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The Role of Digital Technologies in Open Innovation Processes: An exploratory multiple case study analysis

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Abstract

Digital transformation has undoubtedly become a key enabler of innovation as evidenced by the numerous firms that use digital technologies to manage their innovation processes. This issue is even more relevant today when innovation processes have become more open and require greater resources in the different implementation phases to capture and transfer knowledge within and outside the firm's boundaries. This implies additional challenges in managing the increasing amount of knowledge and information flows. Accordingly, digital technologies can be used and implemented to manage open innovation processes through easier access and sharing the knowledge created and transferred. Nevertheless, literature in these fields does not provide a structured view of how and why digital technologies are used to manage innovation processes in an open perspective. This paper aims to bridge this gap by adopting the theoretical lenses of change management to identify the managerial actions at organizational and process level that companies perform to implement digital technologies in their open innovation processes. Accordingly, the paper investigates how and why these managerial actions required for and enabled by digital technologies help firms to develop and nurture open innovation. From an empirical point of view, the exploratory multiple case study analyzes nine firms operating in different industries and varying in size, market share and organizational structure.

1. Introduction

Innovation scholars and practitioners have discussed at length the organizational and process levers that innovation managers can leverage to improve the performance of innovation processes conducted in an open perspective (Chiaroni et al., 2011; Bianchi et al., 2016; Sikimic et al., 2016).

However, to our knowledge, no studies deepen the organizational and process levers ensuing from and enabling the use and implementation of digital technologies to manage open innovation processes. This despite the increasing amount of knowledge and information flows exchanged within and outside the firm's boundaries in open innovation processes (Chesbrough, 2004, 2006; Manyika et al., 2011; Yoo et al., 2012) that call for using and implementing new technologies for their internalization, management, processing and external transfer. Accordingly, digital technologies can allow the management of open innovation processes through easier access, sharing and using the knowledge and information flows created and transferred (Chen et al., 2012).

Although some studies provide anecdotal evidence of the role of digital technologies in open innovation (Dodgson et al., 2006; Natalicchio et al., 2014), this management issue remains unexplored and the gap is even more relevant as the growing proliferation of digital technologies find applicability in innovation processes. Therefore, further theoretical and empirical research that provides a structured view of their use and implementation in the innovation process (Agostini et al., 2017) and particularly in open innovation processes (Del Vecchio et al., 2016) is still required.

Accordingly, understanding how digital technologies help firms to manage open innovation processes implies the establishment of a framework for innovation processes in an open perspective.

Starting from these premises and leveraging on the research streams on digital technologies and open innovation, the paper argues that the use and implementation of digital technologies in open innovation processes requires firms to perform managerial actions at organizational and process level.

This paper employs the theoretical lenses of change management and the exploratory multiple case study analyzes nine companies operating in different industries (i.e., energy, automotive and consultancy) and varying in size, market share and organizational structure. Data from these firms were collected through personal interviews with a set of key respondents and triangulated with secondary sources of information. The outcome of this study is therefore a framework that provides a map of the managerial actions at organizational and process level that companies perform through digital technologies to manage open innovation processes.

In doing so, the paper contributes to the research stream discussing the potential, the applications and managerial implications of digital technologies in firms' innovation processes. The paper also contributes to open innovation stream studying the organizational and process levers that management can adopt to foster and nurture open innovation through digital technologies.

The paper is structured as follows. In Section 2, we highlight the relevance from a theoretical perspective to study digital technologies in the innovation process of companies (Section 2.1.1). Therefore, we explain the selection of our sample of digital technologies (Section 2.1.2) and their role from a practitioner perspective (Section 2.1.3). In Section 2.2., we present the main emerging results on open innovation, especially in the light of the topic under investigation. We conclude this section by developing a theoretical framework based on existing literature on digital technologies in innovation processes and open innovation (Section 2.4). Section 3 describes the rationale and methodology used for the empirical analysis. Section 4 reports the results and the discussion of our exploratory multiple case study analysis. Finally, Section 5 draws the conclusions, summarizing the main implications of our study and suggesting future theoretical and empirical research avenues.

2. State-of-the-art

2.1.1 Digital technologies in the innovation process: a theoretical perspective

The huge proliferation, use and implementation of digital technologies in firms' innovation processes has called scholars operating in the fields of management and innovation to emphasize the need to develop a theory of digital technology management (Fichman et al., 2014; Nambisan et al., 2017). The time for new theorizing about digital technologies invites scholars to deepen the analyses on the use and implementation of digital technologies to nurture the innovation activity of companies (Yoo, et al., 2012). This sound theoretical effort around how digital technologies facilitates innovation processes has resulted, on one hand, in manifold attempts to provide conceptual strategic and innovation frameworks (Yoo et al., 2010; Yoo, 2010). On the other hand, scholars have advanced several research directions for a more fine-grained theoretical understanding of digital technologies in relation to the development of digital business strategies (Woodard et al., 2013), the recombination of existing capabilities with IT-based resources to develop digital capabilities (Lobo & White, 2017), and the creation and capture of value through digital technologies (Pigni et al., 2016).

2.1.2 Selecting a reliable sample of digital technologies

Starting from the above premises, and due to the high number of contributions that is proliferating in this field of study, we were asked to cluster and summarize the key themes related to the main digital technologies used by companies to nurture their innovation activity. Accordingly, we conducted a systematic research in Web of Science (WoS) and searched in the titles and abstracts of the main management and innovation journals the combination of key words, such as digit*, manag*, innovat* and technolog*.

Accordingly, we were able to understand the main key themes on the digital transformation of businesses emerging from the extant research, which resulted in the use and implementation of Big Data, Internet of Things, Product Lifecycle Management Systems, Systems of Rapid Prototyping, Idea and Knowledge Management Systems, and Cloud Computing. Although we are aware of the many emerging and promising digital technologies today available to nurture the innovation activity of companies, such as augmented and virtual reality, artificial intelligence, and cyber-physical systems (Füller and Matzler, 2007; O'Leary, 2013; Lee et al., 2015), we decided to restrict our analysis to the above identified technologies.

However, to corroborate the sample of the main digital technologies obtained from the systematic research, we involved three digital technology experts (one professor and two senior consultants) working at the Digital Innovation Observatory of Politecnico Di Milano. The same experts were later involved for establishing a suitable sample of companies for our research according to the sampled digital technologies.

2.1.3 The sampled digital technologies in the innovation process: a practitioner perspective

The theoretical implications of digital technologies in innovation processes laid beside practical implications for managers with role of responsibility in the innovation units of their companies. Accordingly, we want to provide some recent contributions dealing with the use and application of our sampled digital technologies, underlying their attributes to nurture the innovation activity for companies operating in different contexts.

Big Data

O'Donovan et al. (2015) underline the use of Big Data to generate and develop technologies in the innovation processes in the manufacturing industry through improvements in operational efficiency. Other studies discuss the use of Big Data in the healthcare industry (e.g., Brunswicker, 2015; Hilbert, 2016; Zillner et al., 2014), underlining the improvements in care quality thanks to the acquisition and elaboration of information flows on customer behaviours in real time. In addition, Toga and Dinov (2015) point out the use of Big Data for research and diagnosis in the biomedical and healthcare industry to support the electronic communication of health records and access to a wider scientific community.

Internet of Things (IoT)

Some scholars debate the use and implementation of the IoT to support the connection of devices, machines and things with the aim to support companies in the dynamic creation, analysis and communication of exchanged data (Atzori et al., 2011; Gubbi et al., 2013; Miorandi et al., 2012; Weber, 2010). The rising number of interconnected devices, machines and things is representing the base for the future IoT networks, underlying the innovation dynamics and the technological evolution of IoT in the innovation management field (Ardito et al., 2017). In addition, Del Giudice et al. (2016) underline the relevance of IoT to support the innovation of processes in manufacturing companies. In particular, the IoT technology embeds all the microelectromechanical systems used in the operations and production processes, such as "accelerometers, gyroscopes and magnetometers, which are a good example of process innovations" (p. 389), to increase the productivity and reduce producing costs. Moreover, IoT can be used to support the downstream phases of the innovation process, such as the commercialization, thanks to the processing of real-time information flows along the lifecycle of products, which provides strong data support in terms of marketing and sales (Del Giudice et al., 2016).

Idea and Knowledge Management (IKM) systems

Several research streams point to the use of Idea and Knowledge Management systems to integrate and apply specialized knowledge of organizational members in the idea generation phase to create and sustain the upstream competitive advantage of firms through innovation (Alavi & Leidner, 1999; Chinneck & Bolton, 2013). Moreover, Spiegler (2000) highlights that Idea and Knowledge Management systems can be used to define how to transform (from the idea generation phase) data-to-information, information-to-knowledge and their reverse order, namely, turning data (raw material) into information (finished goods) and then into knowledge (actionable finished goods) applied to innovation purposes (Bansemir & Neyer, 2009; Westerski et al., 2010).

Cloud Computing

Some scientific contributions highlight Cloud Computing (Lian et al., 2014; Marston et al., 2011; Sultan, 2011) as a new online service allowing companies to reduce costs, increase operational advantages and allow more flexible resource management in several phases of the innovation process where this technology is applied (Ercan, 2010; Lin & Chen, 2012). In particular, Wo et al. (2013) underline the use of Cloud Computing to support decision-making processes of companies, by satisfying the information-processing requirements along the phases of their innovation processes. In addition, Boss et al. (2007) have highlighted how companies can use Cloud Computing to quickly develop, test and make their innovations available to the user community, because it enables faster deployment cycles of new products and services.

Product Lifecycle Management (PLM) systems

PLM systems allow companies to integrate all the information on the product lifecycle with every organizational level, both managerial and technical, as well as with customers, suppliers, developers and manufacturers (Ming et al., 2008; Sudarsan et al., 2015). Several contributions point out their use to support the management of a portfolio of products, processes and services from the initial concept through design, engineering, launch, production and use to final disposal (Ming et al., 2008) and by maintaining their integrity (Kiritsis et al., 2003; Kiritsis, 2011).

Systems of Rapid Prototyping (SoRP)

SoRP (such as 3D printing technology) are another tool identified in the innovation management field to accelerate and reconfigure innovative production processes (e.g., Rayna & Striukova, 2016). In particular, this technology finds its main application in prototype generation, test design, refining and commercializing the final product (Dimitrov et al., 2007; Rupp et al., 2003; Sambu et al., 2002). Firms can benefit from SoRP in the product development phase through creating competitive solutions in terms of cost and speed, modifying and personalising products, simultaneously developing several versions of the same product and speeding up the product offering.

2.2 Open Innovation (and digital technologies)

Open innovation is nowadays recognized as “the distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization’s business model” (Chesbrough & Bogers, 2014; p. 12).

Literature on open innovation has proliferated in recent years and the main scientific contributions focused on several streams: (i) how open innovation and the internal organization of innovation units, such as R&D, impact firm performance (Bianchi et al., 2016; West & Bogers, 2014; West et al., 2014); (ii) the interaction between open innovation strategies and appropriability (West et al., 2014); (iii) the modes of acquiring technological knowledge from external sources or transferring technological knowledge from internal sources, also known as inbound (or outside-in) or outbound (or inside-out) open innovation activities (Chesbrough & Crowther, 2006; Knockaert, 2010; Spithoven et al., 2011; Bianchi et al., 2011); (iv) the ability of firms to recognize, assimilate and apply within their boundaries external knowledge sources and technologies, also known as absorptive capacity (Cohen & Levinthal, 1990; Lichtenthaler & Lichtenthaler, 2009, 2010), or the ability to identify technology transfer opportunities and facilitate its implementation for external adopters, also known as desorptive capacity (Lichtenthaler and Lichtenthaler, 2010).

In the light of the topic under investigation, we found a very few contributions that tried to study some of the above open innovation streams in relation to the digital technologies concept. For example, Christensen et al. (2005) analyze how different open innovation strategies can be pursued as a company shift to the adoption of a consolidated technology to a digital technology in dynamic contexts. Moreover, Roberts et al. (2012), study the role of absorptive capacity in the information system research to facilitate the assimilation of complex IT innovation and the synergies between absorptive capacity and IT capabilities to improve the firm’s performance. In addition, some recent contributions have highlighted the emerging role of market for ideas, which operates as virtual marketplace at the intersection between digital technologies and open innovation to connect knowledge owners and seekers for the creation of new solutions (Natalicchio et al., 2014).

Although rich in terms of managerial and practical implications, and in the light of the few attempts to link each open innovation stream with digital technologies concept, from the literature emerges the lack of specific attention to the applications, methods of use and benefits characterizing digital technologies in innovation processes conducted in an open perspective. Above all, the main contribution addressing this aspect is that of Dodgson et al. (2006). The authors, through the Procter and Gamble "Connect and Develop" program, highlight for the first time how a suite of new technologies for data mining, simulation, prototyping and visual representation helped the company support the management of its open innovation process.

However, this literature provides only partial theoretical and practical implications, with several questions remaining open. Accordingly, as highlighted in the Introduction section, the role of digital technologies in the open innovation process still calls for further theoretical and empirical research (Del Vecchio et al., 2016). This gap is even more relevant as the growing proliferation of digital technologies find applicability in innovation processes of companies (Agostini et al., 2017). In this respect, understanding how the aforementioned sample of digital technologies supports firms to manage open innovation processes requires a framework for innovation processes in an open perspective.

2.3 Research Question and Theoretical Framework

Leveraging on the research streams on digital technologies and open innovation, the aim of this paper is to bridge the gap in existing literature (Figure 1) and answer the following research question: *"Which managerial actions at organizational and process level do companies perform to implement with success digital technologies in their open innovation processes?"*

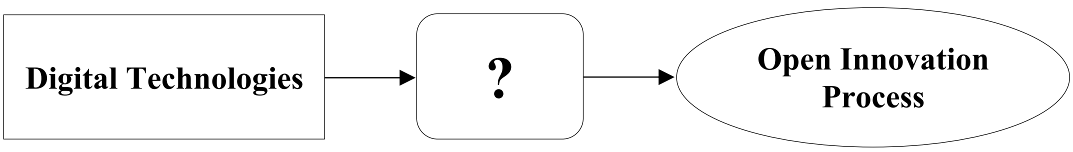

Figure 1. Gap in existing literature.

To address this research question, we propose the theoretical framework in Figure 2, which will be used as guide for the following empirical analysis. Our framework conceives our sampled digital technologies as the independent variables applied in the open innovation process to increase the firms' performance. Therefore, the open innovation process represents the area of investigation where independent and dependent (firms' performance) variables are linked each other. In particular, our area of investigation is conceived as a three-step process, i.e., idea generation, product or service development and commercialization. In addition, our innovation process examines one relevant dimension of open innovation that coherently with several contributions (Bianchi et al., 2016; Chesbrough, 2003; Van de Vrande et al., 2006; Lazzarotti & Manzini, 2009; Spithoven et al., 2011) interacts in each phase of the innovation process to access external knowledge sources, such as technology and know-how, i.e., the inbound (or outside-in) open innovation activity.

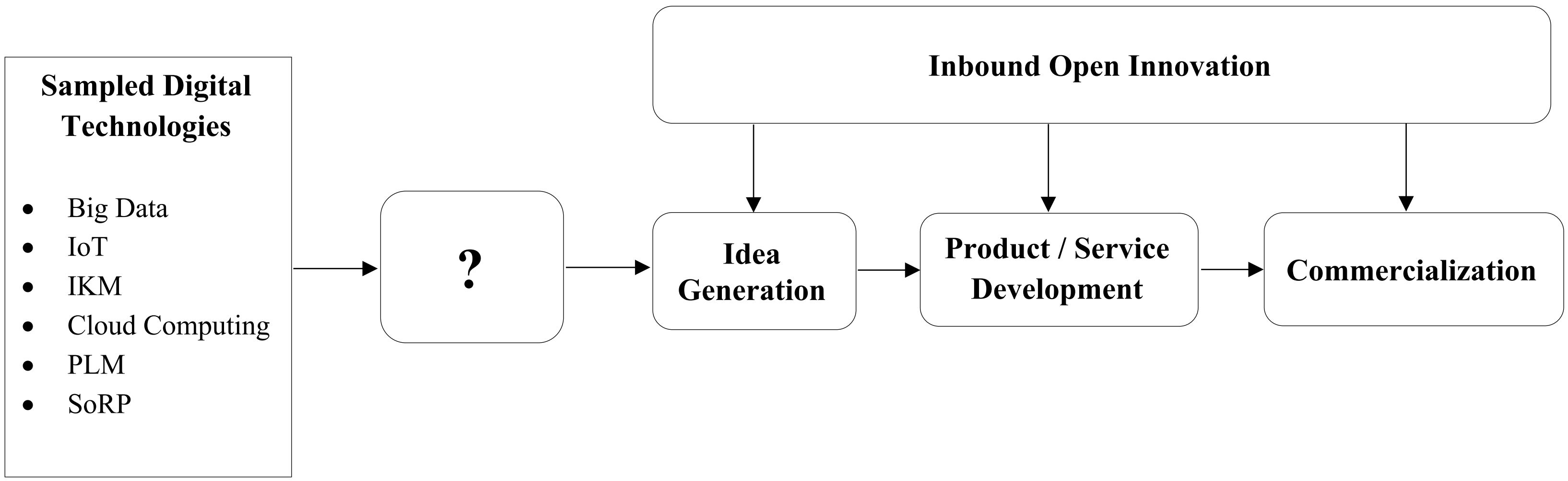

Figure 2. The Theoretical Framework.

We adopt the theoretical lenses of change management applied extensively in the innovation management literature to explain the managerial actions that companies adopt to change traditional organizational practices (Goodman & Dean, 1982; Tidd et al., 1997; Kotter, 2007).

In particular, we leverage on change management studies to understand the managerial actions that companies have to perform at organizational and process level (Davenport, 1993; Todnem By, 2005) to implement with success digital technologies in their innovation process, especially in a context of open innovation (Chiaroni et al., 2011).

3. Methodology and empirical analysis

3.1 Methodology

The paper uses an exploratory multiple case study analysis of nine firms operating in different industries (i.e., energy, automotive and consultancy) and varying in size, market share and organizational structure. According to Yin (2003), multiple case study analysis allows answering "how" and "why" questions and is particularly appropriate for cross-case comparisons (Chiesa et al., 2007).

The same digital technology experts that corroborated the sample of digital technologies ensuing from our review process provided us a set of specific Italian journals dealing with the topic of digital technologies or digitalization in firm innovation processes. The most helpful and frequently referenced sources include TechWeekEurope, Data Manager Online, ZeroUno, ICT Professional, Digital4Executive, TradeManager.it, Datavalue, IctBusiness.it, and Hitech Magazine. We conducted a systematic analysis of the articles published last year searching for keywords such as "digital technology", "digital innovation", "digitalization", "ICT", "open innovation" and "innovation process". We performed a content analysis (Weber, 1990) to cluster the information contained in these documents. We assembled over 150 articles listing around 50 companies using digital technologies to manage their open innovation process.

Thereafter, we shared our analysis with our panel of digital experts and triangulated all the information collected. This allowed identifying around 20 companies using such digital technologies to manage their open innovation process. We contacted them via email and phone, and engaged nine companies in our study (see Table1A in the Appendix for the list of companies and the key respondents involved).

Simultaneously, we began assembling an initial set of questions through which collect and analyze information on the use and implementation of digital technologies in our sample of firms. The analysis of literature on digital technologies and open innovation allowed us to formulate a set of specific questions for our respondents to answer the research question outlined in Section 2. To assemble the final interview protocol, we additionally integrated and adapted the interview template of Dodgson et al. (2006) mostly in the light of the theoretical lenses of change management we leveraged on in this paper. Our final interview protocol (provided in the Appendix, see Table 2A) was initially sent via e-mail to the top managers in charge of innovation in our sample of firms. In a second phase, we conducted personal, direct interviews with the top managers through phone calls and/or face-to-face meetings. We interviewed a panel of 12 innovation managers at least twice to obtain complete responses to all our questions. Overall, each interview lasted on average an hour and half for over 36 hours of interviews. Finally, we triangulated all the information gathered from the key respondents with secondary sources of information, such as reports of companies or the same referenced sources used for identifying the companies, to avoid post hoc rationalizations (Yin, 2003).

In doing so, for each case study, we first analyzed the role of each digital technology adopted in the open innovation process. Thereafter, to identify the common patterns of actions and differences amongst each case study, a cross-case comparison was undertaken. We continuously compared the results of the empirical evidence with the information ensuing from the theoretical setting to refine, enrich and modify the theoretical framework.

3.2 Empirical analysis

We used company websites, reports and project documentation to provide some preliminary key data on our sample of firms. In particular, for each firm we highlight in Table 1 below a brief profile description, the turnover, their inbound open innovation activity, the R&D expenses, the number of employees, the sector of activity, the digital technologies adopted and in which phase. Worth noting is that in some cases, the firms in our sample use more than one digital technology to manage their open innovation process.

Although we interviewed the innovation managers of the Italian branches of each sampled firm, given that data on turnover and R&D expenses are provided as aggregates in the 2015 consolidated financial statements, key data on our sample of firms are provided at the global level.

Table 1. Preliminary key data on our sample of firms.

	Brief profile	Turnover	Inbound (or outside-in) open innovation activity	R&D expenses	Number of employees	Sector of activity	Digital Technology	Phase of the innovation process
Company A	Company A is an American multinational that supplies drivetrain, sealing and thermal-management technologies. It is formed of four business units, i.e., (i) light vehicles, (ii) commercial vehicles, (iii) off highway, (iv) power technologies group. The business unit of Off Highway Products, LLC, manufactures auto parts for off road vehicles. It produces transmissions and controls, axles, drive shafts, tire inflation systems and drivetrain systems. The Off Highway Products business unit supplies the agriculture, construction, forestry, mining, material handling, outdoor power equipment and leisure/utility vehicle industries.	$ 6 bn	Company A particularly leverages on the outside-in activity, mainly through M&A operations and in-licensing with the aim of quickly internalizing new technologies to support its innovation engineering processes. The company also supports its innovation engineering processes through the direct involvement of customers who provide their feedbacks on products and components.	$ 65 - 75 mln	29,000	Automotive	Product Lifecycle Management (PLM)	• Idea generation • Product or service development • Commercialization
Company B	Company B is a publisher and printer in Italy. The company's publications include books, magazines, newspapers, advertising, business information, graphics, direct marketing and on-line information services. Company B also retails books through a large network of bookstores and generates most of its business in Italy.	€ 1 bn	Company B supports its innovation process by leveraging on outside-in activities, such as M&A operations with small Italian publishers and by exploiting its network of 600 bookstores.	€ 0.5 - 2 mln	3,261	Publishing and Retail	Big Data	• Idea generation • Commercialization
							Internet of Things (IoT)	• Idea generation • Commercialization
							Cloud Computing	• Idea generation • Commercialization
Company C	The Italian Company C designs, manufactures, supplies and installs woodworking and panel processing equipment. The company offers beam saws, wide belt sanders, finishing systems, and sizing edge banders. Company C markets its products worldwide.	€ 300 mln	Company C innovates mostly through involving customers in the phases of idea generation and development of its machineries.	€ 18 - 23 mln	3,300	Machinery	Big Data	• Idea generation • Product or service development • Commercialization
							Internet of Things (IoT)	• Product or service development • Commercialization
Company D	Company D provides information technology consulting and system development services. Its services include IT consultancy services on information technology system strategies and organization, technological evolution, models of IT governance, information technology systems architecture and program management; design, creation, and operating support services based on the integration and customization of various technologies; digital interaction advanced services; information technology applications and infrastructures management; IT security services. Company D serves various industries, including telecommunications, banking and financial services, insurance, services and government, manufacturing and distribution, publishing and media and security.	€ 14 bn	Company D is growing thanks to its strong outside-in activity, mostly concerning the acquisition of several overseas companies that provide new business approaches and frameworks, supporting idea generation and creativity. The outside-in activity also concerns the direct involvement of customers along the development phases of projects to acquire constant inputs on their particular needs.	€ 190 - 250 mln	80,550	Consultancy	Big Data	• Idea generation • Product or service development • Commercialization
							System of Rapid Prototyping (SoRP)	• Product or service development

Company E	Company E is a highly specialized teaching and research hospital. Accredited by the National Health Service, Company E combines specialized centres for the treatment of cancer, cardiovascular diseases, neurological and orthopaedic disorders, as well as an Ophthalmology Centre and a Fertility Centre. This Italian private hospital is also equipped with Emergency and Radiotherapy departments. The Italian Ministry of Health granted Company E the status "Research Hospital" (IRCCS) with a focus on diseases of the immune system, ranging from cancer to rheumatoid arthritis. Company E is one of the most technologically advanced private hospitals in Europe.	$ 0,55 bn	Company E exploits outside-in activity, leveraging on the creation of a network of professionals that combines clinics and public institutions, such as research centres and universities; simultaneously, the network provides knowledge through research and training programs as well as public events.	€ 7 - 10 mln	2,811	Healthcare	Big Data	• Commercialization
							Cloud Computing	• Commercialization
Company F	Company F is a leading global professional services company providing a broad range of services and solutions in strategy, consulting, digital, technology and operations. It helps organizations to maximize their performance and achieve their vision. Company F develops and implements technology solutions to improve their clients' productivity and efficiency and run parts of their operations on their behalf. Ultimately, Company F enables clients to become high-performance businesses and public authorities.	$ 31 bn	Company F focuses on maximizing the differentiation and competitiveness of its innovative offering by continuing to make significant investments in the areas of training, acquisitions, emerging technologies, offerings and assets.	$ 3 - 5 bn	375,000	Consultancy	Big Data	• Product or service development • Commercialization
							Idea and Knowledge Management (IKM)	• Idea generation
Company G	Founded in 1979 as a consortium of numerous Italian institutions and several leading public and private industrial groups, today Company G is a non-for-profit consortium limited company. Company G is involved in all the many aspects surrounding research and education in the fields of management, economics and industrial engineering.	€ 16 mln	Company G particularly innovates by leveraging on outside-in activity with a network of technical experts on digital platforms dedicated to the provision of online courses for executives and practitioners. The continuous feedback from students is also a relevant element of the inbound open innovation activity as it allows relevant improvements on the existing platforms.	€ 1 - 2 mln	Over 450	Education	Internet of Things (IoT)	• Idea generation • Product or service development • Commercialization
Company H	The conglomerate Company H is a German company headquartered in Berlin and Munich and the largest engineering company in Europe with branch offices abroad. Company H is a global powerhouse focusing on the areas of electrification, automation and digitalization. One of the world's largest producers of energy-efficient, resource-saving technologies, Company H is a leading supplier of systems for power generation and transmission as well as medical diagnosis. In infrastructure and industry solutions, the company plays a pioneering role.	€ 75.6 bn	Company H mostly grew thanks to outside-in activity by acquiring small-medium companies, providers of specific technological knowledge. Today, Company H takes advantage from its network of customers, who are directly involved in the development phases of projects and their continuous exchange of information allows ideas to be quickly developed.	€ 3.5 - 5.5 bn	348,000	Manufacturing, Healthcare, Energy	Product Lifecycle Management (PLM)	• Idea generation • Product or service development • Commercialization
Company I	Company L is a French multinational insurance firm headquartered in the 8th arrondissement in Paris involved in global insurance, investment management and other financial services. Company L operates primarily in Western Europe, North America, the Asia Pacific region, and the Middle East, with a	€ 98.5 bn	Company L exploits outside-in activity mainly through M&A operations and through involving customers in the development phases of projects to acquire constant inputs on their particular needs.	€ 300 - 400 mln	157,000	Insurance	Big Data	• Commercialization
							Idea and Knowledge Management (IKM)	• Idea generation

	presence also in Africa. Company L is a conglomerate of independently run businesses operating according to the laws and regulations of many different countries. The company is a component of the Euro Stoxx 50 stock market index.						Cloud Computing	• Commercialization

We believe that this sample of companies adequately fits with the theoretical setting and, therefore, it is suitable to respond to the research question proposed in the State-of-the-art section as companies are:

i. Heterogeneous from the point of view of dimension, R&D expenses, number of employees and sector of activity, to explain differences on how they organize the internal units for innovation activities and on how the contextual factors could impact firms' performance;
ii. Homogeneous from the point of view of the digital technologies adopted, to highlight similarities and differences on their potential of application in the open innovation activity;
iii. Homogeneous from the point of view of how they conduct and organize the open innovation activity.

4. Results and Discussions

Our multiple case study analysis shows that digital technologies require firms to perform managerial changes at organizational and process level to support their open innovation process. At organizational level, the adoption of digital technologies has required companies to reorganize the Resource & Development (R&D) units and activities, focusing on (i) technologies' features standardization, (ii) budget formalization for digital investments, and (iii) development of new and formalized procedures for innovation activities (due to digital technologies). At process level, companies perform *ex-ante* and in a particular timeframe deliberate actions to adopt digital technologies. In addition, companies perform *ex-post* new actions triggered by the digital technologies as effect of their previous adoption. We call these two categories of managerial actions, (i) enabled and (ii) enabling capabilities. These capabilities sometimes change from technology to technology and from phase to phase in the open innovation process, allowing firms to manage differently the open innovation process and the inbound open innovation activity. These managerial actions allow companies to implement with success digital technologies to nurture open innovation although they require a change at organizational level and on the way with which companies manage their innovation process. We highlight these in the following discussion and in Figures 3 and 4, which show the emerging exploratory findings collected and mapped onto the dimensions of the theoretical framework.

Managerial actions at organizational level

- ***Reorganization of the R&D units and activities***

Several managerial changes are required to R&D units to manage the transition towards new organizational paradigms (Goodman & Dean, 1982; Kotter, 2007). In particular, the reorganization of R&D unit is historically recognized as one of the main innovation management paradigms for companies that dynamically implement open innovation (Chiaroni et al., 2011). In a context of digital transformation of companies' innovation activities, this issue appears to be even more interesting and important for innovation scholars and practitioners. In particular, our empirical analysis shows how R&D units of the sampled companies have been reorganized in the light of the adoption of digital technologies in their open innovation processes.

As argued by the Italian branch Lead Engineer of Company A, "Our Company has historically grown through acquisitions. Each acquisition has entailed the entrance of new technologies with specific features for specific innovation tasks. Our R&D unit was asked to standardize and streamline all the technologies' features to favour the support to innovation at company level and not only for dedicated purposes". This was particularly important for Company A's R&D activity, which is involved in designing mechanical parts used to transfer the motorcycle from the engine to the wheels for all types of vehicles treated by its different divisions. Accordingly, "Standardization of technologies' features happened through the development of a project based on the implementation of a Product Lifecycle Management (PLM) system able to provide a unique technological framework for innovation engineering processes".

This was not the same for Company B, where all dedicated digital experiences failed in the past. As argued by the Chief Information Officer (CIO), "These failures are mostly linked to the diversity of the internal business of Company B. It is difficult for our Company to have an R&D unit or a digital officer who deals with digital innovation initiatives of all businesses in a transversal way; it often happens that we focus only on some particular cases, and the others move independently to be developed. Another complementary limit is the result-oriented approach of our Company, which contrasts the final purpose of traditional R&D activities". However, before the introduction of digital technologies in Company B, there was not a dedicated budget for R&D activities. The formalization of budget for R&D activities tries to mediate the trade-off between the result-oriented approach and the R&D purposes.

In the case of Company C, digital technologies have enabled the creation of an IoT department for the development of a digital infrastructure that collects all the amount of data generated from the interaction of the machineries produced by the Company and that maintains a solid connection between them. As argued by the Chief Technology Officer (CTO), "The new IoT unit gave also us the possibility to reason on the development of new innovation projects concerning the big themes of Big Data and Cloud Computing. Once we will test the capability of our digital infrastructure to collect and maintain data exchanged by our machineries, we will start within this unit with a set of innovation projects related to the intelligent analysis and storage of these data".

In Company D, the implementation of digital technologies has required reorganizing the R&D unit in the most focused "Digital Entity" to jump-in the digital transformation process of the Company, and the new Head of Digital Entity (of the Italian branch) was called to create a new methodological approach for innovation activities. In particular, he argued, "Within this digital entity several people with very different skills (such as consultants), business experts (with vertical expertise), digital technology specialists, and people who have experience as makers, need to work together. These people have to contaminate each other their knowledge so that innovation is not necessarily derived by the technology expert, but also by a business expert rather than by a maker".

The case of Company E is particularly interesting. In the last years, the share of investments in digital technologies and IT of private hospitals has been considerably higher than in the past. As argued by the Operations Manager, "The main projects we are developing through digital technologies relate to electronic medical records, which allow monitoring the patient's diagnostic-therapeutic pathway. We were required to reorganize our innovation department in a dedicated task force, characterized by a group of 20-25 people including doctors and nurses. The task force was required to match the existing information system functionalities with the new digital tools in order to accelerate the elaboration of information on patients instead of using traditional clinical records on paper. If the manual process allowed elaborating clinical records in 3-4 weeks, the new digital process has allowed elaborating clinical records in approximately 4 working days from the patient's discharge. Our goal in the next few years will be to deliver about 80-85% of complete diagnosis the following day. The introduction of these digital applications within the hospital has brought significant changes".

The use of digital technologies in Company F is strictly related to the knowledge management. In particular, the use of Big Data supports the Idea and Knowledge Management (IKM) system of Company F. Although knowledge management in a consolidate practice in Company F since its founding in 2001, the increasing number of customers and Company's repositories, has required the use and implementation of new emerging technologies to elaborate customers' and internal information in order to create new solutions. In particular, to use and implement the IKM system (and Big Data), Company F had to reorganize its R&D unit in the "Innovation series", a new configuration of innovation unit that tracks new products and services (digitally enabled) on the market and develops new digital service solutions for customers. As argued by the two interviewed managers of the Italian branch (the Digital Strategy Senior Manager and a Consultant Analyst), "The "Innovation series" aims to look at all the digital solutions developed on the market, share them within the IKM system of the Company, and based on this sharing, develop new digital service solutions for our customers. To date, we have shared within the Company at least 4,000 new digital solutions only in the field of financial services (where we have the main customers), but we are also trying to extend this sharing practice to other industries (where we have however smaller customers), such as energy, automotive and food. Today, this innovation unit has become a well-established reality (it has been in operation since about 5 years)".

Company G is a business school that has handled the transition from physical to virtual classroom through the development of a multi-year project, named "Flex EMBA", which led to the reorganization of the old "ICT" unit in the new (and nowadays consolidated) "ICT & Digital Learning" unit. As argued by the interviewed heads of this new entity, "The launch of the "Flex EMBA" project completely changed the role of our R&D unit, which shifted from a pure back-end (a reality of ICT services, such as the help-desk, that supported the other areas) towards a more front-end (an alternative business unit that complemented the sales area) role. In this case, the project based on digital technologies implementation for managerial training was the enabler of the restructuring. The Company was also required to undertake specific formation activities for the first lines (the heads of each area) to create a widespread and cross-functional awareness on the digital transformation process of the company". In addition, as in the case of Company B, Company G formalized a budget of over 10% of the turnover per year for investments in digital learning and new digital technologies.

The "Digital Factory" division of Company H was born in 2014 with the aim to manage the digitalization of Company's industrial processes and provide new digitally developed products. In particular, this unit bases on a comprehensive portfolio of integrated hardware, software and digital technology-based services to enhance the flexibility and efficiency of manufacturing processes and reducing the time to market of products. As argued by the Italian branch Director Business Development Mid-Market, "Through the Digital Factory (and coherently with its goals), we started to give great importance to the technology of Product Lifecycle Management (PLM) system. Indeed, we believe that in order to understand if our customers perceive the new products we offer as good, it is crucial to keep the grip on the management of the entire product life cycle, from its conception to development and commercialization, and a PLM solution clearly fits this objective". As in the case of Company A, the Digital Factory was called to develop a project based on the implementation of a Product Lifecycle Management (PLM) system to provide digitally enabled standardized solutions for innovation of Company H's industrial processes.

Starting from January 2014, Company I has established the "Digital Direction" unit, which responds directly to the CEO. As argued by the Italian branch Head of Web & Social, "Before the "Digital Direction" unit, we conducted all the activities connected with the use and implementation of digital technologies, such as site management, apps, social media, internet campaigns, e-commerce, within different units of our company. In 2014, we gave birth to a six-year strategic plan for establishing a new unit that encompasses and integrates all of these deconstructed activities linked with digital technologies. In particular, the digital transformation of our Company through the "Digital Direction" has been aimed to address two main streams, (i) the digitization of activities towards final customers (marketing and commercialization), and (ii) the digitization of sales processes in charge to sales agents. In order to realize this strategic plan, we were however asked to recover skilled resources in order to bridge the technological/digital gap. Accordingly, we conducted great initiatives in this sense, such as (i) selective search of experts (in case of skills that were difficult to learn only through training courses and in case of a crucial timing performance), (ii) graduate programs for internal offices and employees (also with the support of experts), and (ii) training courses (or "digital days" for training)".

According to the answers of the interviewed managers and the cross-cases comparison, it clearly emerges how digital technologies have called companies to reorganize their R&D units and activities (and sometimes to create *ex-novo* R&D departments) towards more structured entities with a particular focus on innovation activities based on digital technologies. In particular, (i) technologies' features standardization (although the peculiar case of Company B), (ii) budget formalization for digital investments, and (iii) development of new and formalized procedures for innovation activities (due to digital technologies), result as the main organizational levers companies have adopted to support the management of their open innovation processes in the light of the digital technologies' implementation.

Managerial actions at process level

- ***Enabling and enabled capabilities in the open innovation process***

The role of digital technologies in the innovation process of companies has called the attention of scholars to provide further theoretical and empirical contributions (Agostini et al., 2017). Particularly in the open innovation field, researchers were asked to provide a structured view of their use and implementation in open innovation processes (Del Vecchio et al., 2016).

Our empirical analysis tries to answer to these calls, by showing how the use and implementation of digital technologies in open innovation processes requires companies performing managerial actions at process level. We called these managerial actions, (i) enabled and (ii) enabling capabilities. In the first case, companies perform deliberate actions *ex-ante* and in a particular timeframe to adopt digital technologies. In the second case, companies perform *ex-post* new actions triggered by the digital technologies as effect of their previous adoption. According to the answers of the interviewed managers and the cross-cases comparison, we were able to understand how the enabled and enabling capabilities at process level sometimes change from technology to technology and from phase to phase of the open innovation process, allowing firms to manage differently the open innovation process and the inbound open innovation activity. Accordingly, we finally mapped along the phases of the open innovation process these managerial actions (see Figures 3 and 4), whereas in Table 3A of the Appendix, we provide an extensive discussion around these managerial actions at process level due to each digital technology.

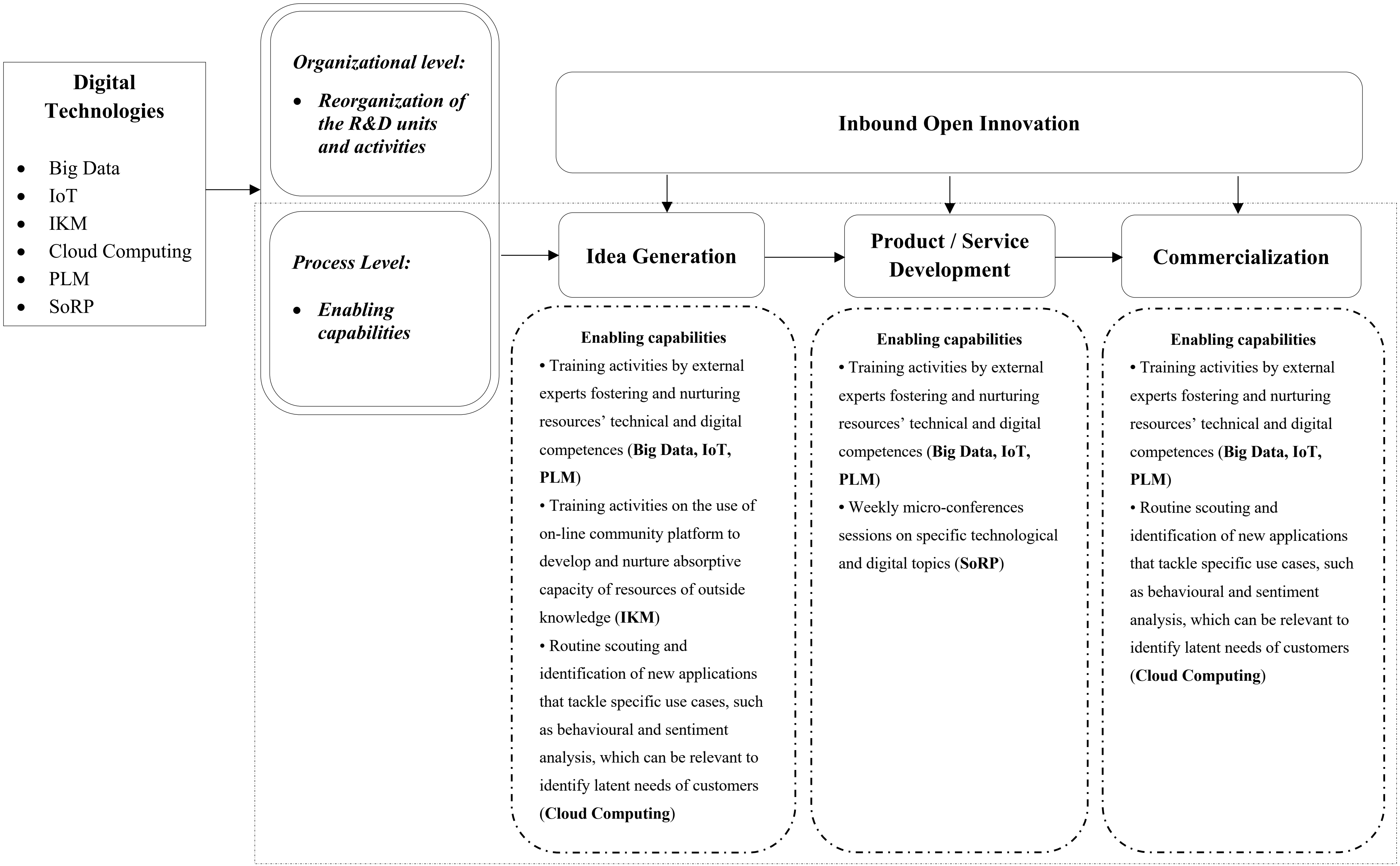

Figure 3. Emerging findings mapped onto the dimensions of our theoretical framework.

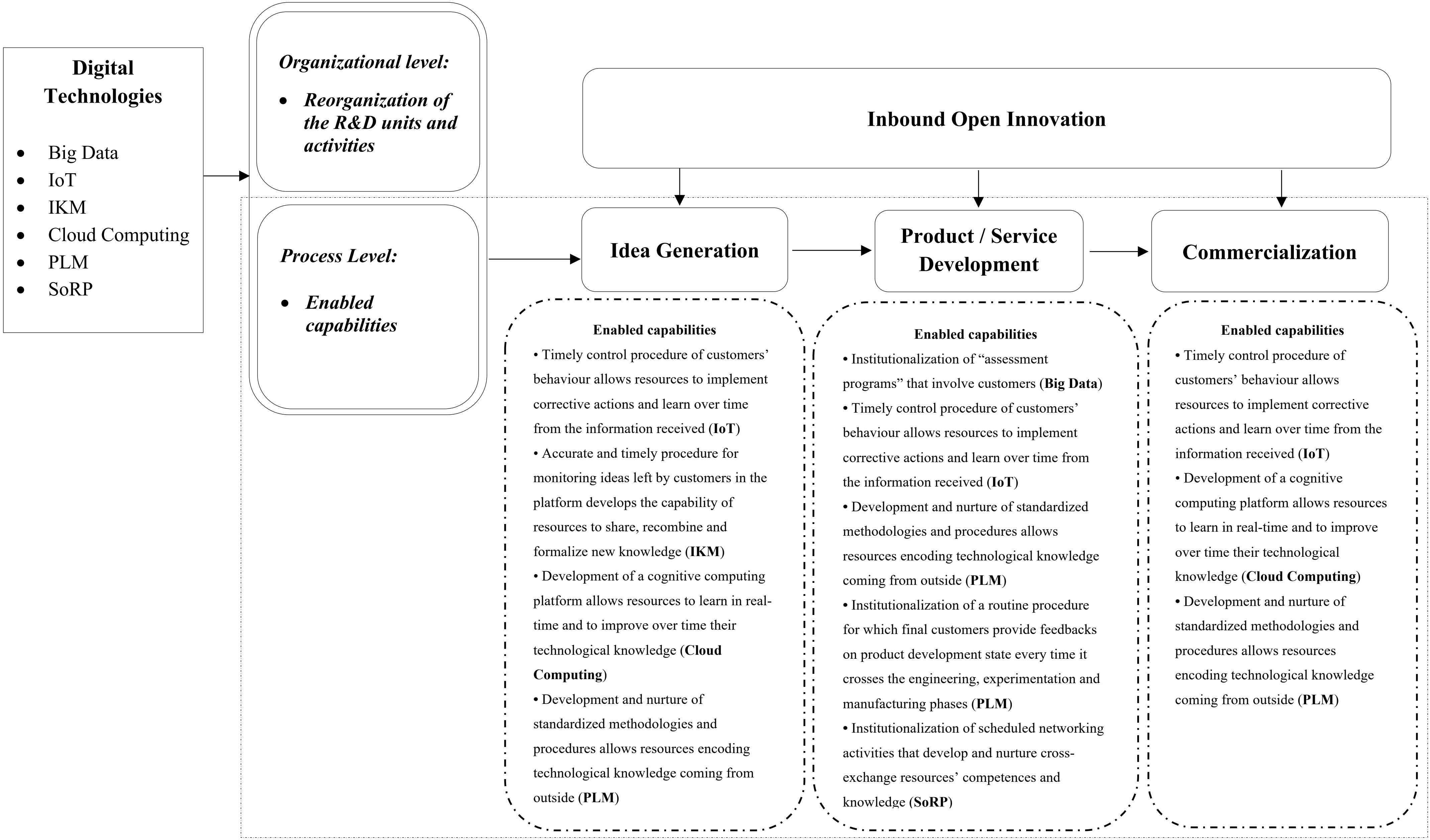

Figure 4. Emerging findings mapped onto the dimensions of our theoretical framework.

5. Conclusions

We believe the paper contributes to the ongoing and emerging debate of open innovation in the era of digital transformation of businesses. The paper leverages on the research streams on digital technologies and open innovation to study how companies use and implement digital technologies in their open innovation process. Accordingly, we adopted the theoretical lenses of change management (Goodman & Dean, 1982; Tidd et al., 1997; Kotter, 2007) to understand the managerial changes at organizational and at process level (Davenport, 1993; Todnem By, 2005) to implement with success digital technologies in their open innovation process (Chiaroni et al., 2011).

In particular, in this paper, we propose an open innovation framework mapping the managerial actions at organizational and process level for the use and implementation of digital technologies in open innovation processes. In doing so, we aim to answer to the call of Yoo (2010) and Yoo et al. (2010), who invite to provide strategic and innovation frameworks in a digital technology context. In addition, we aim to extend existing although limited knowledge on the connection between open innovation and digital technologies (Dodgson et al., 2006; Natalicchio et al., 2014; Del Vecchio et al., 2016; Agostini et al., 2017) and invite future research into this subject. First, we highlighted, at organizational level, the need to reorganize the R&D units and activities (and sometimes to create *ex-novo* R&D departments) for open innovation (Goodman & Dean, 1982; Kotter, 2007; Chiaroni et al., 2011) through digital technologies, focusing on (i) technologies' features standardization, (ii) budget formalization for digital investments, and (iii) development of new and formalized procedures for innovation activities (due to digital technologies). Second, we mapped onto the theoretical framework dimensions (idea generation, product or service development, commercialization, and inbound (or outside-in) open innovation activity) (Bianchi et al., 2016; Chesbrough, 2003; Van de Vrande et al., 2006; Lazzarotti & Manzini, 2009; Spithoven et al., 2011), the (i) enabled and (ii) enabling capabilities ensuing from and required for their use and implementation at process level. In this case, the enabled and enabling capabilities sometimes change from technology to technology and from phase to phase of the open innovation process, allowing firms to manage differently the open innovation process and the inbound open innovation activity. Accordingly, the use and the implementation of our set of digital technologies represents an important opportunity for companies that conduct innovation processes in an open perspective, when we look at the routines, competences, skills and capabilities they require and allow to develop.

Although some interesting findings emerged on the organizational changes and on the capabilities ensuing from and enabling the use and implementation of digital technologies in the open innovation process, further theoretical and empirical research is required to extend knowledge in this field and provide more tools, insights and examples for managerial audience.

First, the theoretical framework is a first tentative approach that needs to be refined and applied to many other cases to be enriched and adapted. In other words, for example, an in-depth analysis of the use and implementation of a specific digital technology in a specific phase of the open innovation process in a specific sector of activity is required. In this case, we find necessary ad hoc research to deepen the analysis on what changes, how changes, how effectively and efficiently changes in each specific phase because of the implementation of a specific digital technology. Second, the theoretical framework maps a few set of capabilities along the phases of the open innovation process, although the exploratory nature of the paper aims to justify why the enabling and enabled capabilities do not want to be exhaustive for each phase and technology. Accordingly, the set of enabling and enabled capabilities discussed in the paper could be used as a starting point to extend the research on how managing the open innovation process and the inbound open innovation activity by using and implementing digital technologies. The exploratory nature of the paper influences also the number of digital technologies analysed. This although we conducted a systematic research in WoS, followed by a confirmation of digital experts, to select a reliable sample of digital technologies. Thus, a wide spectrum of digital technologies that are useful for different innovation tasks and initiatives could be analysed in future research. Third, the paper lacks to consider in the theoretical framework another relevant dimension of open innovation, which is the outbound (or inside-out) open innovation activity. Accordingly, although we took into account the Bianchi et al. (2016, p. 505)'s argumentation that "inbound open innovation is a major component of the innovation approach of most innovative firms" (as we believe for our sampled companies), we invite future research to account peculiar challenges entailed by digital technologies in managing both the relevant dimensions of open innovation.

From a managerial perspective, we believe the paper provides managers, executives and practitioners operating in the field of open innovation and digital technologies with a set of tools, insights and examples on an under-researched management and innovation issue. In particular, we aim to stimulate their own remarks on a set of managerial actions at organizational and process level that have to be performed to use and implement with success digital technologies in open innovation processes. In addition, we believe the managerial audience would benefit from the addition of quantitative elements in our research, such as the intensity of adoption of digital technologies in the different phases of the open innovation process or the amount of investments for their implementation. Indeed, this could provide a more robust discussion around the organizational changes to be performed in the R&D units for digital technologies. Most importantly, this is required because our findings are mostly interpretative and analytical to a limited extent.

Finally, we want to highlight how in several cases the large diffusion of digital technologies such as Big Data, Internet of Things and Cloud Computing, allows obtaining high benefits and creating additional advantages if combined together and used simultaneously. In particular, we point out how a well-functioning and integrated cloud infrastructure is crucial to deal with Big Data in terms of data collection, data storage and data analysis but also to tackle with smart objects connected to a company network and generating data. Therefore, storage and computational power are two critical dimensions that allow benefiting from the use of these technologies. Furthermore, Big Data requires training activities for the development of analytical skills, which grant the possibility of extracting real value from a massive amount of data collected and elaborated. In the case of Internet of Things, training activities allow companies to develop new algorithms, which allow a fast data processing and analysis, a fast time to market, an accurate product/service offering and recommendation practices. Moreover, Internet of Things gives the possibility to be responsive in terms of problems detection and resolution, preventive maintenance programs and product improvement according to customers' feedbacks, together with the opportunity of developing strong collaboration and coordination of activities with customers. In addition, Idea and Knowledge Management systems require a solid digital infrastructure that grants the possibility of storing and retrieving high quality contents in the fastest possible way. By doing so, resources can benefit from standardized solutions and availability of pre-defined frameworks that avoid to waste time in solutions drafting and definition, focusing directly on solution customization. Finally, Systems of Rapid Prototyping and Product Lifecycle Management systems require as well a solid digital infrastructure, highly integrated with processes and systems, and training activities on product features and product management. On one hand, Systems of Rapid Prototyping allow decreasing the amount of time and resources required to develop and test a prototype, while Product Lifecycle Management systems provide companies the possibility of acquiring a high degree of control over the whole product lifecycle, from the idea generation phase to the end of life.

References

Agostini, L., Gastaldi, L., Savino, T., and Appio, F.P. (2017). The digitalization of the innovation process: challenges and opportunities from a managerial perspective. Available at: http://www.emeraldgrouppublishing.com/authors/writing/calls.htm?id=7345.

Alavi, M., and Leidner, D.E. (1999). Knowledge management systems: issues, challenges, and benefits. *Communications of the AIS*, **1**(2es), 1.

Atzori, L., Iera, A., and Morabito, G. (2011). Siot: Giving a social structure to the internet of things. *IEEE Communications Letters*, **15**(11), 1193-1195.

Bansemir, B., and Neyer, A.K. (2009). From idea management systems to interactive innovation management systems: Designing for interaction and knowledge exchange. *IDEA*, **1**, 1-2009.

Bianchi, M., Cavaliere, A., Chiaroni, D., Chiesa, V., and Frattini, F. (2011). Organisational modes for Open Innovation in the bio-pharmaceutical industry: an exploratory analysis. *Technovation*, **31**, 22-33.

Bianchi, M., Croce, A., Dell'Era, C., Di Benedetto, A., and Frattini, F. (2016). Organizing for inbound open innovation: how external consultants and a dedicated R&D unit influence product innovation performance. *Journal of Product Innovation Management*, **33**(4), 492-510.

Boss, G., Malladi, P., Quan, D., Legregni, L., and Hall, H. (2007). Cloud computing. *IBM white paper*, 321, 224-231.

Brunswicker, S., Bertino, E., and Matei, S. (2015). Big Data for open digital innovation: A research roadmap. *Big Data Research*, **2**(2), 53-58.

Chen, H., Chiang, R.H., and Storey, V.C. (2012). Business Intelligence and Analytics: From Big Data to Big Impact. *MIS quarterly*, **36**(4), 1165-1188.

Chesbrough, H.W. (2003). Open Innovation: The New Imperative for Creating and Profiting from Technology, *Harvard Business School Press*.

Chesbrough, H.W. (2004). Managing open innovation. *The Journal Research Technology Management*, 23-26.

Chesbrough, H.W. (2006). Open innovation: a new paradigm for understanding industrial innovation. *Open innovation: Researching a New Paradigm*, **400**, 1-12.

Chesbrough, H.W., and Crowther, A.K. (2006). Beyond high-tech: Early adopters of open innovation in other industries. *R&D Management*, **36** (3), 229-36.

Chesbrough, H.W., and Bogers, M. (2014). Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation. Henry Chesbrough, Wim Vanhaverbeke, and Joel West, eds. *New Frontiers in Open Innovation*. Oxford: Oxford University Press, Forthcoming (pp. 3-28). Available at SSRN: https://ssrn.com/abstract=2427233.

Chiaroni, D., Chiesa, V., and Frattini, F. (2011). The Open Innovation Journey: How firms dynamically implement the emerging innovation management paradigm. *Technovation*, **31**(1), 34-43.

Chiesa, V., Frattini, F., Lazzarotti, V., and Manzini, R. (2007). How do measurement objectives influence the R&D performance measurement system design? Evidence from a multiple case study. *Management Research News*, **30**(3), 187-202.

Chinneck, C., and Bolton, S. (2013). Idea management: The importance of ideas to design business success. *In ICoRD'13 (845-857)*. Springer India.

Cohen, W.M., and Levinthal, D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, 128-152.

Davenport, T.H. (1993). *Process innovation: reengineering work through information technology*. Harvard Business Press.

Del Giudice, M., Caputo, A., Marzi, G., and Pellegrini, M.M. (2016). The internet of things in manufacturing innovation processes: development and application of a conceptual framework. *Business Process Management Journal*, **22**(2), 383-402.

Del Vecchio, P., Di Minin, A., and Messeni Petruzzelli, A. (2016). Big Data for open innovation: Unveiling challenges and opportunities. Available at: http://www.continuous-innovation.net/events/cimworkshops/2016/cfp-si-big-data-and-open-innovation.pdf

Dimitrov, D., Schreve, K., Taylor, A., and Vincent, B. (2007). Rapid prototyping driven design and realisation of large components. Rapid Prototyping Journal, **13**(2), 85-91.

Dodgson, M., Gann, D., and Salter, A. (2006). The role of technology in the shift towards open innovation: the case of Procter & Gamble. *R&D Management*, **36**(3), 333-346.

Eisenhardt, K.M., and Martin, J.A. (2000). Dynamic capabilities: What are they? *Strategic Management Journal*, **21**(10-11), 1105-1121.

Ercan, T. (2010). Effective use of cloud computing in educational institutions. *Procedia-Social and Behavioral Sciences*, **2**(2), 938-942.

Füller, J., and Matzler, K. (2007). Virtual product experience and customer participation—A chance for customer-centred, really new products. *Technovation*, 27(6), 378-387.

Goodman, P.S., Dean Jr., J.W., 1982. Creating long term organizational change. In: Goodman, P.S. (Ed.),Change in Organizations. Jos-sey-Bass, San Francisco, CA, pp. 226-279.

Gubbi, J., Buyya, R., Marusic, S., and Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, **29**(7), 1645-1660.

He, Z.L., and Wong, P.K. (2004). Exploration vs. exploitation: an empirical test of the ambidexterity hypothesis. *Organization Science*, **15**(4), 481–494.

Hilbert, M. (2016). Big Data for Development: A Review of Promises and Challenges. *Development Policy Review*, **34**(1), 135-174.

Kiritsis, D. (2011). Closed-loop PLM for intelligent products in the era of the Internet of things. *Computer-Aided Design*, **43**(5), 479-501.

Kiritsis, D., Bufardi, A., and Xirouchakis, P. (2003). Research issues on product lifecycle management and information tracking using smart embedded systems. *Advanced Engineering Informatics*, **17**(3), 189-202.

Kotter, J.P. (2007). *Leading change*. Harvard Business Review.

Lazzarotti, V., and Manzini, R. (2009). Different modes of open innovation: a theoretical framework and an empirical study. *International Journal of Innovation Management*, **13**(04), 615-636.

Lee, J., Bagheri, B., & Kao, H.A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing Letters*, 3, 18-23.

Lian, J.W., Yen, D.C., and Wang, Y.T. (2014). An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital. *International Journal of Information Management*, **34**(1), 28-36.

Lichtenthaler, U., and Lichtenthaler, E. (2009). A capability-based framework for open innovation: Complementing absorptive capacity. *Journal of Management Studies*, **46**(8), 1315-1338.

Lichtenthaler, U., and Lichtenthaler, E. (2010). Technology transfer across organizational boundaries: absorptive capacity and desorptive capacity. *California Management Review*, **53**(1), 154-170.

Lin, A., and Chen, N.C. (2012). Cloud computing as an innovation: Perception, attitude, and adoption. *International Journal of Information Management*, **32**(6), 533-540.

Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C., and Byers, A.H. (2011). *Big data: The next frontier for innovation, competition, and productivity*. Available at: http://abesit.in/wp-content/uploads/2014/07/big-data-frontier.pdf

March, J.G., (1991). Exploration and exploitation in organizational learning. *Organization Science*, **2**(1), 71-87.

Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., and Ghalsasi, A. (2011). Cloud computing - The business perspective. *Decision Support Systems*, **51**(1), 176-189.

Ming, X.G., Yan, J.Q., Wang, X.H., Li, S.N., Lu, W.F., Peng Q.J., and Ma, Y.S. (2008). Collaborative process planning and manufacturing in product lifecycle management. *Computers in Industry*, **59**, 154-166.

Miorandi, D., Sicari, S., De Pellegrini, F., and Chlamtac, I. (2012). Internet of things: Vision, applications and research challenges. *Ad Hoc Networks*, **10**(7), 1497-1516.

O'Donovan, P., Leahy, K., Bruton, K., and O'Sullivan, D.T. (2015). Big data in manufacturing: a systematic mapping study. *Journal of Big Data*, **2**(1), 1.

O'Leary, D.E. (2013). Artificial intelligence and big data. *IEEE Intelligent Systems*, 28(2), 96-99.

Rayna, T., and Striukova, L. (2016). From rapid prototyping to home fabrication: How 3D printing is changing business model innovation. *Technological Forecasting and Social Change*, **102**, 214-224.

Roberts, N., Galluch, P.S., Dinger, M., and Grover, V. (2012). Absorptive capacity and information systems research: Review, synthesis, and directions for future research. *MIS Quarterly*, 36(2), 625-648.

Rupp, M., Burg, A., and Beck, E. (2003). Rapid prototyping for wireless designs: The five-ones approach. *Signal Processing*, **83**(7), 1427-1444.

Sambu, S., Chen, Y., and Rosen, D.W. (2002). Geometric tailoring: a design for manufacturing method for rapid prototyping and rapid tooling. In ASME 2002 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference (pp. 149-161). *American Society of Mechanical Engineers*.

Sikimic, U., Chiesa, V., Frattini, F., and Scalera, V.G. (2016). Investigating the influence of technology inflows on technology outflows in open innovation processes: A longitudinal analysis. *Journal of Product Innovation Management*, **33**(6), 652-669.

Spiegler, I. (2000). Knowledge management: a new idea or a recycled concept? *Communications of the AIS*, **3**(4es), 2.

Spithoven, A., Clarysse, B., and Knockaert, M. (2011). Building absorptive capacity to organize inbound open innovation in traditional industries. *Technovation*, **30**(2), 130-41.

Sultan, N.A. (2011). Reaching for the "cloud": How SMEs can manage. *International Journal of Information Management*, **31**(3), 272-278.

Sudarsan, R., Fenves, S.J., Sriram, R.D., and Wang, F. (2005). A product information modeling framework for product lifecycle management. *Computer-aided design*, **37**(13), 1399-1411.

Tidd, J., Bessant, J. R., and Pavitt, K. (1997). *Managing innovation: integrating technological, market and organizational change*. Vol. 4, Chichester: Wiley.

Todnem By, R. (2005). Organisational change management: A critical review. *Journal of Change Management*, 5(4), 369-380.

Toga, A.W., and Dinov, I.D. (2015). Sharing big biomedical data. *Journal of Big Data*, **2**(1), 1.

Van de Vrande, V., Lemmens, C., and Vanhaverbeke, W. (2006). Choosing governance modes for external technology sourcing. *R&D Management*, **36**(3), 347-363.

Weber, R.P. (1990). Basic content analysis. *Newbury Park, CA: Sage*.

Weber, R.H. (2010). Internet of Things: New security and privacy challenges. *Computer Law & Security Review*, **26**(1), 23-30.

West, J., and Bogers, M. (2014). Leveraging external sources of innovation: a review of research on open innovation. *Journal of Product Innovation Management*, **31**(4), 814-831.

West, J., Salter, A., Vanhaverbeke, W., and Chesbrough, H.W. (2014). Open innovation: The next decade. *Research Policy*, **43**(5), 805-811.

Westerski, A., Iglesias, C.A., and Rico, F.T. (2010). A model for integration and interlinking of idea management systems. In Research Conference on Metadata and Semantic Research (pp. 183-194). *Springer Berlin Heidelberg*.

Wu, Y., Cegielski, C.G., Hazen, B.T., and Hall, D.J. (2013). Cloud computing in support of supply chain information system infrastructure: understanding when to go to the cloud. *Journal of Supply Chain Management*, **49**(3), 25-41.

Yin, R.K. (2003). *Case Study Research: Design and Methods*. Thousand Oaks. California: Sage Publications.

Yoo, Y., Boland Jr, R.J., Lyytinen, K., and Majchrzak, A. (2012). Organizing for innovation in the digitized world. *Organization Science*, **23**(5), 1398-1408.

Zillner, S., Oberkampf, H., Bretschneider, C., Zaveri, A., Faix, W., and Neururer, S. (2014). Towards a technology roadmap for big data applications in the healthcare domain. *In Information Reuse and Integration (IRI), 2014 IEEE 15th International Conference on (pp. 291-296). IEEE*.

Appendix

Table 1A. Sample of companies and innovation managers involved.

Institution	**Role**
Company A	Lead Engineer of the Italian branch
Company B	Chief Information Officer (CIO)
Company C	Chief Technology Officer (CTO)
Company D	Head of Digital Entity of the Italian branch
Company E	Operations Manager
Company F	Digital Strategy Senior Manager and Consultant Analyst of the Italian branch
Company G	Head of Digital Learning, Head of ICT and Digital Learning Specialist
Company H	Director Business Development Mid-Market of the Italian branch
Company I	Head of Web & Social of the Italian branch

Note: The real names of the companies are withheld for confidentiality reasons.

Table 2A. Interview protocol.

Company background
1. Type of firm: market, size, competence, products 2. Organizational structure and context 3. Organization and innovation management activities 4. Organization and management of the open innovation process
Use of the digital technology
1. What digital technology is used in your company to manage the open innovation process? 2. In which phases of the open innovation process is your digital technology used (i.e., idea generation, product development, commercialization)? 3. Does the use of your digital technology involve external actors (and at which level of the value chain, i.e., suppliers, customers, other types of partners, etc.)? 4. Why is it used? What type of output does it generate?

Impact of use of the digital technology
Impact of use of the digital technology 1. What impact does your digital technology have on the performance of human resources? What impact does it have on human resource habits? Does it change the way they work and how? 2. What impact does the use of the digital technology have on the way the human resources work with partners, clients or customers, suppliers, and across functions and other divisions? 3. Which types of activities are required to use and implement your digital technology? Was your company required to perform specific managerial actions at organizational and process level for its implementation? Were specific managerial actions required at process level in each phase of the innovation process? 4. Does the use of the digital technology change the way the company manages its open innovation process? What impact does your digital technology have on the overall performance of the company? 5. Which lessons have been learned in your company from the use and implementation of the digital technology?
Problems of use of the digital technology 1. Which innovation problems and challenges were faced during the use and implementation of your digital technology?

Table 3A. Enabling and enabled capabilities along the phases of the innovation process.

Big Data	Big Data technology mainly enables acquiring, storing and processing data, and then transform these into new ideas and solutions. This is generally the case in all the firms in our sample that adopt this technology, although its use may change in the different phases of the open innovation process. For instance, Company B mostly uses this technology in the idea generation phase and to create personalized services and product offerings for its customers, as well as monitoring their purchasing behaviour. The reason that Big Data is not involved in the product development phase is explained by the CIO, "Company B is in a second innovation phase: in the past, it was easier to innovate and create new solutions because there was ample room for innovation. Nowadays, being innovative is much more difficult and what happens is that you try to innovate old processes or products using available solutions and try to combine or apply them in a new way by exploiting information flows from outside". Obtaining value from Big Data calls for good analytical skills. Indeed, Big Data analytics allow examining large datasets to identify hidden patterns, unknown correlations, market trends, customer preferences and other useful business information.

	In terms of Company C, the Big Data technology covers all the phases of the innovation process with specific characteristics. In the idea generation phase, Big Data offers a robust database and data analysis procedures that through complex algorithms enable understanding new customer needs and developing new product concepts. The firm's aim is to validate these concepts and once the assessment and validation feedback is positive, start to produce and sell the machineries. The company has institutionalized a procedure according to which the evaluation of new product concepts and their development phase is supported by formal "assessment programs" that directly involve final customers. In doing so, customers can always be connected with the firm. On the other side, the company receives significant quantities of free data, which are stored and carefully analyzed to allow it to understand how its machineries perform in different contexts and how customers use them. Moreover, as asserted by the CTO, "The close relationships established with all customers allows our company to control and continuously monitor the single machineries or the fleet of machineries, and this strongly helps during the product development and testing phase". In particular, Company C usually tests new solutions on a selected cluster of customers that are more willing to adopt new solutions to simplify actual procedures and processes. In the commercialization phase, the high integration with IoT ensures a well-functioning reporting system as well as consistent data and information processing. In the case of Company D, Big Data offers robust database and data analysis procedures in the idea generation phase that enable the firm to understand new customer needs and develop new product concepts. In the product development and commercialization phases, the Big Data technology is adopted to provide new consultancy practices that bring more value to customers or can simply suggest small adjustments to enhance standard practices. The activity of inbound open innovation is particularly supported by the co-design with customers, who actively participate in analyzing problems, bringing internal perspectives and learning new working methodologies. Conversely, Company E uses Big Data only in the commercialization phase mainly to support digital offerings for patients by providing decision-support systems, customer experience and on-demand documentation. The Operations Manager states, "Since the introduction of this digital technology, our company is steadily growing by 10-20% every year. Certainly, maintaining this rate of growth in the coming years will be more and more difficult, but the new data analytics methodologies and procedures enabled by the implementation of Big Data give us the possibility to be competitive on the market by monitoring drug consumption and therapies provided to each patient". In Company F, similarly to Company D, Big Data analytics support the development and offering of new consultancy practices. In particular, they allow examining large datasets to identify hidden patterns, unknown correlations, market trends, customer preferences and other useful business information. The Digital Strategy Senior Manager states, "The analytical findings can lead to more effective marketing, new revenue opportunities, better customer service, improved operational efficiency and competitive advantages over rival organizations". Moreover, in the product development phase, customers are increasingly involved in testing pilot solutions. An important aspect concerns the development of new training activities enabled by digital

	technology adoption. Indeed, as the Digital Strategy Senior Manager pointed out, "Our Company operates in an extremely dynamic environment. This sometimes can be frustrating, but quite interactive and challenging. The external dynamics require our company to internally develop new training activities that employees can attend to support their continuous learning process". Company I combines the use of Big Data in the commercialization phase with the existing CRM to collect and process all the information acquired by the IKM and create a recommendation system able to develop focused marketing-campaigns for potential customers.
Internet of Things (IoT)	IoT solutions allow connecting and analyzing data from different physical sources. In particular, IoT supports Company B in the idea generation phase by connecting point-of-sale digital devices and signage, which allows customers to interact with them and the company to create new ways through which to provide services. On the other side, IoT perceive more accurate customer profiles. Indeed, through the interconnections of physical sensors in the bookstores, the company tracks and monitors customer behaviours. This supports the commercialization phase by optimizing the distribution and shelf positioning of products and services and the management of stores. In the case of Company C, the IoT solution involves the product development and commercialization phases. On the one hand, it allows maintaining connections among machineries in the engineering process and once they are sold to customers. On the other hand, as stated by the company's CTO, IoT allows providing real time reports and information on machinery status and functioning, which are exploited in the commercialization phase by supporting Big Data analytics. IoT aims to enable monitoring both single machinery performance and controlling the entire network of machineries placed on the market. This direct link with all machineries allows Company C to detect potential production defects or problems and solve them promptly in the most appropriate way. Finally, Company G leverages on IoT technology to connect every type of digital device, such as smartphones, wearable devices, personal computers, e-mail, video and social networks, which allows creating a user-friendly, attractive and challenging "learning infrastructure". All these tools, as the Head of ICT underlined, "Make up the student's personal learning environment". IoT devices allow gathering information and data related to user platform utilization or to the customer's e-learning approach and digital device support. Appropriate algorithms and data analytics help analyzing the massive amount of data and apply a continuous data monitoring policy. As the Head of Digital Learning highlighted, "This provides constant and reliable information that can be quickly turned into significant cues or suggestions for improvement actions and new idea generation". Moreover, the possibility to develop new solutions or to improve current ones with the final customer enables real time feedback that helps in understanding which specific aspects should be better developed or exploited and which should be integrated or eliminated. Therefore, the learning process innovation is strongly related to the IoT technology, which enables triggering a higher level of interaction between the professor and the class. The inbound open innovation activity conducted by our three sampled companies, independently of the phase of the innovation process where this technology is applied, is enabled

	by a timely control procedure of customers' behaviour, which happens by constantly monitoring the amount of information collected from the connection of the digital devices. This allows resources to implement corrective actions and learn over time from the information received. Training activities on the use and implementation of IoT are necessary also in this case to foster and nurture resources' technical and digital competences. In the case of company G, training activities are provided under the guise of monthly webinars that allow increasing the knowledge on the potential of IoT in the innovation process.
Idea and Knowledge Management (IKM) systems	As highlighted in the state-of-the-art section, Idea and Knowledge Management systems can integrate and apply the specialized knowledge of internal resources in the idea generation phase to create and sustain the upstream competitive advantage. This occurs, for instance, in Company F. Indeed, when an employee has an idea, the on-line community platform enables uploading the concept and description seeking comments, suggestions and advice from other employees. The on-line community platform consists of (i) a research platform, a type of internal Google browser that is able to retrieve data from the company's repositories, (ii) an online community, which allows employees to directly exchange information or views on specific problems, challenges and innovative solutions with colleagues on a worldwide base, and (iii) a "point of view", a cluster of around 50,000 people belonging to the worldwide R&D units that design and develop research, credentials and project frameworks that are made available for easy analysis and adoption by all top managers. The outside-in activity is enabled by involving customers in the platform to provide insights on the ideas proposed and then analyze customer perceptions and reactions. As the Digital Strategy Senior Manager stated, "Company F has established an accurate and timely procedure of monitoring ideas coming from customers in order to allow internal resources sharing, recombining and formalizing new knowledge". Strictly required are training activities on the use of the on-line community platform to develop and nurture absorptive capacity of internal resources of outside knowledge. In doing so, employees develop a type of desorptive capacity of the recombined inside knowledge, which is exploited to perform better with customers. As for Company I, and similarly to Company F, the Idea and Knowledge Management system supports the idea generation phase and allows transferring the knowledge created by employees once this was shared and recombined with ideas coming from customers. Moreover, the Head of Web & Social of the Italian branch stated, "Frequently, some ideas coming from the Idea and Knowledge Management system are selected to be analyzed more in depth and to evaluate their feasibility. Mostly, ideas that have the potential to solve critical issues or develop interesting solutions are presented to the board that generally requires candidates to bring a business plan to decide whether to implement the proposed ideas or not".
Cloud Computing	Cloud computing is mainly used to support the activity of Big Data and Internet of Things. In the case of Company B, Cloud Computing provides the necessary storage infrastructure that collects and stores the massive amount of data from websites, company applications and all the internet of things sensors and solutions. As the CIO highlighted, "Reliable storage power is fundamental to be able to collect and store all the useful data that will be analyzed to find useful information related to customer needs and behaviours. This with the aim of developing new solutions and

	products and to create ad hoc offerings for all the possible types of customers". An accurate level of computational power helps Company B process data quickly and extract valuable information related to different aspects, i.e., new market trends, new feature requirements, customer satisfaction, new customer behaviours or changes in standard habits. In Company I instead, Cloud Computing supports Big Data in the commercialization phase by guaranteeing the necessary infrastructure for data collection, data storage and data analysis. As the Head of Web & Social of the Italian branch stated, "Cloud Computing can be considered as an overarching technology that provides the possibility for Big Data to work properly and create value for the company. In this case, Big Data requires a well-functioning and reliable cloud infrastructure, which collects, stores and analyzes all the information flows acquired every day". In the case of Company E, the Cloud Computing solution provides an accurate level of computational power by supporting Big Data in the commercialization phase to quickly process data and extract valuable information related to patients' actual conditions, treatment prioritization or other useful cues for internal research projects. The inbound open innovation activity conducted by our three sampled companies, independently of the phase of the innovation process, consists in a routine scouting and identification of new applications that tackle specific use cases, such as behavioural and sentiment analysis, which can be relevant to identify latent needs of external users. In addition, the use and implementation of Cloud Computing has enabled in these companies the establishment of a cognitive computing platform, i.e., a comprehensive set of technological capabilities, such as data mining, pattern recognition, machine vision and natural language processing, which allow resources to learn in real-time and to improve over time their technological knowledge.
Product Lifecycle Management (PLM) systems	The empirical study shows that PLM helps connect, organize, control, manage, track, consolidate, and centralise all the mission-critical information that affects a product, starting from the idea generation up to commercialization phase. In particular, in Company A, the PLM solution "offers a mode to streamline collaboration and communication among product stakeholders, such as technology providers, as well as among the engineering, design, manufacturing and quality phases". Moreover, the PLM system enables reducing the complexity of products and components thanks to standardising the design and planning tools and processes. The inbound open innovation activity is enabled by training activities that conceive the phases of pre-planning, planning, concept, build, test, validation, go live and maintenance, supporting internal resources to develop and nurture standardized methodologies and procedures. In addition, Company A has institutionalized a routine procedure for which final customers provide feedbacks on product development state every time it crosses the engineering, experimentation and manufacturing phases. As Company A's Lead Engineer of the Italian division explained, "The use and implementation of technology is not a problem at all, it just requires good training experience". Indeed, problems immediately arise in getting employees to understand the change suggested, embrace it and then practically carry it out. Resources using PLM must manage and deal with all the product's features and the related issues. This knowledge stems from people's working experience in the company and is improved through ad hoc training activities in all phases of the

	innovation process. As indicated in the synoptic table above, PLM in Company A allows developing standardized procedures and methodologies, which are constantly updated thanks to the exchange of information between business units and organizational divisions enabled by the PLM technology. The same occurs in Company H where PLM enables the constant update of standardized procedures and methodologies that release products to the market on a large scale and in a reasonable time. In addition, the high level of standardization supported by training activities in all phases of the innovation process leads to an easier and faster learning process. In doing so, internal resources can promptly apply what they learn to practical activities, improving the time required to learn new procedures or methodologies and transfer knowledge to final customers. In the case of Company H, the inbound open innovation is triggered by the training activity made by technology providers on the employees on all the phases of product conceptualization, product development and product commercialization. Moreover, as the Mid-Market Business Development Director of the Italian branch affirmed, "Employees have to have good analytical skills and knowledge, regularly nurtured by training activities, to be able to examine the amount of data generated by each procedure related to the product lifecycle and transfer it to our customers".
Systems of Rapid Prototyping (SoRP)	Emerging from our empirical analysis is that only Company D uses SoRP to support the product development phase through prototype generation, test design and refining competitive solutions for manufacturing customers, which allows reducing costs, increasing speed, modifying and customizing the offering. Company D's approach in this phase is strongly linked to practical and complementary activities of prototyping, such as using 3D printers, augmented and virtual reality, which are conducted on a daily basis by both designers and makers in the Digital Entity. In particular, the Digital Entity team works closely with customers to understand problems, develop new ideas and enhance existing solutions. This sometimes allow recurrent prototyping and testing activities to quickly provide adjustments to new or existing solutions as these are co-developed with customers. The Digital Entity team has internally developed a type of training activity called "digital seeds": every week, on a voluntary base, a member of the division organizes a micro-conference on a specific technological topic. In this way, the entire Digital Entity team is always updated on new technological trends and innovative solutions. This methodology can be easily applied within the digital entity division because there are no significant hierarchies or barriers among the people of the team. The objective of this new training practice is to help each member in acquiring knowledge and skills belonging to past projects or solutions and including colleagues' experiences on technological and digital topics. The high quality of the contents discussed during these conferences brought Company D to think about a methodology through which it will be possible to record and provide all the contents on an internal shared platform. Therefore, the "digital seeds" have enabled the institutionalization of scheduled networking activities that develop cross-exchange resources' competences and knowledge.