R&D MANAGEMENT

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

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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 Cloodt, 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	Conducting R&D with external partners	
	Customer involvement	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 multi-dimensionality 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 mis-fit 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 CEOs' 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 ← EO	0.723	12.366***	0.875	0.762
Innovativeness 2 ← EO	0.727	12.425***		
Pro-activeness 1 ← EO	0.757	–		
Pro-activeness 2 ← EO	0.745	12.750***		
Risk-taking 1 ← EO	0.589	9.928***		
Risk-taking 2 ← EO	0.712	12.168***		
Risk-taking 3 ← EO	0.748	12.819***		
Patience 1 ← Patience	0.866	15.137***	0.833	0.745
Patience 2 ← Patience	0.886	15.312***		
Patience 3 ← Patience	0.762	–		
Patience 4 ← Patience	0.512	8.637***		
Voluntariness 1 ← Attitude	0.832	19.069***	0.928	0.854
Voluntariness 2 ← Attitude	0.865	20.482***		
Relative advantage 1 ← Attitude	0.877	–		
Relative advantage 2 ← Attitude	0.836	19.228***		
Relative advantage 3 ← Attitude	0.844	19.561***		
Ease of use ← 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
Independent variables						
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
Control variables						
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
Model fit						
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, *$p < .1$, **$p < .05$, ***$p < .01$.
[1]Base variable is 'other academic discipline'.
[2]Base 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).

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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.	

