Technological Forecasting & Social Change xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

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

Gabriele Santoro [a,*], Demetris Vrontis [b], Alkis Thrassou [b], Luca Dezi [c]

[a] Department of Management, University of Turin, Corso Unione Sovietica 218/bis, 10134 Turin, Italy
[b] School of Business, University of Nicosia, 46 Makedonitissas Ave., P.O. Box 24005, 1700 Nicosia, Cyprus
[c] University of Naples "Parthenope", Via Amm. F. Acton, 38, I-80133 Naples, Italy

ARTICLE INFO

Article history:
Received 1 September 2016
Received in revised form 23 January 2017
Accepted 27 February 2017
Available online xxxx

Keywords:
Internet of Things
Knowledge management system
Knowledge management capacity
Innovation capacity
Open innovation
Knowledge flows

ABSTRACT

New disruptive technologies in the context of the Internet of Things (IoT), especially, are changing the manner in which knowledge is managed within organizations, calling for a 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.

1. 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; Scuotto et al., 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 Arvind 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; Davenport and Prusak, 1998) 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 organizations 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 (López-Nicolás and Meroño-Cerdán, 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; López-Nicolás and Meroño-Cerdán, 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).

* Corresponding author.
E-mail addresses: gabriele.santoro@unito.it (G. Santoro), vrontis.d@unic.ac.cy (D. Vrontis), thrassou.a@unic.ac.cy (A. Thrassou), luca.dezi@uniparthenope.it (L. Dezi).

http://dx.doi.org/10.1016/j.techfore.2017.02.034
0040-1625/© 2017 Elsevier Inc. All rights reserved.

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 organization 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 hypotheses 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.

2. Theoretical framework

2.1. 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 MeroñO-Cerdan, 2008; Bresciani, 2010). Specifically, it assumes that tangible resources are sources of competitive advantage 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 and new knowledge to create new products and processes (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 regard 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 idea 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 and Zare, 2011). In particular, following Alavi and Leidner (2001) we consider and discuss the role of ICTs as a fundamental part of KMS.

2.2. 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 KMS is mainly comprised of three components:

- IT infrastructures, namely the physical technology that helps in manage knowledge effectively such as hardware, software components, extranet, intranet and LAN (Soto-Acosta and MeroñO-Cerdan, 2008).
- Collaborative technologies, including discussion forums, shared databases, document repositories and workflows (Merono-Cerdan et al., 2007).
- The ICT adoption, which can integrate different collaborative technologies, and whose use orientation regards three primary implementation aims (Bafoutsou and 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; and b) the integration of internal databases with databases of external stakeholders.

2.3. 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 Cloodt, 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-Méndez 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). 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; Ferraris et al., 2017).

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., 2017), 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).

3. Development of research hypotheses

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 and Almond, 1989). 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 (Tamer 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

4. Methodology

4.1. 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

Please cite this article as: Santoro, G., et al., The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity, Technol. Forecast. Soc. Change (2017), http://dx.doi.org/10.1016/j.techfore.2017.02.034

sectors and of different sizes (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 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 issues 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 (Table 1). The sample represents firms from different manufacturing and service sectors (Table 1).

4.2. 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 (Fig. 1). 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 regarding the aforementioned aspects.

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 (Hair et al., 2011). 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 (Table 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.(See Appendix A.)

5. Analysis and results

5.1. 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

Table 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%

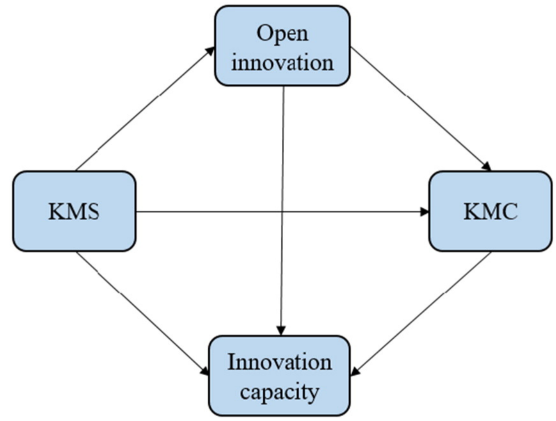

Fig. 1. Design model.

convergent validity. Moreover, we expect content validity since the constructs were developed according to literature (see Table 2). In sum, all fit indexes were superior to the reference values indicating a good fit of the data.

5.2. 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).

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.

As shown in Fig. 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

Table 2
Dimensions and items according the relevant literature.

Constructs	Dimensions	Literature
KMS	IT infrastructures	Soto-Acosta and MeroñO-Cerdan, 2008
	Collaborative technologies	Merono-Cerdan et al., 2007
	ICT adoption	Lopez-Nicolas and Soto-Acosta, 2010
Open innovation	Partner intensity	Aloini et al., 2015
	Openness variety	Aloini et al., 2015
	Readiness to collaborate	Ahn et al., 2016
KMC	Inventive capacity	Lichtenthaler and Lichtenthaler, 2009
	Absorptive capacity	Lichtenthaler and Lichtenthaler, 2009
	Connective capacity	Lichtenthaler and Lichtenthaler, 2009
Innovation capacity	New or improved products or services introduced	Wang et al., 2015; 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

Table 3
Data reliability.

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
ICT adoption	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

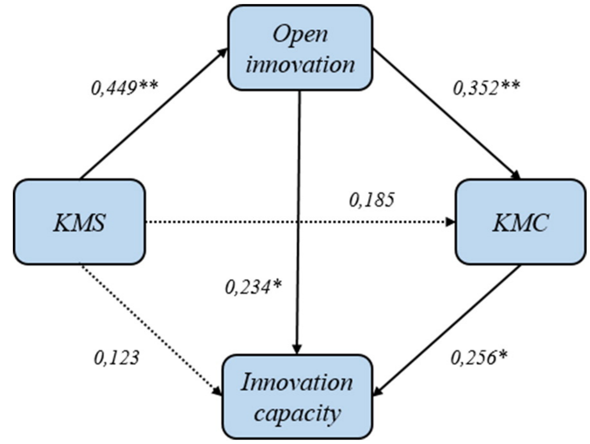

Fig. 2. The structural model. Notes: 1) * = p < 0.05, ** = p < 0.01; 2) dotted lines represent statistical insignificant path.

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 (χ^2/df = 2.89), CFI = 0.905, NFI = 0.852 and RMSEA = 0.062, which show a good level according to the literature.

6. Discussion, conclusions and implications

6.1. 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 KMS based on advanced ICTs, on internal and external knowledge management processes, which in turn foster firms' innovativeness.

All the hypotheses of our study have been supported except for Hp. 1, which proposed a positive and significant relationship between KMS and KMC. This means that KMS by itself rarely creates 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 (Ferreras-Méndez 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 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.

Table 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 capacity	0.256	–	0.256
Open innovation	→	Innovation capacity	0.234	0.09	0.324

6.2. 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.

6.3. 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 efects of open innovation strategies. Therefore, an active attitude towards

Please cite this article as: Santoro, G., et al., The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity, Technol. Forecast. Soc. Change (2017), http://dx.doi.org/10.1016/j.techfore.2017.02.034

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 organizations. This should start from the top management by considering 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 processes result from the capacity to share, combine and create new knowledge in the current dynamic environment. KMS is 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 partners and establishing the intensity of the relationships the intensity of the relationship.

The multidimensional relationship built among KMS, open innovation, KMC, and innovation capacity 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.

6.4. 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 sizes, and thus a firm's size effect could exist. A future study could address this issue by focusing on small or large firms.

Appendix A. Constructs, dimensions and items

Constructs	Dimensions	Items
KMS	IT infrastructures	The amount of funds spent for new information technology hardware and software
		The use of extranet
		The use of intranet
		The use of LAN
		The use of website
	Collaborative technologies	Discussion forums
		Shared databases

(*continued*)

Constructs	Dimensions	Items
		Document repositories
		Workflows
	ICT adoption	The use of ICT to inform employees or receive information from employees
		The use of ICT to exchange knowledge and information with customers
		The use of ICT to exchange knowledge and information with suppliers, competitors and partners
Open innovation	Partner intensity	The collaboration with customers
		The collaboration with suppliers
		The collaboration with competitors
		The collaboration with universities or research centers
		The collaboration with intermediaries
	Openness variety	The degree of collaboration with several stakeholders
		The phase variety
		The content variety
	Readiness to collaborate	The readiness to share experiences
		The trust in external partners
		The top managers' willingness to collaborate
KMC	Inventive capacity	Ability to importance of internally explore knowledge or generate internally new knowledge
		The ability to manage the innovation effort
	Absorptive capacity	The ability to externally explore knowledge
		The capacity of integrate external knowledge
		The ability to internally retain knowledge
	Connective capacity	The ability to retain knowledge in inter-organizational relationships
		The ability to create knowledge through co-R&D projects
		The ability to assess co-innovation projects
Innovation capacity	New or improved innovation (products/services)	Product/service innovations were developed with success
		Product/service innovations were commercialized with success
		Product/service innovations sales expectation
	New or improved innovation (processes)	Process innovations were successfully developed by unit
		Process innovations were important for product/service innovations
	Opening of new markets	Increase in export
		Opening of new markets abroad

References

Ahn, J.M., Ju, Y., Moon, T.H., Minshall, T., Probert, D., Sohn, S.Y., Mortara, L., 2016. Beyond absorptive capacity in open innovation process: the relationships between openness, capacities and firm performance. Tech. Anal. Strat. Manag. 1–20.

Alavi, M., Leidner, D.E., 2001. Review: knowledge management and knowledge management systems: conceptual foundations and research issues. MIS Q. 107–136.

Allameh, S.M., Zare, S.M., 2011. Examining the impact of KM enablers on knowledge management processes. Proc. Comp. Sci. 3, 1211–1223.

Aloini, D., Pellegrini, L., Lazzarotti, V., Manzini, R., 2015. Technological strategy, open innovation and innovation performance: evidences on the basis of a structural-equation-model approach. Meas. Bus. Excell. 19 (3), 22–41.

Amirkhanpour, M., Vrontis, D., Thrassou, A., 2014. Mobile marketing: a contemporary strategic perspective. Int. J. Technol. Market. 9 (3) (ISSN:1741-878X - Inderscience).

Anderson, J.C., Gerbing, D.W., 1988. Structural equation modeling in practice: a review and recommended two-step approach. Psychol. Bull. 103 (3), 411.

Argote, L., Ingram, P., 2000. Knowledge transfer: a basis for competitive advantage in firms. Organ. Behav. Hum. Decis. Process. 82 (1), 150–169.

Aziz, H.H.A., Rizkallah, A., 2015. Effect of organizational factors on employees' generation of innovative ideas: empirical study on the Egyptian software development industry. EuroMed J. Bus. 10 (2):134–146. http://dx.doi.org/10.1108/EMJB-12-2014-0044.

Bafoutsou, G., Mentzas, G., 2002. Review and functional classification of collaborative systems. Int. J. Inf. Manag. 22 (4), 281–305.

Berchicci, L., 2013. Towards an open R&D system: internal R&D investment, external knowledge acquisition and innovative performance. Res. Policy 42 (1), 117–127.

Bogers, M., Zobel, A.K., Afuah, A., Almirall, E., Brunswicker, S., Dahlander, L., ... Hagedoorn, J., 2016. The open innovation research landscape: established perspectives and emerging themes across different levels of analysis. Ind. Innov. 1–33.

Bresciani, S., 2010. Innovation within firms: a survey in the Piedmont area. Int. J. Qual. Innov. 1 (2), 138–152.

Please cite this article as: Santoro, G., et al., The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity, Technol. Forecast. Soc. Change (2017), http://dx.doi.org/10.1016/j.techfore.2017.02.034

Bresciani, S., Thrassou, A., Vrontis, D., 2013. Change through innovation in family businesses: evidence from an Italian sample. World Rev. Entrep. Manag. Sustain. Dev. 9 (2), 195–215.
Cao, Q., Gedajlovic, E., Zhang, H., 2009. Unpacking organizational ambidexterity: dimensions, contingencies, and synergistic effects. Organ. Sci. 20 (4), 781–796.
Carayannis, E.G., 1999. Fostering synergies between information technology and managerial and organizational cognition: the role of knowledge management. Technovation 19 (4), 219–231.
Carayannis, E.G., Rogers, E.M., Kurihara, K., Allbritton, M.M., 1998. High-technology spinoffs from government R&D laboratories and research universities. Technovation 18 (1), 1–11.
Chebbi, H., YChebbi, H., Yahiaoui, D., Thrassou, A., Vrontis, D., 2013. The exploration activity's added value into the innovation process. Glob. Bus. Econ. Rev. 15 (2/3):265–278. http://dx.doi.org/10.1504/GBER.2013.053073 (ISSN: 1097-4954, Inderscience).
Chebbi, H., YChebbi, H., YChebbi, H., YChebbi, H., YChebbi, H., YChebbi, H., Yahiaoui, D., Vrontis, D., Thrassou, A., 2015. Building multiunit ambidextrous organizations: a transformative framework. Hum. Resour. Manag. http://dx.doi.org/10.1002/hrm.21662.
Chen, C.J., Huang, J.W., 2009. Strategic human resource practices and innovation performance—the mediating role of knowledge management capacity. J. Bus. Res. 62 (1), 104–114.
Chesbrough, H., 2004. Managing open innovation. Res. Technol. Manag. 47 (1), 23.
Chesbrough, H.W., 2006. Open Innovation: The New Imperative for Creating and Profiting From Technology. Harvard Business Press.
Chin, W.W., 1998. The partial least squares approach to structural equation modeling. Modern Methods Bus. Res. 295 (2), 295–336.
Choi, B., Poon, S.K., Davis, J.G., 2008. Effects of knowledge management strategy on organizational performance: a complementarity theory-based approach. Omega 36 (2), 235–251.
Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. Adm. Sci. Q. 128–152.
Darroch, J., 2005. Knowledge management, innovation and firm performance. J. Knowl. Manag. 9 (3), 101–115.
Davenport, T.H., Prusak, L., 1998. Working Knowledge: How Organizations Manage What They Know. Harvard Business Press.
Del Giudice, M., Della Peruta, M.R., 2016. The impact of IT-based knowledge management systems on internal venturing and innovation: a structural equation modeling approach to corporate performance. J. Knowl. Manag. 20 (3).
Del Giudice, M., Maggioni, V., 2014. Managerial practices and operative directions of knowledge management within inter-firm networks: a global view. J. Knowl. Manag. 18 (5), 841–846.
Del Giudice, M., Straub, D., 2011. IT and entrepreneurism: an on-again, off-again love affair or a marriage? MIS Q. 35 (4), 3–11.
Dias, R.T., Bresciani, S., 2006. R&D and knowledge: a theoretical assessment of the internationalisation strategies. Int. J. Technol. Policy Manage. 6 (1), 1–32.
Ferraris, A., Santoro, G., Dezi, L., 2017. How MNC's subsidiaries may improve their innovative performance? The role of external sources and knowledge management capabilities. J. Knowl. Manag. (forthcoming).
Ferraris, A., Erhardt, N., Bresciani, S., 2017. Ambidextrous work in smart city project alliances: unpacking the role of human resource management systems. Int. J. Hum. Resour. Manag. 1–22.
Ferreras-Méndez, J.L., Fernández-Mesa, A., Alegre, J., 2016. The Relationship Between Knowledge Search Strategies and Absorptive Capacity: a Deeper Look Technovation.
Garud, R., Nayyar, P.R., 1994. Transformative capacity: continual structuring by intertemporal technology transfer. Strateg. Manag. J. 15 (5), 365–385.
Gerbing, D.W., Anderson, J.C., 1988. An updated paradigm for scale development incorporating unidimensionality and its assessment. J. Mark. Res. 186–192.
Gold, A.H., Arvind Malhotra, A.H.S., 2001. Knowledge management: an organizational capabilities perspective. J. Manag. Inf. Syst. 18 (1), 185–214.
Grant, R.M., 1996. Toward a knowledge-based theory of the firm. Strateg. Manag. J. 17 (S2), 109–122.
Grant, R.M., Baden-Fuller, C., 2004. A knowledge accessing theory of strategic alliances. J. Manag. Stud. 41 (1), 61–84.
Gulati, R., 1999. Network location and learning: the influence of network resources and firm capabilities on alliance formation. Strateg. Manag. J. 20 (5), 397–420.
Hair, J.F., Ringle, C.M., Sarstedt, M., 2011. PLS-SEM: Indeed a silver bullet. Journal of Marketing theory and Practice 19, 139-–152.
Hernaus, T., Mikulić, J., 2014. Work characteristics and work performance of knowledge workers. EuroMed J. Bus. 9 (3):268–292. http://dx.doi.org/10.1108/EMJB-11-2013-0054.
Hulland, J., 1999. Use of partial least squares (PLS) in strategic management research: a review of four recent studies. Strateg. Manag. J. 20 (2), 195–204.
Ichijo, K., Von Krogh, G., Nonaka, I., 1998. Knowledge enablers. Knowing in Firms: Understanding, Managing and Measuring Knowledge, pp. 173–203.
Kale, P., Singh, H., 2007. Building firm capabilities through learning: the role of the alliance learning process in alliance capability and firm-level alliance success. Strateg. Manag. J. 28 (10), 981–1000.
Khilji, S.E., Mroczkowski, T., Bernstein, B., 2006. From invention to innovation: toward developing an integrated innovation model for biotech firms*. J. Prod. Innov. Manag. 23 (6), 528–540.
Kim, S., Kim, S., 2016. A multi-criteria approach toward discovering killer IoT application in Korea. Technol. Forecast. Soc. Chang. 102, 143–155.
King, W.R., Marks, P.V., 2008. Motivating knowledge sharing through a knowledge management system. Omega 36 (1), 131–146.
Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. Strateg. Manag. J. 27 (2), 131–150.
Lee, H., Choi, B., 2003. Knowledge management enablers, processes, and organizational performance: an integrative view and empirical examination. J. Manag. Inf. Syst. 20 (1), 179–228.
Lichtenthaler, U., 2007. The drivers of technology licensing: an industry comparison. Calif. Manag. Rev. 49, 67–89.
Lichtenthaler, U., Lichtenthaler, E., 2009. A capability-based framework for open innovation: complementing absorptive capacity. J. Manag. Stud. 46 (8), 1315–1338.
López-Nicolás, C., Meroño-Cerdán, Á.L., 2011. Strategic knowledge management, innovation and performance. Int. J. Inf. Manag. 31 (6), 502–509.
Lopez-Nicolas, C., Soto-Acosta, P., 2010. Analyzing ICT adoption and use effects on knowledge creation: an empirical investigation in SMEs. Int. J. Inf. Manag. 30 (6), 521–528.
Malhotra, Y., 2000. Knowledge management for e-business performance: advancing information strategy to "internet time". Inf. Strateg. 16 (4), 5–16.
Massey, A.P., Montoya-Weiss, M.M., O'Driscoll, T.M., 2002. Knowledge management in pursuit of performance: insights from Nortel networks. MIS Q. 269–289.
Merono-Cerdan, A.L., Soto-Acosta, P., López-Nicolás, C., 2007. Analyzing collaborative technologies' effect on performance through intranet use orientations. J. Enterp. Inf. Manag. 21 (1), 39–51.
Nonaka, I., 1994. A dynamic theory of organizational knowledge creation. Organ. Sci. 5 (1), 14–37.
Nonaka, I., Takeuchi, H., 1995. The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation. Oxford University Press.
Salter, A., Criscuolo, P., Ter Wal, A.L., 2014. Coping with open innovation. Calif. Manag. Rev. 56 (2), 77–94.
Santoro, G., Ferraris, A., Giacosa, E., Giovando, G., 2016. How SMEs engage in open innovation: a survey. J. Knowl. Econ. 1–14.
Scuotto, V., Ferraris, A., Bresciani, S., 2016. Internet of Things: Applications and challenges in smart cities: a case study of IBM smart city projects. Bus. Process. Manag. J. 22 (2), 357–367.
Smith, E.A., 2001. The role of tacit and explicit knowledge in the workplace. J. Knowl. Manag. 5 (4), 311–321.
Soto-Acosta, P., Cegarra-Navarro, J.G., 2016. New ICTs for knowledge management in organizations. J. Knowl. Manag. 20 (3).
Soto-Acosta, P., Colomo-Palacios, R., Popa, S., 2014. Web knowledge sharing and its effect on innovation: an empirical investigation in SMEs. Knowl. Manag. Res. Pract. 12 (1), 103–113.
Soto-Acosta, P., MeroñO-Cerdan, A.L., 2008. Analyzing e-business value creation from a resource-based perspective. Int. J. Inf. Manag. 28 (1), 49–60.
Soto-Acosta, P., Popa, S., Palacios-Marqués, D., 2015. E-business, organizational innovation and firm performance in manufacturing SMEs: an empirical study in Spain. Technol. Econ. Dev. Econ. 1–20.
Spender, J.C., 1996. Making knowledge the basis of a dynamic theory of the firm. Strateg. Manag. J. 17 (S2), 45–62.
Stata, R., Almond, P., 1989. Organizational learning: the key to management innovation. Train. Dev. Sourcebook 2, 31–42.
Straub, D.W., 1989. Validating instruments in MIS research. MIS Q. 147–169.
Tamer Cavusgil, S., Calantone, R.J., Zhao, Y., 2003. Tacit knowledge transfer and firm innovation capability. J. Bus. Ind. Mark. 18 (1), 6–21.
Teece, D.J., 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strateg. Manag. J. 28 (13), 1319–1350.
Thrassou, A., Vrontis, D., 2008. Internet marketing by SMEs: towards enhanced competitiveness and internationalisation of professional services. Int. J. Internet Market. Advert. 4 (3/4), 241–261 (ISSN: 1477-5212- Inderscience).
Thrassou, A., Vrontis, D., Chebbi, H., Yahiaoui, D., 2012. A preliminary strategic marketing framework for new product development. J. Trans. Manage. 17 (1), 21–44 (ISSN: 1547-5778 – Routledge, Taylor and Francis).
Tseng, S.M., 2008. Knowledge management system performance measure index. Expert Syst. Appl. 34 (1), 734–745.
Vanhaverbeke, W., Cloodt, M., 2014. Theories of the firm and open innovation. New Frontiers in Open Innovation. Oxford University Press, Oxford.
Vrontis, D., Thrassou, A., Chebbi, H., Yahiaoui, D., 2012. Transcending innovativeness towards strategic reflexivity. Qual. Mark. Res. Int. J. 15 (4):420–437. http://dx.doi.org/10.1108/13522751211257097.
Vrontis, D., Thrassou, A., Santoro, G., Papa, A., 2016. Ambidexterity, external knowledge and performance in knowledge-intensive firms. J. Technol. Transf. 1–15.
Wang, C.H., Chang, C.H., Shen, G.C., 2015. The effect of inbound open innovation on firm performance: evidence from high-tech industry. Technol. Forecast. Soc. Chang. 99, 222–230.
Yeh, Y.J., Lai, S.Q., Ho, C.T., 2006. Knowledge management enablers: a case study. Ind. Manag. Data Syst. 106 (6), 793–810.
Zobel, A.K., 2016. Benefiting from open innovation: a multidimensional model of absorptive capacity. J. Prod. Innov. Manag.

Gabriele Santoro is a PhD student in Business and Management in the Department of Management at the University of Torino. His main areas of research include open innovation, knowledge management, social innovation and alliances in smart cities. His works have been published in international academic journals such as Journal of Technology Transfer and Journal of the Knowledge Economy.
Dr. Santoro's research entitled "users generated ideas via Social Media Networks (SMNs): based on open innovation model" was awarded as Best Paper award of the EuroMed\SIMA track "New Challenges in Open Innovation" at the 9th annual EuroMed Academy of Business (EMAB) conference (2016).

Demetris Vrontis is a professor of Marketing, Executive Dean and Director at the University of Nicosia in Cyprus, the editor-in-chief of the EuroMed Journal of Business (EMJB), and the president of the EuroMed Research Business Institute (EMRBI). He has published over 120 refereed articles and 21 books, and gave numerous presentations in conferences around the globe. Professor Vrontis is a fellow member and certified chartered marketer of the Chartered Institute of Marketing and a chartered business and chartered marketing consultant. He also serves as a consultant and member of Board of Directors to a number of international companies.

Alkis Thrassou is a professor at the School of Business, University of Nicosia (Cyprus, EU). He holds a Ph.D. in Strategic Marketing Management from the University of Leeds (UK) and is also a fellow chartered marketer (FCIM, UK), a fellow chartered construction manager (FCIOB, UK), a chartered management consultancy surveyor (MRICS, UK) and a senior research fellow of the EuroMed Academy of Business (SFEMAB/EMRBI). He has extensive academic and professional/industry experience, and his work has been published in dozens of internationally esteemed refereed scientific journals and books. He retains strong ties with the industry, acting also as a consultant.

Luca Dezi is a full professor of Economics and Management of Companies at the University "Parthenope", Faculty of Economics, Naples. Scientific field/SECS - P08, Economy and Company Management. - Professor of Strategic Marketing and International Business at the Faculty of Communication Sciences, Department CO.RI.S., University of Studies of Rome, Sapienza University. - Member of the Company's Board of Auditors San Giovanni Addolorata Hospital in Rome from 2007 to 2011. - Ordinary member of the Italian Academy of Business Economics. - Chartered accountant. - Auditor. - It is a consultant in the field of economic and financial analysis, planning and management control, evaluation of businesses and projects, corporate restructuring, mediations, rationalization and resource management, teaching and training on behalf of medium-sized and large companies, public institutions and organizations.

Please cite this article as: Santoro, G., et al., The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity, Technol. Forecast. Soc. Change (2017), http://dx.doi.org/10.1016/j.techfore.2017.02.034