMEs. The firms represent a suitable sample due to their clear focus on innovation, in a country where SMEs represent a significant proportion of the economy.

The remainder of this paper comprises five sections. We first introduce the theoretical background and develop hypotheses focused on the relationship between CEO characteristics and OI. Then, we describe the measurement of variables and the analysis method and discuss the results. The paper concludes with research implications and limitations.

2. Theoretical background

2.1. Diversity of OI modes

OI embraces a range of innovation activities (modes), leading scholars to derive a variety of classifications. As OI emphasises knowledge flow (Chesbrough et al., 2006; Ahn et al., 2016), the dominant classification uses the direction of knowledge flow, that is, in-bound (outside-in) and out-bound (inside-out), to discriminate amongst the activities. However, the type of changes implicit in the adoption of any OI mode can also play an important role in understanding multidimensionality of OI. Based on their case analysis, Mortara et al. (2011) recognised that OI modes implied changes in technology, market and organisational structure. Ahn et al. (2015) developed this concept further, suggesting a new OI classification, based on the dominant changes involved as a result of their adoption. This classification enables us to recognise the heterogeneity of OI. As shown in Table 1, OI can be classified not only by the knowledge flow direction but also by the types of dominant changes involved. First, 'technology-oriented OI', such as licensing-in and R&D collaboration, refers to innovation activities

Table 1. Open innovation modes

OI mode by direction of knowledge flow		Definition	OI mode by dominant core changes involved
In-bound	In-sourcing	Introducing external knowledge to reduce time-to-market and find new ideas by purchasing or paying royalties.	Technology oriented
	R&D collaboration Customer involvement	Conducting R&D with external partners Accessing new ideas by involving customers in the R&D or design process	Market oriented
	M&A/Strategic alliance	Buying potential companies or building strategic alliances with them to absorb their knowledge	Organisation oriented
Out-bound	Licensing-out	Licensing or selling unused technologies to maximise profit	Market oriented
	Spin-off	Spin-off internal organisations to commercialise disruptive technologies	Organisation oriented

aiming at increasing technological assets (Ahn et al., 2015). The strategic focus of this OI mode is on the development of new technological skills, because licensing-in or R&D collaborations are closely related to the early stage of innovation (i.e., technology development) and usually do not directly demand a high level of marketing strategy or organisational structure change. Second, user involvement or licensing-out can be labelled ‘market-oriented OI’, because user involvement focuses mainly on identifying market demands by means of involving customer into the innovation process and licensing-out aims to commercialise under-utilised internal knowledge in the new market (Ahn et al., 2015). Third, ‘organisation-oriented OI’ causes drastic transitions in organisational structures, and M&A and spin-off are examples of this type of OI modes. This type of OI involves changes in terms of the development of new organisational forms and practices by expanding or contracting an organisation’s boundaries. In fact, this multidimensionality of OI is particularly evident when recognising the nature of knowledge – that is, its complexity and tacitness (Simonin, 1999). As the level of complexity and tacitness of the knowledge exchanged cannot be the same across different innovation activities, the degree of uncertainty and challenges caused by knowledge flows managing will also vary. Subsequently, the adoption of each OI mode will result in changes of varied magnitude, which will require different strategic postures and leadership.

2.2. CEO characteristics

Different perspectives to explain firms’ strategic decisions and choices for innovation have been taken by past literature. The industrial economy and environmental determinism perspectives indicate that the most appropriate firm’s strategic decisions depend on

contingent factors. Prior research using these perspectives has investigated firm characteristics and environment and cultures, so the level of analysis has remained mainly at the firm, industry or country level. However, the strategic leadership, specifically UET, emphasises the role of key individuals in strategic decision making (Hambrick, 2007) and has focused on the micro-foundation of innovation. Based on UET, this paper views the CEO characteristics as an important element affecting OI adoption, particularly in SMEs. Scarce resources and simple hierarchy in small organisations will make CEOs engage in detailed decisions in both strategic and operational function (Lubatkin et al., 2006), and long CEO tenure and weak external interference (e.g., weak boards of directors) will contribute to the increase of the CEO’s influence. Further, the OI adoption will require a high level of leadership because it demands resource reallocation and the establishment of a new culture. Due to the nature of OI importing and exporting knowledge, OI will establish a new innovation process and organisational structure and requires new mind-sets and strong aspiration (Teece, 2007; Alexy et al., 2016). Therefore, strong CEO leadership will be required to mitigate various challenges and to establish an OI-friendly culture. However, because CEOs are typically unable to fully appreciate all the contextual aspects within which their firms operate, their limited awareness makes it more likely that they will perceive a business situation based on their own characteristics and/or past experience, and then interpret it in their own way (Hambrick and Mason, 1984). Consequently, the CEO’s personal and cognitive characteristics, based on ‘bounded rationality’ (Simon, 1957), affect firms’ strategic choices (Hambrick and Mason, 1984). Recognising this aspect, the literature has investigated two types of CEO characteristics (Hambrick, 2007). Psychological characteristics can

mirror individual's true intentions and behavioural propensity (Hambrick, 2007). However, demographic characteristics have also been used for an econometric analysis because of the ease with which data can be obtained and quantified. In this paper, the following CEO characteristics are employed to investigate the role of CEOs on OI.

2.2.1. Attitude towards OI

Innovation requires a champion, in the sense that it demands strong proponents who push forward organisational level changes and disseminate the benefits inside organisations (Smith, 2007). Although firms may not resist technological development, they may resist the changes involved (Schein, 1985). In the case of OI, as openness brings in heterogeneous external knowledge or requires knowledge sharing, the increase of openness may cause internal resistance for changes, such as Not-Invented Here (NIH) (Katz and Allen, 1982) or Not-Shared-Here (NSH) syndrome (de Araújo Burcharth et al., 2014). However, as an agent of change, CEOs can contribute to promoting change, overcoming internal resistance and breaking down institutional barriers (Kitchell, 1997; Jansen et al., 2009). CEOs with a positive attitude of OI can be strong advocates who push it as a top priority and overcome internal resistance (Huston and Sakkab, 2006). According to the theory of reasoned action, "attitude towards an object is viewed as related to the person's intentions to perform a variety of behaviours with respect to that object" (Fishbein and Ajzen, 1975, p. 14). In this respect, CEOs' attitudes towards OI can be a good proxy, reflecting the extent of their intention to adopt OI. As noted by Di Minin et al. (2010), one of the most important drivers of organisational transformation in OI will be a committed, visionary and passionate champion. Hence:

H1: CEOs' positive attitudes towards OI will be positively associated with OI adoption.

2.2.2. Entrepreneurial orientation

Entrepreneurial orientation (EO) can be measured through other sub-traits, such as innovativeness, risk-taking propensity and pro-activeness. An individual's innovativeness has been regarded as an important factor distinguishing between adaptors and innovators (Kirton, 1976), and it is closely related to a key decision maker's intention to adopt innovation (Marcati et al., 2008). A willingness to take risks and high pro-activeness are also important factors in shaping firms' strategic directions (Escriba-Esteve et al., 2009). CEOs with these characteristics are not risk-averse and are apt to boldly adopt innovative strategies

despite resistance and challenges (Khandwalla, 1976/1976; Miller, 1983). Analysing these personality traits can be important in understanding OI adoption, as the high uncertainty of OI demands that individuals be entrepreneurially oriented (Di Minin et al., 2010). However, since the types and extent of uncertainty are not the same throughout all the OI modes, the role of EO will also vary. Technology-oriented OI focuses on an increase of technology knowledge stock, so the challenges involved in this OI mode may be confined to the early stage of technological innovation activities, such as R&D. However, because market or organisation-oriented OI can introduce more drastic changes, such as a new business model formation (licensing-out) or a new organisation establishment (spin-off), these OI modes will demand the CEO to be more aggressive for their adoption. Similarly, the direction of knowledge flow may demand different EO. In in-bound OI, external knowledge flows into an organisation. Thus, firms may perceive that this knowledge absorption is not highly risky, in the sense that they are not losing but gaining new information. However, in out-bound OI, the firm has to take substantial risks of knowledge exposure. As internal knowledge is desorbed and utilised in other organisations, firms cannot control the entire innovation process. Further, this knowledge desorption can decrease technology confidentiality and weaken the firms' appropriability regime (Bianchi et al., 2011). Because of this high level of risk, without strong push from highly entrepreneurial decision makers, it would be difficult to motivate firms to reveal internal knowledge that might be used by rivals. Hence:

H2: CEOs' EO will be positively associated with market or organisation-oriented OI adoption.

H3: CEOs' EO will be positively associated with out-bound OI adoption.

2.2.3. Patience

The key decision maker's patience will be critical in the process of new innovation adoption (Kitchell, 1997), particularly those managed across organisations. In in-bound OI that attempts to integrate external with internal knowledge, long-time commitment is necessary until a tangible positive result is reached. Identifying appropriate external knowledge is a difficult task in itself, but changing it to a form that can be easily assimilated with internal knowledge is a more complex process (West and Bogers, 2013; Salter et al., 2014). Finding trustworthy external partners and building trust with them can take substantial time (Narula, 2004), and the delays arising from different organisational characteristics cannot be ignored.

Thus, whether key decision makers can acknowledge such challenges and delays can be critical in in-bound OI. However, as the goal of out-bound OI is on the realisation of under-utilised knowledge outside an organisation's immediate strategic goals, the ability of enduring such delays may not play a vital role. Out-bound OI releases internal assets by acknowledging that the internal innovation process is not appropriate because of the lack of the necessary capability or misfit between internal knowledge and the firm's market. Thus, out-bound OI may demand key decision makers to swiftly change innovation strategy to identify another possibility of commercialisation route outside the firm. Hence:

H4: *CEOs' patience will be positively associated with in-bound OI adoption.*

H5: *CEOs' patience will be negatively associated with out-bound OI adoption.*

2.2.4. Education and experience

A CEO's expertise is a function of his or her educational background, such as achievements (i.e., academic degree) or academic discipline (Colombo and Grilli, 2005). A CEO's education can be viewed as a measure of the initial human capital invested in small firms (Cooper et al., 1994), which can significantly affect firms' strategic decision (Papadakis, 2006). Strong information processing capabilities enable an individual to search for and analyse complex knowledge and overcome information overload, and good education enables this capability (Carpenter and Fredrickson, 2001). A CEO's educational level influences their strategy planning skills (McMullan and Long, 1987) and even contributes to the increase of a firm's openness to change (Classen et al., 2012). In this respect, a high level of education enables the identification and relevant management of external knowledge, which are essential for absorptive capacity (Roach and Sauermann, 2010). It will enable CEOs to address the intrinsic ambiguity and uncertainty of changes in innovation through their strong information processing capability. As innovation is complex and tacit, a CEO's high information processing ability will enable a firm to detect, codify and manage the necessary knowledge, which will enhance the strong absorptive capacity and establish an open atmosphere for new knowledge. This logic may well be expanded to the length of the CEOs' working experience, in that experience can complement education. The key decision makers' professional experience will help them to acquire necessary skills that cannot be entirely covered through education (Hamori and Koyuncu, 2013). Thus, skills and know-how

reflecting their field experience may enable CEOs to address the intrinsic uncertainty in innovation and to cope with challenges involved in strategic changes. As noted by Chandler and Jansen (1992) and Siegel et al. (1993), lengthy industry experience can play an important role in enhancing strategic agility. Hence:

H6: *CEOs' higher education level will be positively associated with OI adoption.*

H7: *CEOs' longer professional experience will be positively associated with OI adoption.*

The academic discipline studied by CEOs can affect the types of innovation modes that their firms adopt. Technology expertise is a key personal characteristic that enhances knowledge exploration (da Mota Pedrosa et al., 2013), and the literature has showed that CEOs educated in engineering/technology field positively influence technology adoption in a firm (Thong and Yap, 1995; Kitchell, 1997). This may suggest that there is the fit between technological OI and CEOs' education in technology. Innovation activities closely related to technologies discriminates itself from others related to strategies (Ceci and Iubatti, 2012), which suggests that key decision makers' deep understanding of technology may help their firms evaluate any neglected technological opportunities that may arise in innovation process. Thus, it might be well assumed that CEOs educated in technology discipline are able to identify technological needs and make quick decisions on such issues. Similar logic can be applied to the type of CEOs' work experience, in that CEOs usually favour a specific business strategy based on their prior career experience (Hambrick and Mason, 1984). As CEOs are imbued with the managerial experience they gained during their earlier involvement in specific business functions, they perceive and interpret any situation based on their functional training (Barker and Mueller, 2002). Thus, their perspectives, shaped by work experience in functional areas, could affect the way in which they identify and solve problems in innovation (Bantel and Jackson, 1989; Hitt and Tyler, 1991). For example, top executives with work experience in engineering/technology recognise technological alliance opportunities better than those with other types of experience (Tyler and Steensma, 1998), and the CEO's experience in R&D/engineering can positively influence R&D expenditure (Barker and Mueller, 2002). Hence:

H8: *CEOs' education in a technology discipline will be positively associated with technology-oriented OI adoption.*

H9: *CEOs' work experience in a technology function will be positively associated with technology-oriented OI adoption.*

3. Research method

3.1. Data and samples

Data were collected through a survey using the database of the Korean Small and Medium Business Administration (SMBA), a government agency giving a certificate to innovation-oriented SMEs. These firms are assessed with the SMBA according to four major criteria, innovation capacity, commercialisation ability, innovation management and innovation performance (OECD, 1997), and by the second quarter of 2013, a total of 17,295 SMEs had obtained this certification. For the survey, 3,000 manufacturing SMEs were randomly selected from the database, and a structured questionnaire was delivered to the CEOs using an online survey system. A total of 329 responses were collected (11% response rate), and after data cleaning, 306 responses were used for the analysis. To examine any non-response bias, the extrapolation method was used to compare early and late responding mean values of variables, in the sense that late respondents are likely to have similar characteristics as non-respondents (Armstrong and Overton, 1977). In terms of the number of employees, sales and firm age, no significant difference between the two groups was found, suggesting that non-response bias was not a problem. The sample's average number of employees was 28.80, and the average firm age was 11.42 years. The sample firms were highly involved in innovation (i.e., average R&D intensity 11.60), given that the total average R&D intensity across all Korean firms in 2007 was 2.43 (KOITA, 2009).

3.2. Variables measurement

3.2.1. CEO characteristics

CEO characteristics are measured using variables from the literature. Psychological characteristics variables are latent variables that are comprised of multiple indicators, and the details of these indicators are summarised in the Appendix. All factors were measured using a 7-point Likert scale. First, three attitude factors (voluntariness, relative advantage, ease of use), originally suggested by Moore and Benbasat (1991), were used. Voluntariness was employed to identify whether a CEO is an initiator of OI. This was done by asking whether OI is adopted and whether the implemented OI modes followed a top-down impetus as a result of the top-management initiative. For relative advantage, we asked whether a CEO was aware of OI's advantages. For ease of use, we asked how difficult a CEO felt it would be to adopt OI. Second, three indicators, innovativeness, pro-activeness and the degree of risk-taking, were adopted to measure

EO. Based on Miller (1983) and Covin and Slevin (1989), this study adopted seven sub-indicators – two on the degree of innovativeness, two on the degree of pro-activeness and three on risk-taking propensity. Finally, to investigate CEO perseverance, the scale suggested by Kitchell (1997) was used. Four questions were employed to ask how reluctant in general a CEO is to give up or how much they make a persistent effort to achieve goals.

Two education variables, 'degree' and 'discipline', were employed. The 'degree' attempted to measure the level of education attainment using a seven level ordinal scale, where 1 corresponds to secondary school graduate, and 7 corresponds to PhD degree (Lefebvre and Lefebvre, 1992). The 'discipline' was measured using categorical variables according to whether the education discipline was technology (e.g., engineering or science) or management related (e.g., management, finance or economics) or others. CEO work experience was measured using two variables: 'years' and 'functional track'. The former was measured using a seven-level ordinal scale, where 1 corresponded to no prior work experience, and 7 corresponded to more than 20 years. The functional track was measured using categorical variables, that is, whether the respondent had prior work experience in R&D, sales/marketing, production, planning/strategy or other areas.

3.2.2. Dependent and control variables

The dependent variable, OI adoption, was measured using binary variables (where 0 corresponds to 'not adopted' and 1 to 'adopted'). In the questionnaire, CEOs were asked whether in the last three years their firms ever adopted an OI mode, as shown in Table 1. Firm-level (R&D intensity and firm size) and environmental variables (market environment and government support) were used as controls due to their significant impacts on OI. Intensive R&D is an essential prerequisite of strong absorptive capacity, which promotes knowledge integration or knowledge spillover (Spithoven et al., 2011). In this study, 'R&D intensity' was measured as the ratio of R&D expenditure to total sales. Firm size is also an important factor affecting the extent of openness (Van de Vrande et al., 2009), and it was assessed by the natural logarithm of the total number of employees. Government support and market turbulence have been introduced, in the sense that government funding encourages SMEs' networking and interaction with other innovation actors (Kang and Park, 2012) and the competitive market environment is a strong driver for changes (Hung and Chou, 2013). They were measured using a 7-point Likert scale to establish how often the firm received

Table 2. Latent variable assessments

Factor loadings	Standardised estimate	Critical ratio (CR)	Cronbach's α	Composite validity
Innovativeness 1 \leftarrow EO	0.723	12.366***	0.875	0.762
Innovativeness 2 \leftarrow EO	0.727	12.425***		
Pro-activeness 1 \leftarrow EO	0.757	–		
Pro-activeness 2 \leftarrow EO	0.745	12.750***		
Risk-taking 1 \leftarrow EO	0.589	9.928***		
Risk-taking 2 \leftarrow EO	0.712	12.168***		
Risk-taking 3 \leftarrow EO	0.748	12.819***		
Patience 1 \leftarrow Patience	0.866	15.137***	0.833	0.745
Patience 2 \leftarrow Patience	0.886	15.312***		
Patience 3 \leftarrow Patience	0.762	–		
Patience 4 \leftarrow Patience	0.512	8.637***		
Voluntariness 1 \leftarrow Attitude	0.832	19.069***	0.928	0.854
Voluntariness 2 \leftarrow Attitude	0.865	20.482***		
Relative advantage 1 \leftarrow Attitude	0.877	–		
Relative advantage 2 \leftarrow Attitude	0.836	19.228***		
Relative advantage 3 \leftarrow Attitude	0.844	19.561***		
Ease of use \leftarrow Attitude	0.720	14.940***		

* $p < .1$.** $p < .05$.*** $p < .01$.

government support (subsidies, tax deductions, loans and research grants) and to what extent CEOs felt that the market environment was competitive and hostile.

3.3. Latent variable assessment

The reliability of the measurement was assessed by Cronbach's alpha, and all constructed latent variables satisfied the recommended level of 0.7 or over (Field, 2009). As shown in Table 2, the Cronbach's alpha for EO, patience and attitude were 0.875, 0.833 and 0.928, respectively. The validity was assessed using confirmatory factor analysis. The convergent validity was assessed by whether factor loadings of the indicators were statistically significant and greater than 0.5 (Bagozzi and Yi, 1988). All standardised factor loadings were over 0.5 and significant at the 0.001 level. All composite reliability suggested by Fornell and Larcker (1981) were also over 0.6, verifying the convergent validity. It can be said that the discriminant validity is guaranteed if 'the correlation coefficients between latent variable $\pm 2 \times$ standard errors does not include one' (Anderson and Gerbing, 1988, p. 416), and all the correlation coefficients in our data satisfied this condition.

4. Results and discussion

Logit regression was used for the analysis, because it is recognised as a good method for binary choice

analysis. To assess model fitness, Cox & Snell R^2 and Nagelkerke R^2 were reported. Before the regression, multi-collinearity was checked. Myers (1990) suggested that a variance inflation factor (VIF) larger than 10 can cause a serious collinearity problem. For all variables, the VIF values were between 1.055 and 3.588. Thus, it can be said that there was no serious collinearity problem in the sample. Acknowledging the multidimensionality of OI, analyses were conducted to identify possible differences and similarities of CEO impact between OI modes, and the results are reported in Table 3.

The results showed the importance of human factors in OI adoption. However, it was also reported that CEO characteristics impacted OI modes in different ways, suggesting an appropriate fit between them. First, a key decision maker's positive attitude was significant in almost all OI modes, validating Hypothesis 1. OI adoption can be interpreted as a deviation from a current innovation routine, and some important elements hampering this dynamic change will be internal resistance, path dependent behaviour and indifferent attitude of internal members. As new knowledge, processes and structures are adopted through OI, divergent thinking and an open-minded culture are imperative for smooth OI adoption (de Araújo Burcharth et al., 2014). Therefore, to eliminate negative prejudice and establish an OI-friendly atmosphere, the role of CEOs who can strongly support and facilitate it within their firms becomes critical (Ceci and

Table 3. OI adoption for an individual OI mode

Variables/OI mode	In-sourcing	R&D collaboration	Customer involvement	M&A/alliance	Licensing-out	Spin-off
	In-bound			Out-bound OI		
	Technology oriented	Technology oriented	Market oriented	Organisation oriented	Market oriented	Organisation oriented
<i>Independent variables</i>						
Attitude	0.608**	0.450**	0.296*	-0.645	0.516**	0.509**
EO	-0.081	-0.337	0.648***	3.163***	1.379***	0.988***
Patience	0.170	0.896***	0.095	0.056	-0.886***	-0.585**
Degree	0.018	0.124	0.006	0.286	0.134	0.227
Tech-Edu ¹	0.241	2.356***	0.316	0.135	0.777	-0.378
Manage-Edu ¹	0.213	1.763	0.058	4.756**	0.819	1.430
Working years	0.033	-0.051	0.027	-0.008	-0.013	-0.166
Sales/marketing ²	0.888	-1.029	1.076*	1.389	0.219	1.122
R&D work ²	0.331	-0.962	0.970	0.522	-0.325	0.889
Plan/strategy ²	0.608	-0.559	1.686**	1.576	0.964*	0.993
Production ²	0.575	-0.842	0.761	1.187	-0.268	1.499
<i>Control variables</i>						
Environment	-0.071	-0.256*	0.170*	-0.317	-0.099	0.069
Government	0.306**	0.833***	-0.018	0.307	-0.261	0.155
Firm size	0.472**	0.057	-0.056	-0.045	-0.042	0.392**
R&D intensity	0.039**	0.028*	-0.038*	-0.029	0.049**	0.008
<i>Model fit</i>						
Cox & Snell R ²	0.225	0.439	0.235	0.353	0.391	0.380
Nagelkerke R ²	0.308	0.588	0.323	0.418	0.425	0.471

The regression coefficient shown is the beta coefficient; statistical significance, * $p < .1$, ** $p < .05$, *** $p < .01$.

¹Base variable is 'other academic discipline'.

²Base variable is 'other functions'.

Iubatti, 2012). This is because attitudes influence belief, interpretation and judgement, which impact a person's behaviour (Fishbein and Ajzen, 1975). It has already been shown that in large firms, strong support from top management encourages OI adoption, helping them to cope with internal resistance (e.g., Huston and Sakkab, 2006), and this may become critical in SMEs. Internal resistance will decrease a firm's momentum of change, but a CEO's positive attitude will play a critical role in dealing with such negative prejudice while increasing change momentum (Jansen et al., 2009), which will eventually enhance the firm's dynamic capability.

Second, the results showed that CEOs' EO was associated with all market and organisation-oriented OI and out-bound OI, validating Hypotheses 2 and 3. This suggests that these OI modes are strategic changes with a high level of risk, thus demanding key decision makers to be more entrepreneurially oriented. Because the adoption of out-bound OI requires

CEOs to perceive innovation routes in different ways to make profits externally (Chesbrough et al., 2006; Mortara et al., 2011), it will involve more drastic changes and higher uncertainty than in-bound OI adoption. Finding a potential receiver is an important issue in out-bound OI, but overcoming NSH by persuading internal members who are hesitant to be open will require strong leadership and bold decisions. The virtue of out-bound OI lies in identifying new commercialisation routes for internal knowledge, so it is necessary for key decision makers to be innovative to take the necessary risks. Similarly, market and organisation-oriented OI will involve higher risks than technological OI (Ahn et al., 2015). As technological OI focuses on an increase in technological knowledge stock, the changes involved in this OI will mainly affect the focal firm's technology-related domain. However, because other OI modes involve broader changes in terms of market (e.g., licensing-out and customer involvement) and organisational

structures (e.g., spin-off and M&A), changes in this type of OI will require stronger relational and managerial interactions with external partners. Consequently, there will be more company-wide risks in this type of OI, making it necessary for a key decision maker to be more entrepreneurially oriented.

Third, the CEOs' patience was positively associated with in-bound OI (R&D collaboration), suggesting its importance in innovation cooperation context. Owing to substantial system differences between the firm and its partner, coordination in a collaborative R&D project is not easy (Dyer and Singh, 1998). When two (or more) firms with different cultural backgrounds, goals and ways of doing research collaborate, they will inevitably have to cope with the challenges presented by progressive adaptation to approach each other. In this respect, the patience and endurance of CEOs can be critical in R&D collaborations (Kitchell, 1997). However, interestingly, patience was negatively associated with out-bound OI modes. This suggests that persevering CEOs may have a tendency to wait until innovation is achieved internally. The CEO who trusts more in his firm's internal potential may hesitate to release internal ideas in the hope of finding future uses for them, which will negatively influence out-bound OI. This interpretation might be supported by the fact that CEOs' patience and EO showed opposite associational patterns. EO was negatively associated with in-sourcing and R&D collaboration (despite its significance level), but patience was positively associated, and the reverse was the case in licensing-out and spin-off.

Fourth, the results showed that CEOs' education in a technology discipline was positively associated with technology-oriented OI (R&D collaboration). As technology expertise is an important personal characteristic for knowledge exploration (da Mota Pedrosa et al., 2013), the key decision maker's education in science/engineering may help the firm to identify relevant technological knowledge and opportunity more easily. This fit will be more important in small organisations where CEOs have more frequent interaction with employees (Miller and Toulouse, 1986) and often have to be involved in operational functions (Lubatkin et al., 2006).

Finally, CEO academic degrees and working years were examined, but no significant association was observed. This indicates that long immersion in education or experience may cause path dependence, which might be a double-edged sword for openness. On the one hand, CEOs' experience can help them to learn the necessary know-how, but on the other hand, it may lead them into an experience trap that can hamper their readiness for change (Hamori and Koyuncu, 2013). Experienced CEOs may adhere to an

innovation route with which they are familiar, but this path-dependent behaviour can hinder new knowledge acquisition or sharing in their (new) firms which are facing totally different (or rapidly changing) business environments (Hamori and Koyuncu, 2013). This suggests a possible risk of 'dominant logic' or 'industry recipe' formed by cognitive bias (Huff, 1982; Porac and Thomas, 1990), which is also in line with the result that CEO experience in the technology function was not significant. As noted by Barker and Mueller (2002), a CEO's experience in technology-related fields plays an important role in increasing the level of internal R&D investments. Thus, technology-oriented leaders may be typically good at internal innovation, but they often have difficulty in diverting their research interests outwards (Hoffman et al., 1998). As an individual's experience typically reflects his/her past behaviour, longer experience in technology fields may establish a path dependent behaviour more focused on internal technology development and trapped in NIH syndrome.

5. Implications and limitations

Although many different topics have been discussed in the OI literature, to date key individuals' roles have been under-researched (Schroll and Mild, 2012; Wynarczyk et al., 2013; Salter et al., 2014). However, the micro-foundation of OI, in which key individuals' choices and behaviour shape firm-level strategy, cannot be underestimated (Salter et al., 2014), particularly in SMEs, where key players, such as CEOs, have a strong influence on firm-level decisions (Hambrick, 2007). As key agents of change, they will substantially influence the resistance, readiness and momentum of organisational change (Jansen, 2000). The micro-foundation of OI is rooted in an individual's intentional actions, experience and preferences, and top executives' leadership and awareness play an essential role in promoting OI adoption (Chesbrough and Garman, 2009). This paper raised the issue of the importance of human factors and suggested that more attention be given in the OI literature to the field of strategic leadership and entrepreneurship. This paper also identified the fit between CEO characteristics and OI modes by acknowledging the multi-dimensionality of OI. Although scholars have used a list of OI modes as if they were equivalent, they are clearly not in the eyes of implementers. Based on this OI diversity, this paper observed that the effects of CEO characteristics on OI adoption were differently configured according to the nature of each mode. Therefore, we suggest that OI be understood as a wide innovation spectrum,

which requires different types of knowledge and involves various types of change.

The paper also provides some practical implications. CEOs and top managers in SMEs should know that they are at the epicentre of OI adoption, and they are better able to adopt and implement certain types of OI modes than others. Thus, to increase opportunities for successful OI adoption, they have to attempt to compensate for characteristics they may lack by recruiting appropriate complementary people. As it is not possible for a single individual to have all the personal characteristics appropriate for the adoption of all OI modes, by assigning a particular key player to a particular function, firms may be able to manage OI more efficiently. Furthermore, the top management of firms must recognise the importance of culture in OI implementation. Self-motivation and open-mindedness are two important factors that facilitate OI implementation (da Mota Pedrosa et al., 2013), and overcoming NIH and NSH will require the establishment of a new company-wide culture encouraging knowledge import and export. The results might be extended to larger corporations and provide an implication for human resource management.

The results also suggest that SME policy should become more human-oriented. Many governments have tried to enhance innovation collaboration in SMEs by providing financial support, such as R&D grants (Mani, 2004). However, this might not be the best type of policy intervention for stimulating OI. Acknowledging the importance of CEOs, it is necessary for policy makers to realise that top management can also be an efficient policy target. As these key individuals can create and foster readiness for and momentum of organisational change (Jansen, 2000), policy makers need to understand their strong influence on facilitating and stimulating OI in SMEs. Furthermore, it is necessary for policy makers to develop sub-specialised OI policies. As shown in the results, an independent variable can influence OI differently according to the OI mode. Considering this heterogeneity, policy makers have to recognise that one policy cannot have the same results in all OI modes. Therefore, they have to develop sub-specialised policies reflecting the multi-dimensionality of OI.

This paper is not free from research limitations. First, because this was the first to attempt to link different literature domains, OI and UET, the tested CEO characteristics are mainly borrowed from the UET literature. Future research is needed to take into consideration other CEO factors that may significantly affect OI adoption. Theoretical research attempting to analyse the mechanism of OI adoption or in-depth case-studies that solely focus on the impact of human capital can be helpful in developing new CEO variables missing in

the UET literature. In addition, future research can investigate the top management team (TMT) rather than the CEO to extend the findings of this paper to other types of firms (e.g., MNCs or large firms). Although the CEO is a reliable source of innovation activities in SMEs (Zahra and Covin, 1993), using multiple respondents from TMTs could provide a better view for understanding complex organisations, particularly large firms (Hambrick, 2007).

Note

This work was supported by the Sogang University Research Grant of 201610094.01

References

- Ahn, J.M., Ju, Y., Moon, T.H., Minshall, T., Probert, D., Sohn, S.Y., and Mortara, L. (2016) Beyond absorptive capacity in open innovation process: the relationships between openness, capacities and firm performance. *Technology Analysis & Strategic Management*, **28**, 1009–1028.
- Ahn, J.M., Minshall, T., and Mortara, L. (2015) Open innovation: a new classification and its impact on firm performance in innovative SMEs. *Journal of Innovation Management*, **3**, 33–54.
- Alexy, O., Bascavusoglu-Moreau, E., and Salter, A.J. (2016) Toward an aspiration-level theory of open innovation. *Industrial and Corporate Change*, **25**, 289–306.
- Anderson, J.C. and Gerbing, D.W. (1988) Structural equation modeling in practice: a review and recommended two-step approach. *Psychological Bulletin*, **103**, 411–423.
- de Araújo Burcharth, A.L., Knudsen, M.P., and Søndergaard, H.A. (2014) Neither invented nor shared here: the impact and management of attitudes for the adoption of open innovation practices. *Technovation*, **34**, 149–161.
- Armstrong, J.S. and Overton, T.S. (1977) Estimating non-response bias in mail surveys. *Journal of Marketing Research*, **14**, 396–402.
- Bagozzi, R.P. and Yi, Y. (1988) On the evaluation of structural equation models. *Journal of the Academy of Marketing Science*, **16**, 74–94.
- Bantel, K.A. and Jackson, S.E. (1989) Top management and innovations in banking - does the composition of the top team make a difference. *Strategic Management Journal*, **10**, 107–124.
- Barker, V.L. and Mueller, G.C. (2002) CEO characteristics and firm R&D spending. *Management Science*, **48**, 782–801.
- Bianchi, M., Chiaroni, D., Chiesa, V., and Frattini, F. (2011) Exploring the role of human resources in technology out-licensing: an empirical analysis of biotech newtechnology-based firms. *Technology Analysis & Strategic Management*, **23**, 825–849.

- Carpenter, M.A. and Fredrickson, J.W. (2001) Top management teams, global strategic posture, and the moderating role of uncertainty. *Academy of Management Journal*, **44**, 533–545.
- Ceci, F. and Iubatti, D. (2012) Personal relationships and innovation diffusion in SME networks: a content analysis approach. *Research Policy*, **41**, 565–579.
- Chandler, G.N. and Jansen, E. (1992) The founders self-assessed competence and venture performance. *Journal of Business Venturing*, **7**, 223–236.
- Chesbrough, H. and Garman, A.R. (2009) Use open innovation to cope in a downturn. *Harvard Business Review*, **87**, 1–10.
- Chesbrough, H., Vanhaverbeke, W., and West, J. (2006) *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press.
- Classen, N., Van Gils, A., Bammens, Y., and Carree, M. (2012) Accessing resources from innovation partners: the search breadth of family SMEs. *Journal of Small Business Management*, **50**, 191–215.
- Colombo, M.G. and Grilli, L. (2005) Founders' human capital and the growth of new technology-based firms: a competence-based view. *Research Policy*, **34**, 795–816.
- Cooper, A.C., GimenoGascon, F.J., and Woo, C.Y. (1994) Initial human and financial capital as predictors of new venture performance. *Journal of Business Venturing*, **9**, 371–395.
- Covin, J.G. and Slevin, D.P. (1989) Strategic management of small firms in hostile and benign environments. *Strategic Management Journal*, **10**, 75–87.
- Dahlander, L. and Gann, D.M. (2010) How open is innovation? *Research Policy*, **39**, 699–709.
- Di Minin, A., Frattini, F., and Piccaluga, A. (2010) Fiat: open innovation in a downturn (1993–2003). *California Management Review*, **52**, 132–159.
- Dyer, J.H. and Singh, H. (1998) Strategic supplier segmentation: the next “best practice” in supply chain management. *California Management Review*, **40**, 660–679.
- Escriba-Esteve, A., Sanchez-Peinado, L., and Sanchez-Peinado, E. (2009) The influence of top management teams in the strategic orientation and performance of small and medium-sized enterprises. *British Journal of Management*, **20**, 581–597.
- Field, A. 2009. *Discovering Statistics Using SPSS*. London: Sage.
- Fishbein, M. and Ajzen, I. 1975. *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. Reading, MA: Addison-Wesley.
- Fornell, C. and Larcker, D.F. (1981) Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, **18**, 39–50.
- Gavetti, G. and Levinthal, D.A. (2004) The strategy field from the perspective of management science: divergent strands and possible integration. *Management Science*, **50**, 1309–1318.
- Groen, A.J. and Linton, J.D. (2010) Is open innovation a field of study or a communication barrier to theory development? *Technovation*, **30**, 554–554.
- Hambrick, D.C. (2007) Upper echelons theory: an update. *Academy of Management Review*, **32**, 334–343.
- Hambrick, D.C. and Mason, P.A. (1984) Upper echelons: the organization as a reflection of its top managers. *Academy of Management Review*, **9**, 193–206.
- Hamori, M. and Koyuncu, B. (2013) The CEO experience trap. *MIT Sloan Management Review*, **55**, 14–15.
- Hitt, M.A. and Tyler, B.B. (1991) Strategic decision-models - integrating different perspectives. *Strategic Management Journal*, **12**, 327–351.
- Hoffman, K., Parejo, M., Bessant, J., and Perren, L. (1998) Small firms, R&D, technology and innovation in the UK: a literature review. *Technovation*, **18**, 39–55.
- Huff, A.S. (1982) Industry influences on strategy reformulation. *Strategic Management Journal*, **3**, 119–131.
- Humphreys, P., McAdam, R., and Leckey, J. (2005) Longitudinal evaluation of innovation implementation in SMEs. *European Journal of Innovation Management*, **8**, 283–304.
- Hung, K.P. and Chou, C. (2013) The impact of open innovation on firm performance: the moderating effects of internal R&D and environmental turbulence. *Technovation*, **33**, 368–380.
- Huston, L. and Sakkab, N. (2006) Connect and develop: inside Procter & Gamble's new model for innovation. *Harvard Business Review*, **84**, 58–66.
- Jansen, J.J.P., Vera, D., and Crossan, M. (2009) Strategic leadership for exploration and exploitation: the moderating role of environmental dynamism. *Leadership Quarterly*, **20**, 5–18.
- Jansen, K.J. (2000) The emerging dynamics of change: resistance, readiness, and momentum. *Human Resource Planning*, **23**, 53–55.
- Kang, K.N. and Park, H. (2012) Influence of government R&D support and inter-firm collaborations on innovation in Korean biotechnology SMEs. *Technovation*, **32**, 68–78.
- Katz, R. and Allen, T.J. (1982) Investigating the not invented here (NIH) syndrome - a look at the performance, tenure, and communication patterns of 50 R&D project groups. *R & D Management*, **12**, 7–19.
- Khandwalla, P.N. (1976/1977) Some top management styles, their context and performance. *Organization and Administrative Science*, **7**, 21–51.
- Khandwalla, P.N. 1977. *The Design of Organizations*. New York: Harcourt Brace Jovanovich, Inc.
- Kirton, M. (1976) Adaptors and innovators - description and measure. *Journal of Applied Psychology*, **61**, 622–629.
- Kitchell, S. (1997) CEO characteristics and technological innovativeness: a Canadian perspective. *Canadian Journal of Administrative Sciences-Revue Canadienne Des Sciences De L Administration*, **14**, 111–125.
- KOITA. 2009. *Major Indicators of Industrial Technology*. Seoul: Korean Industrial Technology Association.
- Lefebvre, E. and Lefebvre, L.A. (1992) Firm innovativeness and CEO characteristics in small manufacturing firms. *Journal of Engineering and Technology Management*, **9**, 243–277.

- Lubatkin, M.H., Simsek, Z., Ling, Y., and Veiga, J.F. (2006) Ambidexterity and performance in small- to medium-sized firms: the pivotal role of top management team behavioral integration. *Journal of Management*, **32**, 646–672.
- Mani, S. (2004) Government, innovation and technology policy: an international comparative analysis. *International Journal of Technology and Globalisation*, **1**, 29–44.
- Marcati, A., Guido, G., and Peluso, A.M. (2008) The role of SME entrepreneurs' innovativeness and personality in the adoption of innovations. *Research Policy*, **37**, 1579–1590.
- McMullan, W.E. and Long, W.A. (1987) Entrepreneurship education in the nineties. *Journal of Business Venturing*, **2**, 261–275.
- Miller, D. (1983) The correlates of entrepreneurship in 3 types of firms. *Management Science*, **29**, 770–791.
- Miller, D. and Friesen, P.H. (1982) Innovation in conservative and entrepreneurial firms - 2 models of strategic momentum. *Strategic Management Journal*, **3**, 1–25.
- Miller, D. and Toulouse, J. (1986) Chief executive personality and corporate strategy and structure in small firms. *Management Science*, **32**, 1389–1409.
- Moore, G.C. and Benbasat, I. (1991) Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, **2**, 192–221.
- Mortara, L. and Minshall, T. (2011) How do large multinational companies implement open innovation? *Technovation*, **31**, 586–597.
- Mortara, L., Napp, J., Ford, S., and Minshall, T. 2011. Open innovation activities to foster corporate entrepreneurship. In: Cassia, L., Minola, T., & Paleari, S. (eds.) *Entrepreneurship and Technological Change*. Cheltenham, UK: Edward Elgar.
- da Mota Pedrosa, A., Välling, M., and Boyd, B. (2013) Knowledge related activities in open innovation: managers' characteristics and practices. *International Journal of Technology Management*, **12**, 254–273.
- Myers, R. 1990. *Classical and Modern Regression with Applications*. Boston, MA: Duxbury.
- Narula, R. (2004) R&D collaboration by SMEs: new opportunities and limitations in the face of globalisation. *Technovation*, **24**, 153–161.
- OECD. 1997. *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: The Oslo Manual*. Paris: OECD.
- Papadakis, V.M. (2006) Do CEOs shape the process of making strategic decisions? Evidence from Greece. *Management Decision*, **44**, 367–394.
- Porac, J.F. and Thomas, H. (1990) Taxonomic mental models in competitor definition. *Academy of Management Review*, **15**, 224–240.
- Rhee, J., Park, T., and Lee, D.H. (2010) Drivers of innovativeness and performance for innovative SMEs in South Korea: mediation of learning orientation. *Technovation*, **30**, 65–75.
- Roach, M. and Saueremann, H. (2010) A taste for science? PhD scientists' academic orientation and self-selection into research careers in industry. *Research Policy*, **39**, 422–434.
- Rogers, E.M. (1983) *Diffusion of Innovations*. New York: The Free Press.
- Salter, A., Cricuolo, P., and Ter Wal, A. (2014) Coping with open innovation: responding to the challenges of external engagement in R&D. *California Management Review*, **56**, 77–94.
- Schein, E. 1985. *Organizational Culture and Leadership*. San Francisco, CA: Jossey Nass.
- Schroll, A. and Mild, A. (2012) A critical review of empirical research on open innovation adoption. *Journal für Betriebswirtschaft*, **62**, 85–118.
- Siegel, R., Siegel, E., and Macmillan, I.C. (1993) Characteristics distinguishing high-growth ventures. *Journal of Business Venturing*, **8**, 169–180.
- Simon, H.A. 1957. *Models of Man*. New York: Wiley.
- Simonin, B.L. (1999) Transfer of marketing know-how in international strategic alliances: an empirical investigation of the role and antecedents of knowledge ambiguity. *Journal of International Business Studies*, **30**, 463–490.
- Smith, D. (2007) The politics of innovation: why innovations need a godfather. *Technovation*, **27**, 95–104.
- Spithoven, A., Clarysse, B., and Knockaert, M. (2011) Building absorptive capacity to organise inbound open innovation in traditional industries. *Technovation*, **31**, 10–21.
- Spithoven, A., Vanhaverbeke, W., and Roijakkers, N. (2013) Open innovation practices in SMEs and large enterprises. *Small Business Economics*, **41**, 537–562.
- Teece, D.J. (2007) Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, **28**, 1319–1350.
- Thong, J.Y.L. and Yap, C.S. (1995) CEO characteristics, organizational characteristics and information technology adoption in small businesses. *Omega-International Journal of Management Science*, **23**, 429–442.
- Trott, P. and Hartmann, D. (2009) Why 'Open Innovation' is old wine in new bottle. *International Journal of Innovation Management*, **13**, 715–736.
- Tucci, C.L., Chesbrough, H., Piller, F., and West, J. (2016) When do firms undertake open, collaborative activities? Introduction to the special section on open innovation and open business models. *Industrial and Corporate Change*, **25**, 283–288.
- Tyler, B.B. and Steensma, H.K. (1998) The effects of executives' experiences and perceptions on their assessment of potential technological alliances. *Strategic Management Journal*, **19**, 939–965.
- Vanhaverbeke, W. and Cloudt, M. (2014) Theories of the firm and open innovation. In: Chesbrough, H., Vanhaverbeke, W., and West, J. (eds.), *New Frontiers in Open Innovation*. Oxford: Oxford University Press.
- Vanhaverbeke, W. and Roijakkers, N. 2014. Enriching open innovation theory and practice by strengthening the relationship with strategic thinking. In: Pfeffermann, N.,

- Minshall, T., and Mortara, L. (eds.), *Strategy and Communication for Innovation*, 2nd edn. London: Springer.
- van de Vrande, V., de Jong, J.P.J., Vanhaverbeke, W., and de Rochemont, M. (2009) Open innovation in SMEs: trends, motives and management challenges. *Technovation*, **29**, 423–437.
- West, J. and Bogers, M. (2013) Leveraging external sources of innovation: a review of research on open innovation. *Journal of Product Innovation Management*, **31**, 814–831.
- West, J., Salter, A., Vanhaverbeke, W., and Chesbrough, H. (2014) Open innovation: the next decade. *Research Policy*, **43**, 805–811.
- Wynarczyk, P., Piperopoulos, P., and McAdam, M. (2013) Open innovation in small and medium-sized enterprises: an overview. *International Small Business Journal*, **31**, 240–255.
- Zahra, S.A. and Covin, J.G. (1993) Business strategy, technology policy and firm performance. *Strategic Management Journal*, **14**, 451–478.

Joon Mo Ahn is an Assistant Professor at Graduate School of MOT (Management of Technology), Sogang University, Korea. Prior to joining Sogang University he worked for Korean government agencies, such as the Small Medium Business Administration and the Ministry of Education, Science and Technology, and the Ministry of Science, ICT and Future Planning where he engaged in the development of innovation policies. He has a BSc in Chemical Engineering from Seoul National University, Korea and a Ph.D. from the University of Cambridge, UK. His current research is focused on open innovation in small firms, innovation management, innovation policy and entrepreneurship.

Tim Minshall is a Reader at the University of Cambridge, Centre for Technology Management. He researches, teaches, writes and consults on the topics of open innovation, technology enterprise, the financing of innovation and university-industry knowledge exchange. He is a non-executive director of St. John's Innovation Centre Ltd., Cambridge and a Visiting Professor at Doshisha University Institute for Technology, Enterprise and Competitiveness in Japan. He has a BEng from Aston University, and a Ph.D. from Cambridge University Engineering Department. His current research is focused on innovation collaborations, the emergence of additive manufacturing/3D printing and the development of engineering skills.

Letizia Mortara is a Senior Research Associate at the University of Cambridge IfM's Centre for Technology Management. Her expertise and key research interests concern the understanding of how companies implement Open Innovation and Technology Intelligence systems. Letizia's research currently concentrates on understanding how Digital Fabrication technologies could have an impact on innovation and manufacturing. She has authored several papers and reports in these areas. She is also an Associate Editor for the R&D Management journal. Prior to joining the University of Cambridge in 2005, Letizia gained a first degree in Industrial Chemistry from the University of Bologna in Italy. After spending three years working as a process/product manager in the chemical industry, she moved to the UK where she obtained her Ph.D. in processing and scale-up of advanced ceramic materials at Cranfield University.

Appendix

Variables	Indicators (strongly disagree to strongly agree)	Reference			
EO	Innovativeness 1	I favour a strong emphasis on R&D, technological leadership, and innovation.	Covin and Slevin (1989), Khandwalla (1977), Miller and Friesen (1982), Miller (1983), Rhee et al. (2010)		
	Innovativeness 2	I like to seek innovative ideas to improve products and services.			
	Pro-activeness 1	I like to introduce changes before other competitors do so.			
	Pro-activeness 2	I typically adopt a very competitive, 'undo-the-competitors' posture.			
	Risk-taking 1	I have a strong proclivity for high-risk projects with chances of very high returns.			
	Risk-taking 2	I believe that bold, wide-ranging acts are necessary to achieve the firm's objective.			
	Risk-taking 3	I typically adopt an aggressive posture in order to maximise the probability of exploiting potential opportunities.			
	Patience (Perseverance)	Patience 1		I do not give up easily	Kitchell (1997)
		Patience 2		I do not stop until I have found a way to get around it.	
		Patience 3		I have the staying power to do work that requires long hours and hard work.	
Patience 4		I do not leave a job unfinished.			
Attitude towards open innovation	Voluntariness 1	I actively support the adoption/implementation of open innovation.	Moore and Benbasat (1991), Rogers (1983), Thong and Yap (1995)		
	Voluntariness 2	I emphasise the importance of open innovation to my employees.			
	Relative-advantage 1	I believe that open innovation can be beneficial to new product and service development.			
	Relative-advantage 2	I believe that open innovation will increase company sales.			
	Relative-advantage 3	I believe that open innovation is helpful in seizing new opportunities.			
Ease of use	I find open innovation easy to adopt.				