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The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity

Abstract

New disruptive technologies in the context of the Internet of Things (IoT), especially, are changing the manner in which knowledge is managed within organisations, calling for new and inventive knowledge management system and an open approach, to foster knowledge flows. This pattern expectedly should also enhance the development of internal knowledge management capacity, which in turn is a prerequisite of firm's innovativeness. In this context, the main goal of this research is to investigate the relationship among knowledge management system, open innovation, knowledge management capacity and innovation capacity. To reach this goal, the research employs structural equation modelling on a sample of 298 Italian firms from different sectors. The findings indicate that knowledge management system facilitates the creation of open and collaborative ecosystems, and the exploitation of internal and external flows of knowledge, through the development of internal knowledge management capacity, which in turn increases innovation capacity. The research further draws on its findings to identify significant scholarly and managerial implications, and to prescribe future research directions.

Keywords: Internet of Things, Knowledge Management System, Knowledge Management Capacity, Innovation Capacity, Open Innovation, Knowledge Flows

Introduction

The Internet of Things (IoT) concept has aroused much excitement in the last years. Descriptively, the IoT can be considered as a series of disruptive digital technologies, influencing the daily life of both individuals and businesses (Kim and Kim, 2016). In line with this phenomenon, firms are becoming more intelligent in developing, adopting and adapting disruptive technologies in their business processes, in order to increase their efficiency and innovativeness through knowledge flows and data/information gathering

(Malhotra, 2000; Vrontis et al., 2012). Facing the knowledge and technology-driven contemporary economy – characterized by trends such as globalization, technological and industrial convergence – successful firms use specific mechanisms to manage knowledge (Gold and Arvin Malhotra, 2001). In fact, the widespread scholarly and applied interest in organizational knowledge has primarily addressed the issue of managing knowledge to increase organizational benefits.

Knowledge management regards the processes of organize and leveraging firm's collective knowledge to achieve sustainability (Argote and Ingram, 2000) and to improve innovativeness and responsiveness to environmental changes (Teece, 2007, Thrassou and Vrontis, 2008). Strikingly, though, little research exists on the design, use, or success of ICTs and systems to support knowledge management (Del Giudice and Della Peruta, 2016). This constitutes a significant gap in scientific business knowledge, as well as in its applied context, since many organisations are developing knowledge management system (KMS) designed specifically to facilitate the creation, sharing and storage of knowledge. Considering also the emerging and increasing momentum of the IoT phenomenon, which is changing the nature of innovation itself, firms can gain competitive advantage through data gathering and exchange, by building digital ecosystems through ICT tools and infrastructures, experimental technology platforms, and applications (Soto-Acosta and Cegarra-Navarro, 2016).

However, despite the significant advances in several knowledge management aspects, results have been inconsistent and confusing regarding the variables that affect knowledge management programs (Lopes-Nicolas and Merono-Cerdan, 2011). More specifically, the effects of knowledge management practices have been scarcely investigated in literature (Choi et al., 2008), and thus is not clear how firms benefit from these practices (Tseng, 2008). Thus, focus is naturally drawn to the relationship between knowledge management, innovativeness and firm performance (Darroch, 2005; Lopes-Nicolas and Merono-Cerdan, 2011). Moreover, knowledge management research, specific to internal knowledge, is often limited and neglects the integrative perspective of both internal and external knowledge (Teece, 2007). In fact, in the current dynamic environment, firms increasingly have to heighten internal knowledge management capacity (KMC) in order to manage inward and outward flows of knowledge exploiting and exploring external opportunities. Here, KMC refers to the ability of an organisation to explore both internal and external knowledge, and to retain knowledge over time within the firm (Chen and Huang, 2009). Accordingly, when

adopting an open innovation approach, firms tend to build up collaborations with actors of their own ecosystem acquiring knowledge (Wang et al., 2015; Bogers et al., 2016).

In this context, this research develops a conceptual model, proposing that firms can and should exploit the IoT through the development, implementation and sustainment of KMS that involve advanced ICTs and the exploration of external sources of knowledge; which in turn is translated into higher innovation performance (considered here as the ability to introduce new products/services, processes or opening of new markets).

This research thus aims at contributing to knowledge management, innovation management and open innovation literature by shedding light on whether and how an open KMS can facilitate higher innovation capacity. Specifically, we tested our hypothesis using the structural equations modelling (SEM), on a sample of firms from different manufacturing and service sectors.

The research has been structured in the following sections: section 2 proposes the theoretical background of the paper regarding knowledge management, with focus on KMS and their relationship with open innovation theory; section 3 develops the hypotheses and the conceptual model; section 4 describes the methodology, including the sample information and variables; section 5 analyses data; and section 6 discusses the findings and provides conclusions of the research.

Theoretical Framework

Knowledge management

Knowledge management has already been recognized as a key managerial process necessary for achieving competitive advantage (Carayannis, 1999; Argote and Ingram, 2000; Dias and Bresciani, 2006). In fact, the knowledge-based view has reached growing interest in both information technology and systems, strategic management, innovation management and organizational literature (Nonaka, 1994; Spender, 1996; Nonaka and Takeuchi, 1995; Alavi and Leidner, 2001; Soto-Acosta and Merono-Cerdan, 2008; Bresciani, 2010). Specifically, it assumes that tangible resources are sources of competitive advantages only when they are applied with certain knowledge and they are hard to imitate (Grant, 1996). However, the true competitive advantage is built through the ability of the firm to apply effectively existing knowledge to create new products and processes exploiting new knowledge (Thrassou et al.,

2012). Thus, knowledge management regards the identifying and leveraging of knowledge to foster innovation processes (Darroch, 2005).

Knowledge and its management, however, relate even to the more basic work processes of the firm. Typically, Hernaus and Mikulić (2014) find that even with regards to the existence and importance of the interaction between work characteristics and work outcomes, only knowledge characteristics of work design exhibit a significant effect on both dimensions of work behaviour. In the opposite side of the spectrum, Aziz and Rizkallah (2015) measure the relationship between the idea generation of employees and the organizational factors that affect innovation performance. In detail, they find that while many factors proved to be significantly correlated with employees' innovative ideas generation, the functional and motivational factors appear to be the most important.

Two main dimensions are essential in knowledge management, namely enablers and processes. Enablers are mechanisms that facilitate knowledge management activities, such as codifying and sharing among individuals and teams (Ichijo et al., 1998). Moreover, they stimulate knowledge creation, sharing and protection, and provide the infrastructure necessary to improve the knowledge processes (Yeh et al., 2006). In turn, knowledge management processes refer to the structured coordination of managing knowledge effectively, such as knowledge creation, sharing, storage, and application (Lee and Choi, 2003). In this paper, we focus on the role of technology, which is seen as crucial in removing the boundaries to communication and knowledge flows and therefore can be considered an enabler of knowledge management (Allameh et al., 2011). In particular, following Alavi and Leidner (2001) we consider and discuss the role of ICTs as a fundamental part of KMS.

Knowledge Management Systems in the IoT context

The IoT can be considered as a series of disruptive technologies influencing the daily life of both individuals and companies (Kim and Kim, 2016). In fact, modern firms are increasingly developing and implementing disruptive ICTs in several business processes in order to increase their efficiency and innovativeness through new methods of knowledge flow and data/information gathering (Del Giudice and Straub, 2011; Del Giudice and Della Peruta, 2016). Therefore, the management of knowledge can be strongly supported by advanced ICTs. As pointed out by both knowledge management and information system's literature, KMS is essentially based on ITCs (Alavi and Leidner, 2001), because innovative ITCs (for

example the internet, intranets, extranets, data warehouses, data mining techniques, and software agents) can be used to systematize knowledge.

In detail, KMS refers to information systems applied to manage organizational knowledge and to improve the creation, storage, transfer, and application of knowledge. Thus, from a knowledge-based perspective, a KMS can be considered as a knowledge management enabler, since it allows the capturing of individuals' knowledge, so that the broader organization can benefit from its dissemination (King and Marks, 2008). Effective KMSs are mainly comprised of three components:

- IT infrastructures, namely the physical technology that helps in manage knowledge effectively such as hardware, software components and LAN (Soto-Acosta and Merono-Cerdan, 2008).
- Collaborative technologies, including the intranet, discussion forums, shared databases, document repositories and workflows (Merono-Cerdan et al., 2007).
- The intranet, which can integrate different collaborative technologies, and whose use orientation regards three primary implementation aims (Bafoutsou & Mentzas, 2002; Lopez-Nicolas and Soto-Acosta, 2010): (a) The ICT informative orientation aims at providing commercial information to several stakeholders, across organizational and functional boundaries; (b) the ICT communicative orientation allows costs' reduction and interaction with several business agents within and outside the organization; and (c) the ICT workflow orientation, through which electronic processes within corporate technologies are established.

In addition, in an open and collaborative IoT-driven environment, firms can and should integrate technologies (Soto-Acosta et al., 2014). This technology integration regards: a) the integration of the website with back-end systems and databases; a) the integration of internal databases with databases of external stakeholders.

Knowledge management and open innovation theory

As noted in the previous section, knowledge management is recognized as a necessary process in sustaining and maintaining competitive advantages in this knowledge-driven global economy. Nevertheless, research in this field is often focused on internal knowledge (Lichtenthaler and Lichtenthaler, 2009), while a more integrative perspective, which considers both internal and external knowledge, is relatively scarce (Grant and Baden-Fuller, 2004;

Chesbrough, 2006; Teece, 2007; Del Giudice and Maggioni, 2014). From a dynamic capabilities perspective, Teece (2007) supports that firms could combine internal and external knowledge in order to cope with the dynamic environment.

Lichtenthaler and Lichtenthaler (2009) further develop a framework for examining a firm's ability to manage knowledge in the open innovation context. The authors, considering knowledge exploration, retention and exploitation inside and outside the organizational boundaries and relying on previous relevant studies, identify six different knowledge management capacities: (a) inventive capacity regards the firm's ability to internally explore or generate new knowledge (Chebbi et al., 2013); (b) absorptive capacity refers to a firm's ability to explore and utilize external knowledge (Cohen and Levinthal, 1990); (c) transformative capacity is the firm's ability of internally store knowledge (Garud and Nayyar, 1994); (d) connective capacity represents the firm's ability to store knowledge in inter-organizational relationships (Kale and Singh, 2007); (e) innovative capacity is the final process stage of developing new products and services (Khilji et al., 2006); and (f) desorptive capacity regards the outward knowledge transfer (Lichtenthaler, 2007).

Recent literature suggests that the knowledge-based view of the firm is an appropriate theoretical background to explain open innovation processes (Vanhaverbeke and Cloudt, 2014), in which firms try to have right internal and external resources in place to create new products and services. Moreover, the knowledge-based view of the firm focuses only on internal resources in line with closed innovation (Nonaka, 1994; Lichtenthaler and Lichtenthaler, 2009).

Ferreras-Mendez et al. (2016), extending the absorptive capacity concept, investigate the effects of external sourcing strategies on explorative learning, transformative learning, and exploitative learning, to find that different search strategies exert different effects on different learning processes. Open innovation theory goes beyond the internal perspective proposed by knowledge management literature, suggesting that firms should use both external and internal knowledge (Chesbrough, 2004; Ferraris et al., 2017b). Thus, new innovation models suggest new forms of interactions and collaborations for fostering new products and processes development (Bresciani et al., 2013; Chebbi et al., 2015).

With regard to the inbound open innovation model, firms can acquire or source for external knowledge from different market-based partners, such as customers, suppliers and competitors (Wang et al., 2015; Ferraris et al., 2017a), or science-based partners, such as

research centers and universities (Carayannis et al., 1998; Santoro et al., 2016). Openness variety regards the number of external sources involved in the innovation process, and partner intensity is the depth of these relationships (Aloini et al., 2015). Openness in innovation can be also explained in terms of readiness to collaborate, namely the propensity of a firm to open to several forms of collaborations; and in terms of trust developed with external partners (Ahn et al., 2016).

Hypothesis development

Several studies on knowledge management suggest that KMS advantages include the ability of organizations to be flexible and to respond more quickly to changing market conditions, and the ability to be more innovative, as well as improving decision making and productivity leveraging internal knowledge (Stata, 1997). From a knowledge-based view perspective, implementing effective ITCs helps in managing knowledge and developing internal KMC. In particular, the flexibility of modern ITCs can foster knowledge inventiveness, knowledge absorption, knowledge transformation and knowledge connection (Alavi and Leidner, 2001; Lichtenthaler and Lichtenthaler, 2009). This is because KMS can encourage the employees to become proactive. Moreover, access to an increasing amount of information allows them to improve capacities and ideas creation (Del Giudice and Della Peruta, 2016).

We thus propose that the application of a KMS can create infrastructures and an environment that positively contribute to organizational knowledge management by developing internal KMC.

Hp. 1: KMS is positively associated with KMC

In addition, the above literature indicates that an open approach to innovation can help in developing internal KMC, and that ITC applications allow firms to convey relevant information useful in reconfiguring internal mechanisms (Del Giudice and Della Peruta, 2016). This means that, with higher openness, KMS improves KMC. In particular, exploiting internal and external knowledge flows, and developing digital ecosystems through new ICTs, is essential in bearing the knowledge management and acquisition (Soto-Acosta and Cegarra-Navarro, 2016). In addition, the nature of the relationship, the search mode, and the level of trust with external partners could also affect the development of internal KMC (Ahn et al., 2016). Thus, we propose that an open approach to innovation is likely to enhance internal KMC.

Hp. 2: KMS positively influences KMC in an indirect manner via open innovation

Hp. 3: Open innovation helps in building KMC

To date, empirical evidence exists that open innovation strategy enhances the innovativeness of firms. Laursen and Salter (2006) assess open innovation strategy on firms' innovative performance by introducing the concepts of "search breadth" i.e. the number of external sources incorporated in the innovation process, and "search depth" i.e. the intensity of the collaboration with each partner. Following this contribution, several studies confirm that openness propensity is beneficial for both a firm's innovative and financial performance, even though some scholars indicate that over-searching risks also exist (Berchicci, 2013). However, other studies suggest that firms enhance open innovation performance only developing internal capabilities (Gulati, 1999; Lichtenthaler and Lichtenthaler, 2009), and therefore without internal mechanisms open innovation strategy does not increase innovativeness (Amirkhanpour et al., 2014; Zobel, 2016). One possible explanation is that an increase in knowledge flows inside and outside the firm can intensify the challenge related to knowledge management. Lichtenthaler and Lichtenthaler (2009) underline that firms have to develop six different capacities in order to better integrate internal and external stimuli to innovation. Thus, knowledge is the essential asset for increasing a firm's innovativeness. Converting general knowledge into specific knowledge is essential in achieving this (Smith, 2001). Developing internal KMC helps in generating new ideas and exploiting the organization's thinking power, in turn supporting the development of innovative capacity (Lichtenthaler and Lichtenthaler, 2009). In fact, a firm with internal KMC is also likely to be more innovative (Massey et al., 2002) and to address and manage complexity (Cavusgil et al., 2003). This is because, in order to be more innovative, firms should ensure that knowledge is used effectively and efficiently, through the development of internal mechanisms.

As a result, we propose that open innovation is directly associated with innovation capacity, and that KMC affects the relationship between open innovation and innovation capacity.

Hp. 4: Open innovation is positively associated with innovation capacity

Hp. 5: Open innovation will positively influence innovation capacity in an indirect manner via KMC

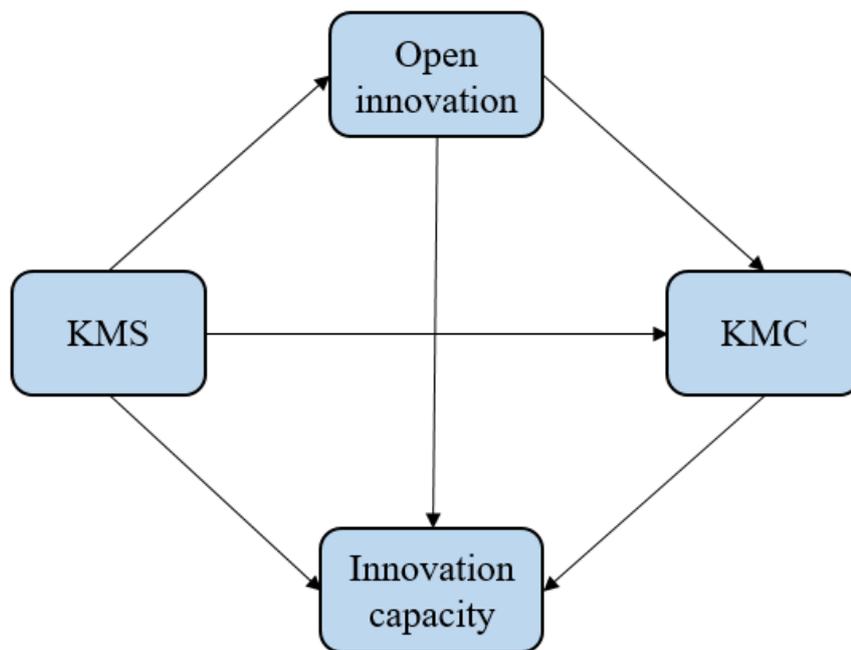


Fig. 1: design model

Methodology

Sample and data collection

In order to test our hypotheses, we have carried out a survey of Italian firms. A questionnaire was distributed to 689 firms from different sectors and of different size (Table 1), selected from the Italian database AIDA of Bureau Van Dijk. Although a single respondent approach is frequently used in knowledge management and open innovation studies, we selected both CEO and CTO managers to serve as the key informants. This is because these hold the most important information on knowledge management and innovation processes within a firm, and each role possesses different information on key relevant issue regarding the firm (Cao et al., 2009). Furthermore, this practice allows avoiding problems of common variance (CMV).

Due to non-respondents, incomplete/invalid questionnaires that have been discarded, the final sample comprises 298 firms, which corresponds to around 43% of the original sample. Of the responses, 28 (9.39%) were from large firms, 154 (51.68%) from medium sized firms, and 116 (38.93%) from smaller firms (tab. 1). The sample represents firms from different manufacturing and service sectors (tab. 1).

Tab. 1: sample description

Firm size	No.	%	Industry sector	No	%
Small	116	38.93%	Biotechnology	36	12.08%
Medium	154	51.68%	Finance	32	10.74%
Large	28	9.39%	Food and Beverage	72	24.16%
			ITC service	28	9.40%
			Manufacturing	88	29.54%
			Pharmaceutical	12	4.02%
			Others	30	10.06%
Total	298	100%	Total	298	100%

Research design and variables

The scope of the empirical research included the investigation of diverse aspects, such as the adoption of KMS, open innovation approach, KMC and innovation capacity. The survey was built on several closed-end questions with a brief statement about the research purpose, starting from basic firm information, such as the sector. The questionnaire subsequently asked for specific information about knowledge management and open innovation, involving a statement of value on a range of 1 (low importance) to 7 (high importance).

Data were then analysed and employed to build the four latent variables, namely KMS, open innovation, KMC, and innovation capacity; all useful for the SEM. Several authors from ICT, knowledge management and open innovation have used this method (Aloini et al., 2015; Ahn et al., 2016; Vrontis et al., 2016), which is an appropriate technique for testing a theory when latent constructs are involved. In addition, SEM allows the estimation of both direct and indirect effects among factors and it is characterized by its flexible interplay between theory and data. Furthermore, SEM considers errors in measurement and variables with multiple

indicators. For these reasons, we support that this method is the most appropriate for our research purpose.

To each construct, three dimensions were associated, following the relevant literature (Tab. 2). For each dimension, we developed several questions for capturing the importance of the item through a 7-Likert scale where 1 represents low importance and 7 represents high importance.

Tab. 2: Dimensions and items according the relevant literature

<i>Constructs</i>	<i>Dimensions</i>	<i>Literature</i>
<i>KMS</i>	IT infrastructures	Soto-Acosta and Merono-Cerdan, 2008
	Collaborative technologies	Merono-Cerdan et al., 2007
	Intranet use orientation	Merono-Cerdan et al., 2007
<i>Open innovation</i>	Partner intensity	Aloini et al., 2015
	Openness variety	Aloini et al., 2015
	Readiness to collaborate	Ahn et al., 2016
<i>KMC</i>	Inventive capacity	Lichtenthaler and Lichtenthaler, 2009
	Absorptive capacity	Lichtenthaler and Lichtenthaler, 2009
	Connective capacity	Lichtenthaler and Lichtenthaler, 2009
<i>Innovation capacity</i>	New or improved products or services introduced	Wang and Ahmed, 2004; Laursen and Salter, 2006; Soto-Acosta et al., 2015

New or improved process of producing introduced	Soto-Acosta et al., 2015
Opening of new markets	Aloini et al., 2015

Analysis and Results

Measurement model

First of all, we assessed the psychometric properties of the measurement scales (Gerbing and Anderson, 1988). In order to test the relationship between each factor and its measurement variables, we estimated reliability, which represents the degree to which measures are free from random error, by observing the Cronbach's alpha and composite reliability, which are adequate according to literature (Hulland, 1999). Then, we assessed construct validity (Straub, 1989). The items' loadings varied from 0.703 to 0.843 for all the latent factors, suggesting good convergent validity. Moreover, we expect content validity since the constructs were developed according to literature (see tab. 2). In sum, all fit indexes were superior to the reference values indicating a good fit of the data.

Tab. 3: data reliability and validity

Latent factors	Mean	S.D.	Cronbach's Alpha	Composite reliability
KMS				
IT infrastructures	4.298	0.718	0.81	0.80
Collaborative technologies	4.129	0.725	0.83	0.73
Intranet use orientation	4.356	0.821	0.79	0.71
Open innovation				
Partner intensity	4.898	0.805	0.82	0.80
Openness variety	4.632	0.825	0.78	0.80
Readiness to collaborate	4.268	0.816	0.72	0.70

KMC				
Inventive capacity	4.961	0.785	0.79	0.85
Absorptive capacity	4.932	0.865	0.83	0.79
Connective capacity	4.441	0.709	0.70	0.72
Innovation capacity				
New or improved products or services introduced	4.725	0.843	0.84	0.80
New or improved process of producing introduced	3.965	0.717	0.86	0.82
Opening of new markets	4.093	0.801	0.76	0.74

Hypotheses testing

All the relationships between manifested endogenous and exogenous variables were measured via a path analysis and bootstrap approach in order to conduct hypotheses testing (Anderson and Gerbing, 1988; Chin, 1998). The direct and indirect effects of the factors have been tested to find the one most influential on innovation capacity. In detail, the direct effect is the path coefficient, while the indirect effect is calculated by multiplying each path coefficient from one latent factor to a target factor. Finally, the sum of the direct and indirect effect of each factor is the total effect (table 4).

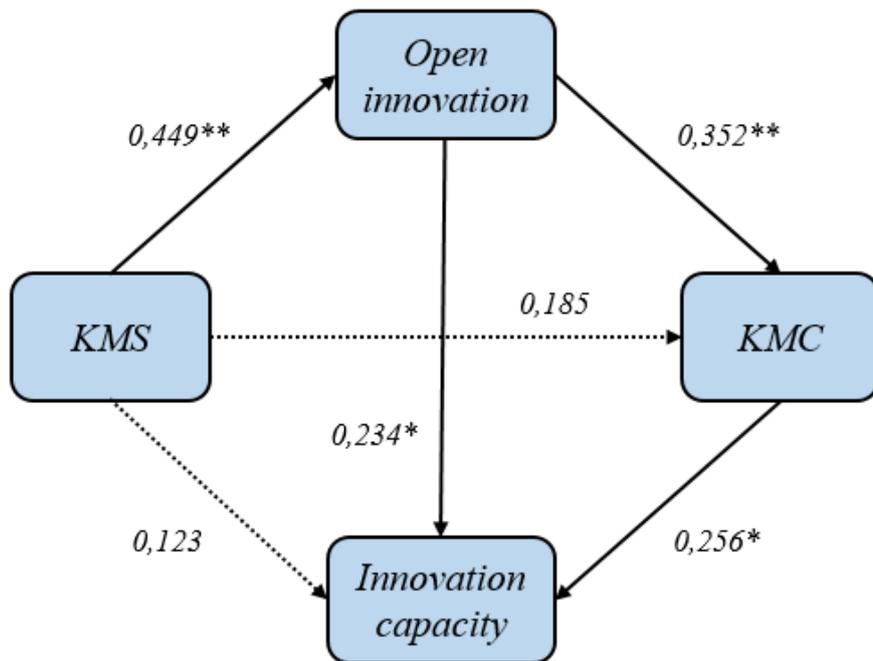


Fig. 2: the structural model

Notes: 1) $*=p<0.05$, $**=p<0.01$; 2) dotted lines represent statistical insignificant path.

All path coefficients appeared to be significant at the 10% level, except for two paths, shown through dotted lines, between (1) KMS and KMC (2) KMS and innovation capacity.

Tab. 4: direct, indirect and total effects

Factor		Factor	Direct	Indirect	Total
KMS	→	KMC	0.185	0.158	0.343
KMS	→	Innovation capacity	0.123	-	0.123
KMS	→	Open innovation	0.449	-	0.449
Open innovation	→	KMC	0.352	-	0.352
KMC	→	Innovation	0.256	-	0.256

		capacity			
Open innovation	→	Innovation capacity	0.234	0.09	0.324

As shown in figure 2, KMS is positively associated with KMC, but not significantly ($\beta=0.185$; $p>0.05$); thus *Hp 1* is not confirmed. Regarding to *Hp 2*, KMS positively and indirectly influences KMC via open innovation (total effect=0.343), as shown in table 4. In this, case the hypothesis is supported. This is in line with the third result, namely open innovation exerts a positive and significant effect on KMC ($\beta=0.352$; $p<0.01$). Thus, also *Hp 3* is supported. In turn, *Hp 4*, based on the relationship between open innovation and innovation capacity is significant ($\beta=0.234$; $p<0.05$), but data suggest also that KMC affects positively this relationship enhancing the indirect effect of open innovation on innovation capacity via KMC (total effect=0.324). Summarizing, all the hypotheses are confirmed except for *Hp 1*.

To evaluate the model fit, some indexes were measured such as the chi-square-to-degrees-of-freedom ratio ($\chi^2/df=2,89$), CFI=0,905, NFI=0.852 and RMSEA=0,062, which show a good level according to literature.

Discussion, conclusions and implications

Discussion

The main purpose of this paper was to investigate the relationship among KMS, open innovation, KMC, and finally, how this relationship affects innovation capacity of the firms. Traversing the current knowledge-economy era, knowledge management is being significantly affected by technological progress and collaborative actions between economic players. In this context, the IoT offers to businesses new opportunities to improve knowledge management practices and to increase knowledge flow through advanced ICTs (Kim and Kim, 2016). In fact, IoT is affecting the approach of organizations to innovation and the way they create and capture value in everyday business activities. Despite this, few studies attempted to investigate the impact of ITCs and developing KMS, on internal and external knowledge management processes, which in turn foster firms' innovativeness.

All the hypotheses of our study have been supported except for the *Hp 1*, which proposed a positive and significant relationship between KMS and KMC. This means that KMS by itself rarely create competitive advantage. Notwithstanding that, our findings indicate that KMS helps in creating an open and collaborative ecosystem, in exploiting internal and external flows of knowledge, and in effecting a strong impact on the development of internal KMC (Ahn et al., 2016), therefore confirming *Hp 2* and *Hp 3*. In addition, firms have to have the necessary internal capacities to commercialize knowledge provided by external partners (Ferrerias-Mendez et al., 2016). Moreover, firms must cope with both explicit and tacit knowledge. The latter, has to be interpreted and reprocessed to be converted in innovation (Salter et al. 2014). In this guise, *Hp 4* and *Hp 5*, which are confirmed by our results, indicate that KMS helps in storing and combining both explicit and tacit knowledge, thus also significantly enhancing knowledge exploitation (Alavi and Leidner, 2001; Vrontis et al., 2016).

Therefore, the emerging phenomenon of the IoT, where network connectivity enables individuals and organizations from different sectors to gather and exchange data, suggests that firms from different manufacturing and service sectors should invest in new ICTs and develop KMS in order to create internal and external KMC. The disruptive technologies that arose over the last few decades bear an evident and widely accepted increasing potential to change the way businesses gather and use data. More importantly perhaps, they also have the ability to transform information into knowledge, itself constituting a lasting and inimitable competitive advantage.

Theoretical implications

From a theoretical point of view, despite the existence of a large amount of studies on knowledge management, most of these studies focused on specific internal knowledge processes (Nonaka, 1994; Lichtenthaler and Lichtenthaler, 2009), and integrative perspectives which consider both internal and external knowledge are rare (Chesbrough, 2006). In such a context, our study contributes to literature by suggesting a comprehensive view of knowledge management and open innovation that considers both internal and external sources of knowledge as basis of competitive advantage. In addition, ITC studies focused on internal knowledge management processes, neglecting intra- and inter-knowledge flows. Our study suggests focusing on KMS as an enabler of knowledge management. Summarizing, as some

scholars suggest that new ICTs play a pivotal role in supporting knowledge management processes (Lopez-Nicolas and Soto-Acosta, 2010), we further indicate that KMS facilitates the knowledge flows. We support that in the current hypercompetitive environment, KMS will be interlaced with knowledge management, and thus advise and predict that there are insights to investigate more this relationship.

Managerial implications

From a managerial point of view, it emerges that firms adopting an active open approach to innovation, are more likely to develop innovation capacity. Then, since openness in innovation is recognized as a strong enabler of innovativeness, developing internal KMC extols the effects of open innovation strategies. Therefore, an active attitude towards openness can increase the likelihood of creating internal capacities. In particular, an open approach fosters knowledge creation, absorption, and connection, which in turn enhance the efficiency of an open innovation strategy. This confirms the importance of expanding firms' boundaries and suggests that it may offer several opportunities in discovering new markets and exploring new knowledge. One possible explanation is that engaging with several partners of varying nature (partners' variety) can generate new ideas, since firm can thereby access different knowledge bases. In turn, the high diffusion of new ICTs in the knowledge-economy era should at least challenge the open-mindedness inside the organisations. This should start from the top management and consider the role of digital and open ecosystems for innovation.

Another managerial implication is that the development of KMS is likely to generate an open environment, presenting new opportunities of knowledge exploitation and exploration. In fact, intra- and inter-organizational innovation results from the capacity to share, combine and create new knowledge in the current dynamic environment. KMS are the starting point for collaboration and knowledge exchange among internal departments, while creating virtual spaces with external partners where participants can share information and knowledge through common platforms. However, technology alone is necessary, but not sufficient to increase innovativeness. Firms have to strengthen their propensity to collaborate by selecting the right partner and adjusting the intensity of the relationship.

The multidimensional relationship built among KMS, open innovation, KMC, and innovation capacity (fig. 1), appears to create an "open knowledge system", in which information and knowledge circulate through technological systems, creating internal capacities. These

capacities, in turn, enhance the innovativeness required to respond quickly to the external dynamic environment. Additionally, not only internal KMC enhances the effect of external collaboration on firm's innovativeness, but it also nurtures the conditions for select accurately external sources and partners.

Clearly, different KMS and OI strategies could exert different effects depending on the firm's size and industry in which firms operate. The management must be competent in choosing the appropriate ICTs and knowledge sourcing mode, and in scanning the external environment and recognizing the opportunities.

Research Limitations and future research

The present work presents some limitations. First, our sample includes firms from very different sectors, each carrying its individual and unique characteristics, thus requiring both qualitatively and quantitatively different capacities. Future studies should therefore investigate the relationship among the above variables within a single sector for a more refined analysis and accuracy. Second, data was collected only from Italian firms. A comparative study between several countries could and should expand our knowledge on and understanding of the subject, particularly if the underlying cultural factors are introduced to the local innovation system. Third, our sample considers firms of different size, and thus a firm's size effect could exist. A future study could address this issue by focusing on small or large firms.

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Appendix. Constructs, dimensions and items

CONSTRUCTS	DIMENSIONS	ITEMS
KMS	IT infrastructures	<i>the amount of funds spent for new information technology hardware and software</i>
		<i>the use of extranet</i>
		<i>the use of LAN</i>
	Collaborative technologies	<i>the use of online technologies to exchange documents electronically with your customers, suppliers and business partners</i>
		<i>the use of electronic invoicing system</i>
		<i>the use of website</i>
Intranet use orientation	<i>the use of online tools to share documents or to perform collaborative work in an online environment</i>	
	<i>the use of intranet to support internal processes automation</i>	
OPEN INNOVATION	Partner intensity	<i>the collaboration with customers</i>
		<i>the collaboration with suppliers</i>
		<i>the collaboration with competitors</i>
		<i>the collaboration with universities or research centers</i>
	Openness variety	<i>the collaboration with intermediaries</i>
		<i>the degree of collaboration with several stakeholders</i>
		<i>the phase variety</i>
	Readiness to collaborate	<i>the content variety</i>
		<i>the readiness to share experiences</i>
KMC	Inventive capacity	<i>the trust in external partners</i>
		<i>the top managers' willingness to collaborate</i>
	Absorptive capacity	<i>ability to importance of internally explore knowledge or generate internally new knowledge</i>
		<i>the ability to manage the innovation effort</i>
	<i>the ability to externally explore knowledge</i>	
	<i>the capacity of integrate external knowledge</i>	

	Connective capacity	<i>the ability to internally retain knowledge</i> <i>the ability to retain knowledge in inter-organizational relationships</i>
INNOVATION CAPACITY	New or improved innovation (products/services)	<i>the ability to create knowledge through co-R&D projects</i> <i>the ability to assess co-innovation projects</i>
		<i>product/service innovations were developed with success</i> <i>product/service innovations were commercialized with success</i>
	New or improved innovation (processes)	<i>product/service innovations sales expectation</i> <i>process innovations were successfully developed by unit</i>
		<i>process innovations were important for product/service innovations</i> <i>increase in export</i>
Opening of new markets	<i>opening of new markets abroad</i>	