The role of employee autonomy for open innovation performance

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Abstract

Purpose – The purpose of this paper is to examine how organisational activities that formally provide employees with work autonomy explain the performance of open innovation (OI).
Design/methodology/approach – The study reports the results of mediation analyses conducted on the basis of survey data from 307 firms.
Findings – The economic benefits of both inbound and outbound OI are fully captured only if firms provide employees with time, freedom and independence. The results show that employee autonomy fully mediates the relationship between openness and innovation sales, while the adoption of inbound OI is positively associated with the introduction of new products.
Practical implications – The opening of innovation induces managers to provide employees with discretion, as OI requires high levels of flexibility and experimentation.
Originality/value – The paper addresses theoretically and empirically the role of job design in the implementation of OI, while also distinguishing between the effects of inbound and outbound practices on innovation performance.

Keywords Innovation performance, Employee autonomy, Inbound open innovation, Outbound open innovation

Paper type Research paper

1. Introduction

Strategies emphasising open approaches to innovation have topped executive agendas in the past decade, though many companies struggle with implementation (Cassiman and Valentini, 2016). Managerial issues are a persistent conundrum. Once firms commit to external collaboration, the existing routines, practices and incentive systems become obsolete and require adaptations or even application of new organisational tools (Dahlander and Gann, 2010; Van De Vrande *et al.*, 2010; West and Bogers, 2014).

The trend towards more porous firm boundaries is known as "open innovation" (OI) and refers to the execution of a wide range of practices related to external knowledge acquisition and commercialisation, which are characterised according to their directionality – inbound and outbound (Chesbrough, 2003). This approach has become popular (West *et al.*, 2014), since it is recognised as a means of achieving increased innovative performance (Laursen

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and Salter, 2006; Lilien *et al.*, 2002). The overall expectations are optimistic: bottom-line efficiency gains, greater top-line growth and shorter developmental processes are some of the most cited value-generating outcomes of engagement with external partners (Spithoven *et al.*, 2010; Trott and Hartmann, 2009; Fu, 2012; Dittrich and Duysters, 2007; Gianiodis *et al.*, 2014; Barge-Gil, 2013). However, the evidence is not entirely positive. While Laursen and Salter (2006) identified a limit to the positive effects, Knudsen and Mortensen (2011) and Tranekjer and Søndergaard (2013) found negative effects of openness on new product development outcomes. Faems *et al.* (2010) arrived at a negative total effect of technology alliances on profit margins and Czarnitzki and Thorwarth (2012) found no significant influence of design conducted in external collaboration on new product success. Similarly, Cassiman and Valentini (2016) discovered that concurrently conducting inbound and outbound practices reduces overall innovation productivity.

Existing evidence thus suggests great heterogeneity not only in the extent of adoption, but also in the extent to which firms are able to capture value from openness. However, the literature provides an incomplete account for the causes of this heterogeneity. We contend that it is more fruitful to investigate mechanisms, which may facilitate implementation of OI (or not) rather than just focusing on the performance implications of openness. While some scholars have suggested that the success of OI depends on in-house R&D investments since they are seen as complementary rather than substitute activities (Cassiman and Veugelers, 2006; Hagerdoorn and Wang, 2012; Schmiedeberg, 2008), others have stressed the importance of external contingency factors. Strong appropriability regimes and high-technology intensity are some of the industrial characteristics associated with higher reliance on external actors (Chesbrough and Crowther, 2006; Huizingh, 2011; Laursen and Salter, 2014). As for the organisational characteristics, focus has mostly been on traditional context features such as size, age and ownership type (West and Bogers, 2014; Van de Vrande *et al.*, 2009). Contemporary research with limited exceptions (Buganza *et al.*, 2011; Fu, 2012; Foss *et al.*, 2011; Gambardella and Panico, 2014; Bianchi *et al.*, 2011), however, remains to add little to our understanding of how management systems facilitate or hamper the functioning of openness. As these studies are exploratory in nature (Bianchi *et al.*, 2011; Buganza *et al.*, 2011), based on a specific type of knowledge source such as customers (Foss *et al.*, 2011), and centred on overarching governance mechanisms (Fu, 2012; Gambardella and Panico, 2014), they provide only a partial (yet valuable) explanation of the organisational solutions used to leverage OI.

An interesting aspect to address is whether and how openness relates to the level of autonomy formally granted by firms. The trade-offs between autonomy and control have long been debated in innovation research (Bailyn, 1985), as well as in practice, following the "free-time" models adopted by companies such as 3M and Google (Bonn, 2001; Finkle, 2012). These trade-offs are likely exacerbated in the context of OI, which demands significant flexibility and experimentation (Gianiodis *et al.*, 2014), but also careful coordination (Huston and Sakkab, 2006).

Our study addresses this issue by posing the question: how do internal organisational activities that promote employee autonomy relate to the performance outcomes of inbound and outbound OI?

We study autonomous forms of work design and particularly how firms give employees discretion to define their own undertakings. Consequently, we analyse employee autonomy as the mediator of the OI-innovation performance link. Drawing on survey data from 307 firms, our overall finding is that activities promoting employee autonomy (including intrapreneurial initiatives, freedom to choose the problems on which to work, and allowance of time for creativity) are mechanisms that enable firms to benefit from openness. Our main contribution is to empirically verify how a key activity related to the firms' management system (i.e. job design) relates to the reasons why some firms benefit from the use of purposive knowledge inflows and outflows and others do not.

Understanding the joint performance implications of OI and internal organisational activities is of critical importance both from an academic and a managerial perspective. A more refined theory is absolutely crucial for identifying the organisational mechanisms that support the outcomes of OI. Ultimately, OI should be better understood to avoid that it gets applied as an "all-purpose" solution in any setting. Furthermore, managers ought to know how an open approach to innovation is related to in-house activities such as job design and how it can be successfully implemented in practice. This research reinforces the notion that the focus on R&D and external contingencies needs to be complemented with a focus on the internal organisation to explain the outcomes of openness.

2. Organising for OI

OI integrates a wide range of phenomena as it goes well beyond the involvement of external actors in new product development projects. Inbound practices range from simple internet searches to complex practices such as R&D purchases. Outbound practices refer to outward technology transfer that may include out-licensing agreements, provider activities (i.e. that firms are active in providing input and knowledge to other firms' innovation efforts) and free revealing of inventions. In addition to establishing outward-looking practices that transcend organisational boundaries, OI also requires relevant changes within firms (Salter *et al.*, 2014). In emphasising a direct association between external engagement and innovation performance, the literature is, however, not entirely forthcoming with respect to the organisational activities needed to exploit external paths for innovation generation and commercialisation. Even in studies showing that connections to the outside world are necessary but not sufficient (Whelan *et al.*, 2011), the organisational requirements for openness remain unclear. There is scant research but increasing attention to organisational mechanisms that support OI strategies (Keinz *et al.*, 2012).

Three aspects of internal organisation have been investigated so far: organisational structure, organisational procedures, and rewards and incentive systems (Buganza *et al.*, 2011). The first aspect has been primarily studied with respect to the allocation of decision rights. Delegation, particularly to the weaker party, has been found to facilitate external collaboration (Foss *et al.*, 2011; Gambardella and Panico, 2014; Bianchi *et al.*, 2011). As to procedures, the emphasis has been on those that facilitate internal communication and knowledge exchange, following Cohen and Levinthal's (1990) specification of the inward-looking dimensions of absorptive capacity (Foss *et al.*, 2011). The provision of incentives and rewards systems is the aspect that has raised most interest, but also most controversy. Whereas Fu (2012) discovered that the overall importance of incentives diminishes when firms open up for innovation, Foss *et al.* (2011) found that paying employees to acquire and share knowledge is useful for tapping customer contributions, and Bianchi *et al.* (2011) realised that extrinsic rewards did not affect licensing managers.

Prior research has thus highlighted the role of overarching governance mechanisms in the management of OI. In turn, there has been limited attention to the question of how decisions regarding job design (specifically autonomy) change as external collaborative efforts intensify. We argue that it is necessary to revisit the dilemma between coordination and autonomy as to understand the conditions under which firms translate the benefits of outward-looking practices into performance outcomes (Kanter, 1977; Morgan, 2006).

In terms of performance outcomes, OI is regarded as a means of accelerating internal development processes and of maximising profits from innovation (Van de Vrande *et al.*, 2009). It is expected to facilitate access to resources, knowledge and competencies otherwise unavailable to the firm, as well as enable companies to better realise the monetary and strategic potential of the active commercialisation of knowledge (Guilhon *et al.*, 2004; Koruna, 2004). Nevertheless, openness also involves relevant costs with respect to knowledge absorption and

transfer: cognitive costs (e.g. managerial attention), transaction costs (e.g. fear of opportunism) and organisational costs (e.g. time) (Cassiman and Valentini, 2016). These may manifest as worse time to market and product success, slower and more expensive product development projects (Knudsen and Mortensen, 2011; Czarnitzki and Thorwarth, 2012; Tranekjer and Søndergaard, 2013; Faems *et al.*, 2010), as well as reduced market share (Fosfuri, 2006). While the theoretical rationale of OI advocates for the joint adoption of inbound and outbound practices, empirical evidence challenges this complementarity argument. Interestingly, the investigation of Cassiman and Valentini (2016) reveal that buying and selling knowledge simultaneously yield a decrease in total innovation productivity.

The final gains of openness, hence, seem to be driven by the interaction of technological and managerial dimensions. Taken together, our review indicates the need for a better conceptual understanding of the drivers and tools in the internal organisation for OI.

3. Theoretical model and hypotheses

We argue that it is the provision of employee autonomy that allows firms to turn OI practices into improved innovation performance. We refer to employee autonomy as "the degree to which the job provides substantial freedom, independence, and discretion to the individual in scheduling the work and in determining the procedures to be used in carrying it out" (Hackman and Oldham, 1976, p. 258). Our focus is thus on autonomy formally granted by firms, as opposed to the autonomy individuals proactively claim for themselves via bootlegging behaviour (Criscuolo *et al.*, 2013)[1]. Specifically, we are interested in autonomy in planning and conducting the job – also called "strategic autonomy" by Bailyn (1985) – and in the support management extends to employees by encouraging them to engage in entrepreneurial behaviour (Hornsby *et al.*, 2002). In the context of employee's entrepreneurial behaviour, strategic autonomy refers to the freedom to carry out innovative activities without supervisory approval, even if they are not closely related to the firm's strategic scope (Globocnik and Salomo, 2015).

We draw on three streams of literature – corporate entrepreneurship (Burgelman, 1983; Kuratko *et al.*, 2015), creativity (Amabile *et al.*, 1996), and human resource management (Foss *et al.*, 2009) – to argue that internal organisational activities related to employee autonomy act as intervention mechanisms between openness and performance. Opening of innovation processes is in tune with firms that provide employees with latitude and freedom to work independently. Besides impacting affective reactions such as job satisfaction and well-being, employee autonomy is a key aspect of job design that is positively associated with creativity, intrinsic motivation, proactive role orientation, entrepreneurial behaviour and ownership of problems (Foss *et al.*, 2009; Parker *et al.*, 1997; Fini *et al.*, 2012). Therefore, it is likely correlated with innovation outcomes.

Our conceptual framework is illustrated in Figure 1. The relationships are split in two parts: the direct relationship between OI and employee autonomy and the mediation effects of employee autonomy on the OI-innovation performance relationship.

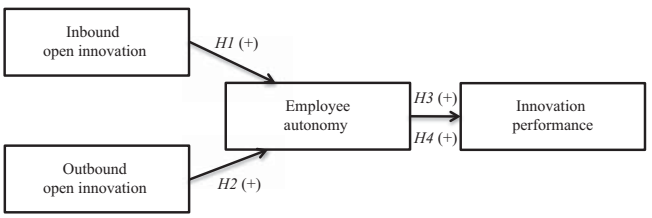


Figure 1.
Conceptual model of the performance outcomes of open innovation

3.1 The relationship between openness and employee autonomy

When collaborating with a variety of outside individuals (such as users) and organisations (such as suppliers), firms necessarily need to give up full control and make compromises in order to engage in fruitful cooperation. Each partner has different norms, habits and rules, which require different practices to make the search process useful (Laursen, 2012). Employees who get the freedom to make adaptations and decisions in a timely and flexible fashion may benefit the collaborative venture. If they are required to consult upper-echelon managers for every decision, the likely outcome is an unproductive collaborative environment marked by a slow pace of progress, characterised by employees who follow tight procedures and make uninformed decisions. By increasing the speed and accountability of decision making, organisational commitment to autonomy enables firms to take advantage of the knowledge gained through outside sources (Gambardella and Panico, 2014). Foss *et al.* (2011) found empirical support for this argument, indicating that a reallocation of decision rights was necessary to improve the sourcing and use of knowledge held by customers.

Hierarchical control can seldom be fully exercised in interorganisational contexts that depend on cooperative exchanges (Feldman, 1989). In order to tap external providers of ideas and competencies, firms need to encourage a proactive and broad exploration of market information and knowledge inputs, thereby balancing local and non-local search (Laursen, 2012). Knowledge sourcing is a highly uncertain endeavour requiring that employees are endowed to take advantage of opportunities and to react if unforeseen events arise by acting autonomously. Independence and slack are needed for the integration of ideas, insights and know-how from outside partners, since they cannot be fully anticipated. Given the important role of serendipity, tight monitoring may prevent employees from scanning the environment efficiently.

Moreover, institutional relations are often initiated by social interactions. It is the personal initiative of employees to mobilise their networks of relations that leads to boundary-spanning behaviour and cross-fertilisation with partnering entities. Anecdotal evidence reveals that when pursuing a strategic orientation towards openness, firms stimulate employees to be more active in leveraging their own relations in the search for new ideas (Salter *et al.*, 2014).

Put briefly, we expect the implementation of inbound open practices to be related to more self-directed behaviour. Thus, the following is hypothesised:

H1. The adoption of inbound OI practices is related to employee autonomy.

Similarly, the adoption of outbound OI stimulates an active and self-starting approach to work. As most companies do not exploit all the inventions they produce (Cassiman and Valentini, 2016), the selling of technologies is typically a marginal and temporary strategic concern (Granstrand, 2004), for which there are no well-established structures and processes. Such practice depends on employees who are proactive and take initiative to transcend organisational routines and to create new processes that challenge established ways of doing things, e.g. the tradition for selling primarily products and not licences. In this respect, it is often a departure from existing values and business models that may create resistance to the commercialisation of underutilised knowledge. In investigating the implementation of OI in a large multinational, Salter *et al.* (2014) documented various coping strategies employees cultivated to circumvent these challenges. Such strategies were marked by the development of personal approaches to problems and workarounds that deviated from conventions and expectations, thus indicating highly autonomous actions.

In addition to breaking internal routines, the selling of unused ideas leads to freestanding behaviour externally. Information asymmetries and other imperfections of the markets for knowledge (Natalicchio *et al.*, 2014) bring about highly entrepreneurial behaviour.

Employees need to be granted latitude as to be able to identify knowledge transfer opportunities, shepherd them through internal processes, then exploit and deliver on them. As Natalicchio *et al.* (2014) noticed, the undertakings in the market for ideas require a "more proactive approach in matching demand and supply" (p. 68). Given the substantial efforts individuals must make to successfully transfer knowledge, they need to be given both the power to decide what to do with unexploited inventions and the means to invest in external channels. The challenge for management is to build a "can-do" climate that supports entrepreneurial individuals in championing outward transactions.

In short, it seems that an effective way to stimulate outbound OI is to make the company more conducive to creativity and entrepreneurship by granting work discretion to the staff. Thus, the following is hypothesised:

H2. The adoption of outbound OI practices is related to employee autonomy.

3.2 Employee autonomy as a mediator

Employee autonomy has been studied as a way of inducing new behaviour, promoting entrepreneurship (Hornsby *et al.*, 2002) and creativity (Amabile *et al.*, 1996). In the corporate entrepreneurship literature, autonomy is an underlying element of the internal organisation that is perceived to support entrepreneurial behaviour (Hornsby *et al.*, 2002), as well as a central dimension of measuring entrepreneurial orientation (Lumpkin *et al.*, 2009), which in turn is linked to performance (Lumpkin and Dess, 1996).

When employees receive encouragement for their creative efforts and do not experience high time pressure, they are more likely to persist in their idea generation endeavours (Baer and Oldham, 2006) and even start inventing in their spare time (Davis *et al.*, 2013). As research on creativity has revealed (Amabile *et al.*, 1996), individuals produce more creative work when they perceive themselves to have choices regarding how to go about accomplishing the tasks they are given. Allowing the staff to pursue their own ideas during work hours provides time to observe, experiment and speculate with others. These activities are vital for innovation outcomes (Deschamps, 2009). Some job slack is needed, because it nourishes the pursuit of innovative projects associated with high levels of uncertainty and potentially high pay-offs (Laursen, 2012). In contrast, tightly defined jobs with low autonomy tend to encourage narrow perspectives (Parker *et al.*, 1997). Because opportunities identified through external search channels are often poorly defined and hardly ever ready to be exploited immediately (Huston and Sakkab, 2006), they are intrinsically dependent on the creative act of employees in terms of finding new applications for a given idea or technology and of translating and integrating it into local requirements. The need for creativity is intensified by the fact that, in inbound OI, knowledge must be transferred to contexts where it was not initially meant to be used and, furthermore, is not aligned with the existing knowledge base of the company. Experimental work is thus an integral part of knowledge sourcing practices, for which autonomy is critical to foster the necessary out-of-the-box thinking.

Another important point relates to motivation. According to the corporate entrepreneurship literature, when employees work in an intrapreneurial culture, they are likely to be more involved and motivated to champion ideas (Kuratko *et al.*, 1990). From a psychological perspective, employees view autonomy as the opportunity to influence their work, which builds enthusiasm and commitment. As a result, they are willing to take more risk compared to their peers with lower autonomy (Globocnik and Salomo, 2015). Motivation plays a key role in the context of inbound openness because of the high coordination costs external knowledge transactions imply (Grant, 1996). Unless individuals are motivated to surmount external knowledge sourcing challenges such as protective attitudes, information asymmetries and opportunism risks (Salter *et al.*, 2014; Burcharth *et al.*, 2014), they are

unlikely to carry out the inbound knowledge transactions. In a similar vein, research on human resource management has found that autonomy increases employee's intrinsic motivation toward knowledge sharing (Foss *et al.*, 2009). Internal knowledge sharing is in turn crucial for fruitful knowledge absorption (Cohen and Levinthal, 1990). As extensive empirical evidence shows, a firm's success in incorporating outside ideas depends on how these ideas reach others in the organisation who are better able to exploit them (Whelan *et al.*, 2011; Jansen *et al.*, 2005; Volberda *et al.*, 2010).

One visible example is Open Source Software (OSS) firms. Many firms have the practice of authorising their programmers to contribute autonomously to OSS project during working hours. This practice is used to scout external OSS projects for new knowledge of potential relevance for the firm's for profit activities (Colombo *et al.*, 2013).

All in all, encouraging employees to work autonomously as well as providing them with the skills and resources to do so is expected to support their ability to fully implement inbound open practices that is ultimately associated with higher innovation performance. Thus, the following is hypothesised:

H3. Employee autonomy fully mediates the relationship between inbound OI practices and innovation performance.

Outbound OI requires a creative outlook too. Autonomy fosters a high degree of playfulness that stimulates the non-obvious and non-trivial (Criscuolo *et al.*, 2013) which often permeates licensing-related decisions (e.g. keep-or-sell decisions and partner selection). Being able to imagine how others can make use of proprietary/own knowledge or technology entails both creativity skills and time to engage with external actors, as it is leveraged by a combination of technical and business insights. Conversely, managerial control restricts flexibility and creativity and therefore limits the scope for experimentation. The case studies conducted by Bianchi *et al.* (2011) provide suggestive evidence for this point. While in some cases a high degree of autonomy allowed the licensing manager to use his skills for making accurate choices in terms of pricing and partners' selection, in others these decisions were overruled by the CEO, a fact that slowed the completion of the deal and caused frustration.

Autonomy also leads to more proactive behaviour and personal initiative (Foss *et al.*, 2009; Parker *et al.*, 1997). Proactivity plays a key role in the context of outbound openness because of the inherent imperfections of markets for technology (Arora *et al.*, 2001; Guilhon *et al.*, 2004), which require individuals to devote extra efforts in completing transactions that often go beyond established norms (ideally with the support of the hierarchy). Interestingly, formally granted autonomy has been found to encourage not only authorised innovative activities, but also constructive creative deviance (bootlegging behaviour) – an employee's attempt to pursue an idea in an illegitimate manner (Augsdorfer, 2005). Bootlegging includes engaging in underground market-related and business-planning tasks, as well as making efforts to communicate with potential customers outside of official channels (Globocnik and Salomo, 2015). Outward knowledge transfer occurs when individuals take initiative and sometimes apply unorthodox approaches, ignoring formal directions and compliant behaviour, i.e. when they come up with new ways and contexts to employ unused inventions and ideas. These new ways encompass not only agreements with external partners, but also the establishment of spin-offs to exploit a misfit technology. Autonomy makes employees feel encouraged to engage in new venture creation and commercialisation (Hornsby *et al.*, 2002; Kuratko *et al.*, 2015); such ventures may have been created internally but can just as well be spun out to reach the market via alternative routes (Chesbrough and Garman, 2009).

Moreover, autonomy fosters hands-on learning as employees interact with the environment and become more involved in, and more knowledgeable about, the wider work process. This experience likely leads to broader ownership of problems and higher intrinsic motivation (Foss *et al.*, 2009; Parker *et al.*, 1997). It is the sense of ownership towards one's own ideas that

can spur employees to find external markets for ideas and technologies that cannot be implemented within the company, thereby attaining results from activities such as licensing, spin-offs, venture investments and free revealing. Inventors often develop solutions to issues that they find personally rewarding and work harder when they perceive that their ideas are not shelved within the company's boundaries (Cassiman and Valentini, 2016). As a result, highly involved and motivated employees are more likely to work outside the existing knowledge, market and technological domains of the company. Remarkably, intrinsic rewards such as peer recognition have been found to be more effective motivators for licensing managers than extrinsic incentives such as pay-for-performance incentive plans (Bianchi *et al.*, 2011).

A case from the banking industry exemplifies our argument. When pursuing an innovation initiative based on the inside-out principles, BBVA gave the responsible team "greater freedom from existing financial and operational norms employed in existing business units". The team relied on a "laboratory method to experiment" with new processes and services, leading the bank to outperform its European peers (Gianiodis *et al.*, 2014, p. 83).

Overall, the realisation of external opportunities via outbound practices requires not only that managers strategically facilitate such activities, but also that the employees are allowed to exercise freedom in the conduct of their work based on their ability to take initiative and find new opportunities in the surrounding environment. Thus, the following is hypothesised:

H4. Employee autonomy fully mediates the relationship between outbound OI practices and innovation performance.

4. Method

4.1 Sample and data

The empirical analysis of the paper is based on survey data collected in the Fall of 2010. The data were gathered among a population of Danish firms in the R&D (NACE 72) and manufacturing industries (NACE 10-37) and in the category of small- and medium-sized enterprises (SMEs), i.e. with 5-499 employees. The firms were identified in a nationwide database (KOB), considered the most detailed and updated directory of companies in the country. A total of 4,445 firms were identified as our population target. All of them were contacted by phone to introduce the study, identify the right informants (the R&D or innovation manager), obtain their e-mail addresses, and get their consent for sending the survey. The questionnaire was carried out online and in Danish. Of the 4,445 companies contacted, 1,051 (40.2 per cent) agreed to participate and therefore received the link to the survey. A total of 345 questionnaires were returned after two reminders. After screening for inconsistent answers, there were 331 usable questionnaires. Due to the peculiarities of firms belonging to the R&D sector (in terms of the intensity of R&D expenditures and outcome), they were excluded from the database (NACE codes 7211 and 7219). As a result, our final sample consisted of 321 firms, which were then further checked for missing responses in the core variables for this study. After cleaning for missing responses, the sample used for the study amounted to 307 firms, which equals a response rate of 29.2 per cent (based on the achieved acceptances) or 6.9 per cent (based on the original population).

Our choice of sampling was motivated by several criteria. First, a multi-industry approach was preferred, because our aim was to move beyond the prevalent focus on high-tech industries (Van De Vrande *et al.*, 2010). Second, we selected SMEs as they have been largely overlooked in this research field (Huizingh, 2011), despite the fact that they rely to a great extent on inflows and outflows of knowledge to sustain innovation (Bierly and Daly, 2007) and seem to utilise them differently from larger firms (Kim and Park, 2010). Third, we considered the R&D or innovation managers as the most appropriate informants for our survey because of their expertise to make informed assessments about internal

innovation endeavours, as well as about practices related to knowledge in-sourcing and out-sourcing. In the cases of firms without these job titles/functions, we asked the business owner or general manager to fill out the questionnaire. In all cases, we requested that informants have more than three years of work experience in the company to ensure that they possessed sufficient proficiency. We tested the sample for representativeness with *t*-tests with respect to variables such as industry classification, firm size and regional distribution. As the comparisons did not reveal any significant differences between any of the three groups (population, accepts and respondents), we are confident that the sample is representative with respect to these objective measures.

4.2 Dependent variables

Innovation performance, the dependent variable, is measured both as the output (whether or not a firm has introduced a new product in the market within three years prior to data collection), labelled "product innovation", and as the economic success of innovations (the percentage of revenues from new products that were launched within the last three years), labelled "innovation sales". These proxies have been extensively used in the literature to illustrate innovation performance (Laursen and Salter, 2006; Knudsen, 2007; Barge-Gil, 2013). Whereas "product innovation" is a binary variable (yes/no), "innovation sales" is double censored and highly skewed, as its distribution is truncated close to 0. A total of 79 per cent of the sampled firms introduced a new product in the last three years. On average, 22.0 per cent of the revenue of the firms in our sample was achieved from products that were finalised in the last three years (see Table AI), while 45.4 per cent of the firms have renewed 10 per cent or less of their revenues in the last three years. The further analyses rest on two sub-samples of the total sample, namely the firms responding to the product innovation question ($n = 307$) and the firms that have responded positively to the product innovation question and have provided an answer to the share of revenue from new products ($n = 229$). The latter sample is smaller than the positive answers given to the product innovation question (yes = 241), since 12 firms have not responded to the follow-up question. Hence, the two samples contain 307 firms (responses for the dependent variable product innovation) and 229 firms (responses for the dependent variable share of revenue from new products).

4.3 Openness

Openness is assessed according to a set of practices related to knowledge inflows and outflows (see Table I). We contend that even though a relationship measure based on the scope and the extent of use of external sources of knowledge (i.e. search breadth and depth)

Construct	Practices	Yes	%
Inbound open innovation practices	Used the internet to search for new trends or technology	274	85
	Reading technical magazines	266	83
	Used information from trade organisations	249	78
	Participated in innovation related fairs or shows	222	69
	Purchased R&D work from others	189	59
	Purchased licences, patents or know-how	80	25
	Worked with lead users	69	22
	Used innovation brokers	16	5
Outbound open innovation practices	Actively participated in other's innovation projects	171	55
	Sold patents, licences or know-how	24	8
	Made own innovations available to others for free	15	5

Note: $n = 321$

Table I.
The use of the open innovation practices among Danish SMEs

has prevailed in the literature (Laursen and Salter, 2006; Leiponen and Helfat, 2010; Fu, 2012), it does not fully capture the multifaceted nature of the concept. While recognising the valuable contributions of these studies, appropriate attention should be given to the fact that external relations constitute a limited proxy of OI, since they cover only part of the multitude of practices it encompasses. OI may happen, for instance, via other (informal) means such as internet searches (see Pisano and Verganti, 2008 for a description and examples of these practices). Furthermore, the relationship measure carries a substantial limitation since it does not capture knowledge outflows, i.e. the outbound dimension. While underscoring the relevance of external ties for innovation, this paper argues that it constitutes a particular mechanism rather than a manifestation of openness itself.

As an alternative, we used a practice-based approach to measure openness following Burcharth *et al.* (2014). The 11 practices were then divided into two groups: inbound and outbound OI. Inbound practices denote knowledge inflows and range from simple internet searches to complex arrangements such as R&D purchases. Outbound practices refer to outward knowledge transfers that support the external exploitation of technology assets, either exclusively or in addition to their internal application. They comprise out-licensing agreements, provider practices (i.e. those that provide input and knowledge to other firms' innovation efforts) and free revealing of ideas.

All practices were measured on a binary scale (yes/no) and the two indicators were calculated as the sum of their respective practices (see Table II). The average number of practices used for all companies is 4.9 (mode $=6$), while the innovative firms (5.1) generally use a higher number of practices as compared to the non-innovative firms (4.3). The most commonly adopted practices are inbound OI practices with a mode of 5, as 77 firms use five of the eight practices constituting the inbound dimension (mean $=4.2$). Very few firms do not engage in any inbound OI (3.6 per cent); however, a much larger share of firms does not engage in any outbound OI (40.1 per cent). The mode is 1 (53 per cent use 1 outbound OI practice and 7 per cent use 2 practices). As the number of used outbound practices is either 1 or 2 across the sample, we analysed the extent of use of outbound OI on the basis of two dummy variables (first dummy has value 1 for 1 outbound practice, rest 0; whereas the second dummy has value 1 for 2 outbound practices, rest 0).

Table II.
The number of open innovation practices among Danish SMEs

Number of practices	Frequency	%	Cum. %
Inbound			
0	11	3.6	3.6
1	9	2.9	6.5
2	22	7.2	13.7
3	50	16.3	30.0
4	65	21.2	51.1
5	73	23.8	74.9
6	67	21.8	96.7
7	10	3.3	100.0
Total	307	100.0	
Outbound			
0	123	40.1	40.1
1	163	53.1	93.2
2	21	6.8	100.0
3	0	0.0	100.0
Total	307	100.0	

4.4 Employee autonomy

Three internal organisational activities were used to measure employee autonomy, namely: supporting employees to work on their own ideas (yes = 54.8 per cent); providing employees with time for creativity (yes = 35.8 per cent); and initiating intrapreneurial activities (yes = 26.2 per cent). First, supporting employees to work with own ideas refers to the activities that give employees the discretion to conduct projects they defined and initiated independently, but that do not constitute a specified task in their list of job responsibilities, e.g. skunk work (Augsdorfer, 2005). Second, time for creativity refers to the "free time" employees are granted so that they can engage in exploratory thinking and experimentation with novel approaches to solve problems. Whereas the first activity focuses on the content of the task, i.e. the employee may work on own ideas, the second activity directly awards resources to it, i.e. time. Third, supporting intrapreneurial activities means that the company encourages and facilitates a culture of autonomous opportunity searching, also called an entrepreneurial mindset (McGrath and MacMillan, 2000) or entrepreneurial behaviour (Hornsby *et al.*, 2002), as well as the creation of new ventures in existing organisations via corporate entrepreneurship programmes (Kuratko *et al.*, 2015).

These three activities were assessed in the form of binary measures (yes/no; see descriptive statistics and correlations in Table III), which were then summed up to form the final construct used as the mediator variable (Table IV). It ranges from 0-3 (mean = 1.2; mode = 1). Table III shows that the most frequent practice related to employee autonomy is support for employees to work on their own ideas, and Table IV shows that most firms use only one of the practices although almost 12 per cent of the firms use all three practices. Over a quarter of the firms (28.3 per cent) have not adopted any of these employee autonomy practices.

4.5 Control variables

We control for firm size, since the literature has suggested that this is a key characteristic negatively affecting the innovative performance of companies (Ahuja *et al.*, 2008). We also control for firm age, because older firms are less likely to introduce new and radically new products (Ahuja *et al.*, 2008). As the distribution in our sample is skewed towards younger firms, we corrected the variable using the logarithmic function. Industry affiliation is used as a means of controlling for external contingencies, since we employed

Activities	*n* (= yes)	Mean	SD	1	2	3
Initiated intrapreneurial activities internally in the company	84	0.26	0.44	1		
Supported employees to work on their own ideas for the company	176	0.55	0.50	0.23***	1	
Provided time for creativity	115	0.36	0.48	0.23***	0.16***	1

Notes: $n = 321$. *,**,***Significant 0.1, 0.05 and 0.001 levels, respectively

Table III. Employee autonomy among Danish SMEs: descriptive statistics and correlations

Number of employee autonomy practices	Frequency	%	Cum. %
0	87	28.3	28.3
1	114	37.1	65.5
2	71	23.1	88.6
3	35	11.4	100.0
Total	307	100.0	

Table IV. The use of employee autonomy practices among Danish SMEs

a multi-industry approach. We include industry controls with respect to their technology intensity, as defined by the OECD sectors, because high-tech industries have been related to higher innovative performance (Gassman *et al.*, 2010; Pavitt, 1984). We introduced two dummy variables (i.e. high-tech sector and low-tech sector), each having medium-tech as the basis level. We further introduced a structural control variable for the firm's location, in particular if the firm is located in the greater Copenhagen area (dummy variable = 1 if the firm was located in the capital area of Denmark; 0 = location in rest of Denmark). Firms located in densely populated areas may have greater access to external networks. We also take into account whether the firm had implemented process innovation (dummy variable = 1 if the firm has implemented production methods or processes that are new to the firm in the last three years; 0 = no). This control was entered to accommodate the observations of Pisano and Wheelwright (1995), who argue that the simultaneous development of product and process is necessary. According to these authors, process innovation smoothens the launch of new products and ensures faster market penetration. Finally, patent application is included as a dummy variable to account for the firms that have applied (once or several times) for the formal protection of their inventions in the period from 2007 to 2009 (1 = yes; 0 = no). Patents are added because they are considered important instruments in safeguarding the profitability of innovations (Teece, 1986).

4.6 Strategy for hypotheses testing

Besides the descriptive facts (see Table AI), the paper employs mediation analysis to test the hypotheses using the software SPSS (v.23)[2] and STATA (v.14). We preferred regression techniques (fractional regression, binary logit and ordinal regression) over structural equation modelling due to the use of single indicator variables (vs a model with latent variables) and to the possibility of including control variables.

To establish the existence and type of mediation, we applied the method described by Hayes (2013) and Zhao *et al.* (2010) consisting of three steps. The first step is to establish that there is a significant indirect relation between the predictor and the outcome variable[3]. It requires two estimation procedures assessing: the predictor-mediator relation, the mediator–outcome relation, controlling for the effects of the predictor. The initial estimation procedure corresponds to the testing of *H1* and *H2*, where we applied ordinal regression due to the categorical nature of the mediator (employee autonomy). The subsequent estimation procedure refers to *H3* and *H4*. For the product innovation outcome, we adopted binary logistic regression fully specified with controls. For the innovation sales outcome, we adopted fractional regression analysis, also fully specified with controls. Fractional regression is preferred over the commonly applied Tobit (e.g. Laursen and Salter, 2006), as it requires that the dependent variable is a share taking on values between 0 and 1. The second step is to assess the direct effect of the predictor, conditional to the mediator. It is used to classify the type of mediation effect. If significant, the overall effect of the predictor is calculated, as to indicate whether the mediation is complementary or competitive in nature. The third step examines the significance of the mediated effect using bootstrapped confidence intervals[4]. In the estimations, we bootstrapped 1,000 times. The suggested approach for analysing mediation is preferred over the well-known Baron and Kenny's (1986) approach. Recently the approach has been criticised for using as the main starting point of the mediation analysis the effect of X (independent variable) on Y (the dependent variable), which must be significant if one is to continue the search for mediation. However, according to Zhao *et al.* (2010, p. 199) this approach would result in only complementary mediations being identifiable. Further advantages of the suggested approach are that we can include the entire model with controls in the estimation of the mediation effects and that we can categorise the type of mediation. Baron and Kenny (1986) recommend that the significance of the indirect

path is established using the Sobel test, which is also subject to criticism. We calculated it nonetheless as a supplementary check (see Footnote 4).

4.7 Common method bias

In order to address concerns related to common method variance, we applied the Harman's single factor test in which all variables of our study were loaded into one exploratory factor analysis. As the un-rotated solution of this analysis resulted in four factors with eigenvalues greater than 1 (each single factor accounted for no more than 20 per cent of total variance), common method bias is not considered a serious issue for our study (Podsakoff *et al.*, 2003).

5. Results

Tables V and VII present the results (full model specification), respectively, for inbound and outbound OI, whereas Tables VI and VIII present the results of the mediation analyses. Tables V and VII first present findings related to *H1* and *H2* – with autonomy as the dependent variable. Notice that these are calculated for both sub-samples of the data set (see bottom of tables for sub-sample), in order to ensure that the calculations for the mediation analyses are carried out on comparable samples. The tables then introduce the outcomes referred to in *H3* and *H4* for the two dependent variables – product innovation and innovation sales.

5.1 Inbound OI

The results of Table V reveal that inbound OI is positively and significantly related to employee autonomy ($p < 0.001$) in models 1 and 3, thereby confirming *H1*. Employee autonomy, in turn, is positively and significantly related to innovation sales ($p < 0.001$). As the (conditional) direct relation between inbound OI and innovation sales is not significant ($p > 0.1$), it can be concluded that inbound OI presents an indirect-only (mediation) relationship with innovation sales (see also Table VI). On the contrary, no significant association is found between employee autonomy and product innovation ($p > 0.1$), while the (conditional) direct relationship between inbound and product innovation is positive and significant ($p < 0.05$). Thus, only a direct positive relationship between inbound OI and product innovation can be confirmed (direct-only, non-mediation). Hence, *H3* is corroborated only with respect to innovation sales.

5.2 Outbound OI

In a similar fashion, the results of Table VII show a positive and significant association between outbound OI and the employee autonomy ($p < 0.001$). In particular, we distinguish between adoption of 1 and 2 outbound OI practices and show results for the two sub-samples separately (models 7 and 9). We find that both levels of outbound OI are significant ($p < 0.001$) for the product innovation sub-sample. In the innovation sales sample, the adoption of 2 outbound is significant ($p < 0.05$), while the adoption of 1 outbound OI practice is only tentatively significant ($p < 0.1$). The results thereby confirm *H2*, with the strongest relationship found for two outbound practices.

Employee autonomy and innovation sales are positively and significantly related ($p < 0.001$). Since the (conditional) direct relationship is also positive and significant ($p < 0.05$) for two practices, it thus implies a complementary mediation in the relationship between outbound OI and innovation sales. No association is found between employee autonomy and product innovation ($p > 0.1$) and since the (conditional) direct relationship is not significant either, it can be concluded that outbound OI presents no relationship with product innovation (see also Table VIII). In this way, *H4* can only be verified with respect to innovation sales (with the caveat that not a full, but a complementary mediation was found).

Table V.
Regression analysis for inbound open innovation

	Model 1 Autonomy (*H1*)			Model 2 Product innovation (*H3*)			Model 3 Autonomy (*H1*)			Model 4 Innovation sales (*H3*)		
	β	SE	*p*	*β*	SE	*p*	*β*	SE	*p*	*β*	SE	*p*
Antecedents												
Inbound OI	0.476	0.102	0.000***	0.307	0.129	0.018**	0.424	0.126	0.001***	−0.032	0.071	0.645ns
Mediator												
Autonomy				0.127	0.200	0.524ns				0.386	0.095	0.000***
Controls												
Firm age	−0.109	0.160	0.497ns	−0.141	0.204	0.488ns	−0.200	0.190	0.292ns	−0.312	0.127	0.014**
Firm size	−0.154	0.169	0.363ns	0.056	0.231	0.809ns	−0.106	0.197	0.589ns	0.135	0.112	0.228ns
High-tech sector	−0.595	0.582	0.307ns	0.146	0.885	0.869ns	−0.743	0.655	0.257ns	0.725	0.394	0.065*
Low-tech sector	0.513	0.313	0.100*	0.019	0.399	0.962ns	0.385	0.383	0.314ns	−0.272	0.279	0.331ns
Location in Copenhagen area	0.084	0.398	0.833ns	0.068	0.551	0.901ns	0.184	0.461	0.690ns	0.202	0.293	0.491ns
Process innovation	1.067	0.290	0.000***	0.721	0.357	0.044**	1.127	0.362	0.002***	−0.891	0.237	0.000***
Patent application	0.209	0.336	0.534ns	1.492	0.650	0.022**	0.021	0.369	0.954ns	0.289	0.207	0.162ns
Model												
Specification	Ordinal regression			Binary logistic regression			Ordinal regression			Fractional regression		
Fit type	Cox and Snell/Test of parallel lines			Cox and Snell/Hosmer and Lemeshow			Cox and Snell/Test of parallel lines			Wald statistic		
Fit stats	0.204		0.646	0.147		0.173	0.161		0.508	37.37		0.000
Sample	307			307			229			229		

Notes: *,**,***Significant 0.1, 0.05 and 0.001 levels, respectively

Relations	Model 5 Product innovation (*H3*)	Model 6 Innovation sales (*H3*)
(a) Inbound open innovation → Employee autonomy	0.420 (0.000***)	0.420 (0.000***)
(b) Employee autonomy → Innovation performance	0.127 (0.524ns)	0.386 (0.000***)
(c) Inbound open innovation → innovation performance	0.307 (0.018**)	−0.033 (0.645ns)
(a) × (b) – Indirect effect of inbound open innovation on innovation performance	0.027	0.006
Confidence interval (95%)	(−0.065: 0.132)	(0.012: 0.103)
Sobel test	(0.537ns)	(0.035**)
Conclusion	No mediation	Indirect-only mediation

Notes: The coefficients and significance levels are provided from the models estimated with control variables (the fully specified models). *,**,***Significant 0.1, 0.05 and 0.001 levels, respectively

Table VI. Mediational analysis for inbound open innovation

It is worth mentioning that process innovation ($p < 0.05$) is the only control variable consistently significant across the different model specifications. Whereas the effect of process innovation on product innovation is positive and significant, pointing to a possible complementary effect, the effect is negative and significant for innovation sales, indicating a possible offsetting relationship. Patent application is positive and significantly related to product innovation, which validates our expectation that intellectual property rights increase the chance of new product launch, but it is not related to innovation sales. Firm age is significant and negative for innovation sales. This thereby implies that older firms are less likely to reshape their revenues through innovation, which may be because they either have older and better selling products or are very conservative and unable to introduce changes in their portfolio of offerings.

The outcomes with respect to the Haye's mediational process are presented in Tables VI and VIII. Results suggest robustness across regression techniques. They confirm the positive and significant relation between inbound OI and employee autonomy, as well as between outbound OI and employee autonomy. Once more, *H1* and *H2* are supported. The association of employee autonomy to innovation sales is established, yet not to product innovation, when controlling for openness. The bootstrap confidence intervals are outside zero for inbound OI (0.01 to 0.10) and for outbound OI (2 practices) (0.01 to 0.11). Additionally, the Sobel tests are significant: $\beta = 0.03$, $p < 0.05$ and $\beta = 0.05$, $p < 0.10$, respectively. Consequently, the mediation effects put forward by *H3* and *H4* are again confirmed with respect to innovation sales, while rejected for product innovation. Hence, an indirect-only mediation is found for employee autonomy in the link between inbound practices and innovation performance, while a complementary mediation is found for employee autonomy in the link between outbound practices and innovation performance. Our findings are illustrated in Figures 2 and 3.

6. Discussion and conclusions

We conclude that an important reason why firms profit from adopting an OI model is that they grant autonomy to their employees. The economic benefits of OI are completely captured only if firms adopt a number of internal organisational practices that provide employees with time, freedom and independence to conduct their work. We find that, in combination, these activities mediate the effect of openness on innovation sales (although not on product innovation).

To conduct our mediation study, we also investigated direct outcomes of the two dimensions of OI. Interestingly, we found that inbound practices positively increase the likelihood of a firm introducing new products, while outbound practices did not demonstrate

Table VII.
Regression analysis for outbound open innovation

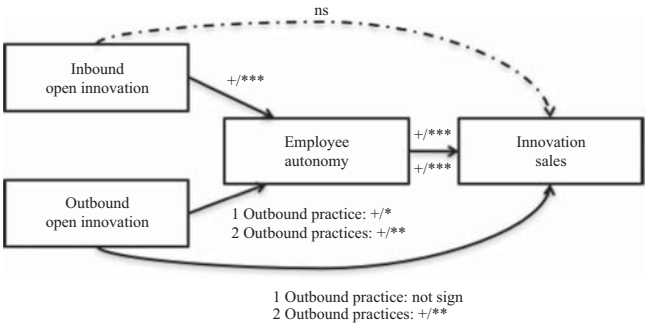
	Model 7 Autonomy (*H2*)			Model 8 Product innovation (*H4*)			Model 9 Autonomy (*H2*)			Model 10 Innovation sales (*H4*)		
	β	SE	*p*	*β*	SE	*p*	*β*	SE	*p*	*β*	SE	*p*
Antecedents												
Outbound OI – 1 outbound practice	1.025	0.287	0.000***	0.153	0.358	0.669ns	0.643	0.338	0.057*	0.173	0.236	0.464ns
2 outbound practices	2.112	0.538	0.000***	−0.086	0.754	0.909ns	1.746	0.608	0.004**	0.749	0.330	0.023**
Mediator												
Autonomy				0.277	0.199	0.163ns				0.325	0.088	0.000***
Controls												
Firm age	0.024	0.159	0.878ns	−0.087	0.204	0.671ns	−0.071	0.189	0.705ns	−0.296	0.129	0.021**
Firm size	0.006	0.167	0.974ns	0.123	0.228	0.590ns	0.042	0.195	0.828ns	0.135	0.113	0.232ns
High-tech sector	−0.411	0.581	0.479ns	0.598	0.886	0.499ns	−0.588	0.649	0.365ns	0.585	0.362	0.106ns
Low-tech sector	0.356	0.310	0.250ns	−0.132	0.389	0.734ns	0.165	0.379	0.663ns	−0.299	0.279	0.285ns
Location in Copenhagen area	0.157	0.396	0.691ns	0.032	0.538	0.952ns	0.114	0.460	0.805ns	0.162	0.283	0.566ns
Process innovation	1.069	0.287	0.000***	0.775	0.353	0.028**	1.036	0.358	0.004***	−0.922	0.237	0.000***
Patent application	0.514	0.323	0.112ns	1.772	0.640	0.006***	0.221	0.360	0.540ns	0.220	0.196	0.262ns
Model												
Specification	Ordinal regression			Binary logistic regression			Ordinal regression			Fractional regression		
Fit type	Cox and Snell/Test of parallel lines			Cox and Snell/Test of parallel lines			Cox and Snell/Test of parallel lines			Wald statistic		
Fit stats	0.194		0.986	0.124		0.298	0.144		0.899	46.12		0.000
Sample	307			307			229			229		

Notes: *,**,***Significant 0.1, 0.05 and 0.001 levels, respectively

Relations	Model 11 Product innovation (*H4*)	Model 12 Innovation sales (*H4*)
(a) Outbound open innovation → Employee autonomy		
1 Outbound practice	0.773 (0.010***)	0.773 (0.010***)
2 Outbound practices	1.891 (0.000***)	1.891 (0.000***)
(b) Employee autonomy → Innovation performance	0.277 (0.163ns)	0.325 (0.000***)
(c) Outbound open innovation → Innovation performance		
1 Outbound practice	0.153 (0.669ns)	0.173 (0.464ns)
2 Outbound practices	−0.086 (0.909ns)	0.749 (0.023**)
(a) × (b) – Indirect effect of outbound open innovation on innovation performance		
1 Outbound practice	0.069	0.007
2 Outbound practices	0.281	0.038
Confidence interval (95%)		
1 Outbound practice	(−0.146: 0.289)	(−0.030: 0.069)
2 Outbound practices	(−0.056: 0.693)	(0.011: 0.110)
Sobel test		
1 Outbound practice	(0.289ns)	(0.523ns)
2 Outbound practices	(186ns)	(0.064*)
Conclusion		
1 Outbound practice	No mediation	No mediation
2 Outbound practices	No mediation	Complementary mediation

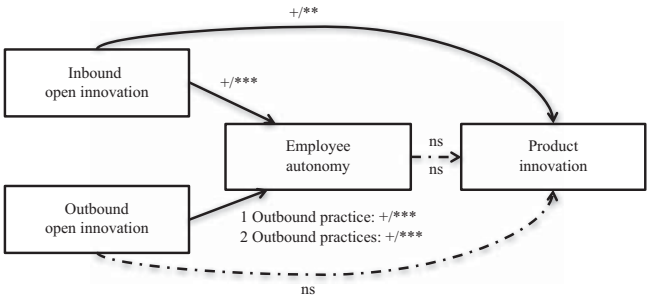
Notes: The coefficients and significance levels are provided from the models estimated with control variables (fully specified models). *,**,***Significant 0.1, 0.05 and 0.001 levels, respectively

Table VIII. Mediational analysis for outbound open innovation



Notes: *,**,***Significant 0.1, 0.05 and 0.001 levels, respectively

Figure 2. Results for innovation sales



Notes: *,**,***Significant 0.1, 0.05 and 0.001 levels, respectively

Figure 3. Results for product innovation

any direct effects on product innovation. However, the more extensive use of outbound innovation is directly related to higher innovation sales. Opening up the innovation process to external knowledge input thus directly enhances firms' ability to market new products.

With respect to theory, our findings contribute to a more nuanced understanding of the management of OI. Specifically, our study highlights the role job design plays with respect to autonomy as a mediator between firms' external engagement and improved innovation performance. Drawing on theories of creativity, corporate entrepreneurship, and human resource management, our model explicates how openness links to autonomy, suggesting that the high levels of flexibility and experimentation characteristic of OI require employees to work independently so as to be creative, intrinsically motivated, proactive, entrepreneurial and responsible for problems. These findings provide important information towards identifying mechanisms behind an approach that has been promoted as "imperative" for innovation strategy (Chesbrough, 2003).

In this way, our study extends the link between the literature on human resource management (Parker *et al.*, 1997; Foss *et al.*, 2009) and research on OI. While the role of incentives and rewards systems have been investigated in this context (Foss *et al.*, 2011; Fu, 2012), a fundamental human resource responsibility such as job design had not. Furthermore, our results suggest a link worth pursuing between the OI and the corporate entrepreneurship literature (Hornsby *et al.*, 2002; Kuratko *et al.*, 2015), especially when considering the intra- and entrepreneurial qualities required for OI. There seems to be a considerable overlap between the aims and mechanisms employed in the implementation of entrepreneurial and OI strategies. Our study establishes another interesting theoretical connection with the creativity literature. While creativity has long been assumed to drive innovation inside the firm, it has not been comprehensively addressed in the relationship of the firm with outside contexts. In stressing the highly experimental nature of OI practices, we underscore how creative work may play out in the realisation of opportunities beyond firm boundaries. The integration of OI literature with other intellectual streams resonates with a call from the recent review by Randhawa *et al.* (2016), who diagnosed the inward-looking and idiosyncratic theoretical base of the field.

This paper contributes to the discussion related to the conflict between professional autonomy and managerial control (Bailyn, 1985; Criscuolo *et al.*, 2013), which looks at how the trade-offs between freedom and accountability may sustain innovation performance. We find an emphasised need for employee autonomy in settings of intensified external engagement, where firms source and share technological know-how beyond their boundaries.

In this regard, our study also links to a research tradition that focuses on analysing the relationship between external ties and innovation performance by providing a contribution in terms of measurement that is worth mentioning. Compared to existing literature on performance outcomes of openness, which primarily uses the Community Innovation Survey data and relies exclusively on some indicators of inbound openness (e.g. Barge-Gil, 2013; Fosfuri and Tribó, 2008; Laursen and Salter, 2006), this paper adds a practice-based perspective to the study of OI. Our findings extend work on simultaneously analysing the inbound and the outbound dimensions (Burcharth *et al.*, 2014). Prior empirical work in the field mainly investigated these two dimensions separately and on the basis of distinct proxies, which limits the comparability of the findings (Dahlander and Gann, 2010). Furthermore, we apply different performance measures, enabling an elaborated and more nuanced view of the effectiveness of openness.

Our study provides useful insights for practitioners too. It shows that OI requires not only connections to the outside world, but also relevant in-house changes in the job design of the staff. Apart from explicit efforts to encourage the use of inbound and outbound practices, managers that want to yield economic results should simultaneously guarantee autonomy to their employees, formalizing ways in which they can self-direct their work. Our research suggests that managers may implement three distinct activities to enable

discretion: support employees to work on their own ideas; provide them with time for creativity, and allow employees to initiate intrapreneurial activities. This is a far from straightforward task that conceivably requires involvement of several organisational functions, e.g. the HR function, in addition to the technical staff. Besides, autonomy presupposes the engagement of middle managers who can ultimately endow their team members with freedom. Limiting employees' autonomy and closely monitoring their behaviour may hamper OI, while it may produce positive side effects such as greater coordination, strategic alignment and more efficient use of resources. We do not ignore well-known trade-offs between autonomy and control, rather we pinpoint how they play out in the context of openness. As it is the case with other managerial paradoxes, the middle way is not necessarily the best way or even a concrete possibility for most executives. Managers need to make informed decisions in balancing such trade-offs, and our work suggests that they may choose to sacrifice control in favour of autonomy to more proficiently implement OI. Moreover, our analysis reveals that managers may find more success with increasing the number of product innovations if they apply inbound OI practices.

Our study has a number of noteworthy shortcomings. First, the results are based on a sample of medium-sized firms from manufacturing industries. One may question whether these results would differ for particular industries e.g. services. Second, the paper studies the number of OI practices at an aggregated level, but it does not investigate the specific types of practices and their individual effects on innovation performance. We encourage such analyses in the next step along this line of research. Additionally, further tests and validation of the list of OI practices are needed in forthcoming data collections. Fourth, we investigated only the short-term performance implications of openness due to the cross-sectional nature of the data. A collection of longitudinal data can enrich the analysis, as it will enable an examination of long-term effects. Fifth, our expectations of causality are built on extensive theoretical rationale, yet the restrictions of our dataset do not allow us to completely rule out the possibility of reverse causality. Finally, this study does not explore the coordination and agency costs that may be engendered by autonomy. A future step in this field of investigation is to study the costs of employee autonomy and the conditions under which it is more effective (i.e. for small firms or large firms; or for particular projects).

Notes

1. We investigate autonomy as an organisational practice, that is, as an element of job design established by management. While the examination of the microfoundations at the individual level constitutes a promising research avenue, it does not constitute the focus of our study.
2. Using the mediation process plugin from http://afhayes.com/introduction-to-mediation-moderation-and-conditional-process-analysis.html
3. According to the state-of-the-art, mediation analysis no longer imposes evidence of simple association between the predictor and the outcome as a precondition (Hayes, 2013).
4. Bootstrapped confidence intervals are used because they represent a better alternative to the Sobel test. The Sobel test has important flaws as it is relatively low power and has unrealistic normality assumptions (Frazier *et al.*, 2004; Zhao *et al.*, 2010).

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Appendix

Table AI. Descriptive statistics and correlations among study variables

Variables	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Product innovation	0.79	0.41	1.000													
2. Innovation sales	21.9	21.9	na	1.000												
3. Inbound OI	4.23	1.63	0.188***	0.089	1.000											
4. Outbound OI (1 prac.)	0.53	0.49	0.017	−0.006	0.132**	1.000										
5. Outbound OI (2 prac.)	0.07	0.25	0.048	0.171***	0.152***	−0.288***	1.000									
6. Employee autonomy	1.18	0.97	0.144**	0.180***	0.334***	0.117**	0.164***	1.000								
7. Firm age (Ln)	3.32	0.91	−0.035	−0.227***	0.088	−0.030	−0.069	−0.086	1.000							
8. Firm size (Ln)	1.39	0.50	0.088	−0.092	0.253***	−0.001	−0.050	0.065	0.383***	1.000						
9. High-tech sector	0.06	0.24	0.065	0.169**	0.063	0.079	0.038	−0.005	−0.099*	−0.097*	1.000					
10. Medium-tech sector	0.67	0.47	−0.001	0.011	0.076	0.071	−0.028	−0.072	−0.036	0.039	−0.364***	1.000				
11. Low-tech sector	0.27	0.44	−0.038	−0.114*	−0.115**	−0.119**	0.009	0.079	0.092	0.011	−0.156***	−0.863***	1.000			
12. Process innovation	0.66	0.47	0.211***	−0.250***	0.146**	0.008	0.090	0.285***	0.013	0.129*	−0.084	−0.062	0.113*	1.000		
13. Location (Cph.)	0.12	0.33	0.028	0.074	0.055	−0.033	0.016	0.024	0.110*	0.066	0.232***	−0.029	−0.095*	0.083	1.000	
14. Patent application	0.23	0.42	0.223**	0.170**	0.328**	0.115*	0.137**	−0.007	0.314**	0.127*	0.057	0.054	0.124	0.207**	0.055	1.000

Notes: *,**,***Significant 0.1, 0.05 and 0.001 levels, respectively

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