Industry 4.0 and Knowledge Management: An Introduction

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Abstract The fourth industrial revolution promises to deeply transform the business landscape offering new opportunities to create and use knowledge. However, firm's knowledge management strategies have been supported by technological investments for decades. The chapter explores two prior "revolutions" connected to the digital technologies—ERP and the Web—and their implications for knowledge management dynamics, identifying how Industry 4.0 technologies can further enhance those processes and the related challenges. The main contributions from the book are outlined in terms of relationships between Industry 4.0 technologies and competences and geographical implications, focusing on new firms and connection with the two strategic goals of operational excellence and environmental sustainability.

1 Introduction

The study related to knowledge management and the firm is vast and has covered a large set of topics. However, it is far from being exhaustive since the emerging dynamic technological scenario related to digital technologies in general and Industry 4.0 ones specifically asks for further attention on how knowledge is created, by whom, for what purpose, and with which outcomes.

In management studies a large set of contributions have referred to knowledge management as the key concept and relevant process firms have to deal with. From a strategic management perspective, firms manage knowledge in order to sustain their competitiveness and knowledge becomes the driver for the firm's competitive

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advantage (Kogut & Zander, 1996). Differently from other theoretical frameworks such as the transaction cost theory (Coase, 1937), the firm as a decision-making mechanism (Cyert & March, 1963), or the agency theory of the firm (Alchian & Demsetz, 1972), according to the knowledge-based theory of the firm, the firm can be interpreted as a mechanism oriented to managing knowledge (Nonaka, 2000; Spender, 1996). Knowledge becomes a key resource for firms, which have to transform individual knowledge into organizational knowledge (Grant, 1996) through appropriate processes of organizational learning.

Creating, elaborating, and transferring knowledge define different steps of the knowledge management process and imply a variety of actors involved—both within and outside the firms taking into consideration the variety of forms of knowledge (Nonaka & Takeuchi, 1995). Knowledge management is seen as an open, distributed, and extended process where individuals and organizations are connected (Argyris & Schon, 1978; March, 1991; Pfeffer & Sutton, 2000). This perspective has guided studies on innovation, which consider both technological and user-driven forms of innovation and the degree of openness of such dynamics (Chesbrough, 2003; Jensen, Johnson, Lorenz, & Lundvall, 2007). From a knowledge sourcing perspective, actors within the firms with different levels of specialization and background are relevant (from R&D to marketing, from managers to blue-collar employees), but also actors external to the organizational boundaries are as relevant as internal ones—KIBS, suppliers, and customers (Di Bernardo, Grandinetti, & Di Maria, 2012; Laursen & Salter, 2006). This is also reflected in the geography of knowledge management, since knowledge sources can benefit not only from physical proximity but also from other forms of proximity, such as social, relational, or cognitive ones (Bathelt, Malmberg, & Maskell, 2004; Boschma, 2005; Brown & Duguid, 2001).

In terms of processes of knowledge management, much attention has been given to the level of knowledge codification to evaluate the degree of "stickiness" of knowledge transfer (Szulanski, 2000; von Hippel, 1994) and how knowledge can flow across actors and places (Cowan, David, & Foray, 2000). With the idea of exploring the transformation of tacit knowledge into codified one, many studies have put the attention on the role of information systems and on information and communication technologies more in general. Among the many studies, Hansen, Nohria, and Tierney (1999) provide a relevant contribution to the debate by suggesting two possible strategies to managing knowledge transfer among individuals (organizations) also across the space: the people-to-people and people-to-document strategies. While in the first one the emphasis is on personal interaction and social dynamics to allow knowledge flows—especially in case of complexity of the knowledge to be transferred—the second one is instead more focused on the exploitation of information technological solutions—digital knowledge repositories—to collect embodied knowledge, allowing distributed access. In the knowledge processes of knowledge creation and acquisition/transfer different technological tools can be used (Baskerville & Dulipovici, 2006). The need to put attention toward the human side of application of information technologies for effective knowledge management purposes has been stressed also by Davenport (1994), who was among the many scholars debating this topic. Davenport explores information technologies for knowledge management quite extensively (Davenport, 2007; Davenport & Prusak, 2000). According to his study, different types of complexity of the work to be done by knowledge workers—routine vs. expert model/judgement/interpretation—as well as the level of interdependency (individual vs. collaborative groups) generate four different types of knowledge works which are associated with different sets of information technologies that can support such works. Alternative technological solutions should fit with the variety of knowledge to be managed: the more open, collaborative, and complex is the work, the more is required for firms to have knowledge repositories and collaborative tools, relying also on data mining and analytics solutions. On the contrary, process applications and workflow management or transactional technologies are more consistent with routinized, individual works, while decision automation is for medium complex knowledge work. The rise of information systems as technological systems oriented to support organization process can be interpreted as a revolution occurring at the knowledge management level. New set of technologies not focused on manufacturing—in the operations department—but oriented to enhance the work of knowledge workers (in the office) increase their productivity (Drucker, 1999).

This scenario has been further enlarged with the rise of the Web and the opportunity for other actors to be involved in the knowledge management process outside the organization (Kozinets, Hemetsberger, & Schau, 2008), where the role of virtual communities has been emphasized (Rheingold, 1993). From this point of view, the new economy has been seen as another technology-driven revolution, where the focus is on the C in the information and communications technologies (ICT) context. Beyond data management, the Web became the digital tool stressing the connectivity potentiality and the transformation of forms of interaction at distance among actors—especially in the consumer sphere (Armstrong & Hagel, 1996). Within the studies on lead users and customer-centric innovation processes (von Hippel, 1986), the Web became the enabling infrastructure to provide customers new toolkits (Von Hippel, 2001) and the new digital environment when distributed innovation could take place (Nambisan & Nambisan, 2008).

Now the rise of new technologies related to Industry 4.0 (Schneider, 2018; Ustundag & Cevikcan, 2018) is further changing the knowledge management framework and how firms can leverage on such technologies for managing knowledge and enhance their competitive advantage. Industry 4.0 as fourth industrial revolution is the new competitive context in which the firm defines its strategy and through which it creates value (Reinhard, Jesper, & Stefan, 2016). Industry 4.0 challenges strategic processes in terms of value generated within different activities of the value chain (value of manufacturing) (Rehnberg & Ponte, 2018) as well as geography (Strange & Zucchella, 2017).

From a knowledge management standpoint, Industry 4.0 opens new questions on the process of organizational learning (knowledge creation, codification, and transfer)—within the firm (Nonaka & Takeuchi, 1995)—but also across actors—may they be firms (networks) (Inkpen, 1996), but also customers/users (communities) (Brown & Duguid, 2001). The book aims at presenting the challenges of managing knowledge in the context of Industry 4.0. The development of digital technologies applied to manufacturing (additive manufacturing, IoT, robotics, etc.) suggests a paradigmatic change in value creation. Through theoretical and empirical contributions, the book provides insights on the way the Industry 4.0 technologies allow firms to create and exploit knowledge. New technologies offer the opportunity to acquire knowledge from a larger number of sources and open issues on how firms approach innovation, organize activities, and develop new relationships with their stakeholders in order to deliver on the market customized products and services.

2 Knowledge Management and Technological Revolutions

2.1 Knowledge Management, BPR, and ERP

The first managerial revolution linked to the introduction of digital in companies coincides with the introduction of so-called integrated management systems as a digital infrastructure for the management of companies. These technologies represented an important technological leap forward compared to the traditional IT tools available to companies since the end of the 1980s. Up to that date, business IT had developed software solutions capable of responding to specific business functions (administration, finance, production, marketing, etc.) without it being possible to rely on shared databases and without being able to rely on simple solutions for the management of inter-functional processes. Software for integrated business management (i.e., the world leader SAP) named Enterprise Resource Planning (ERP) overturned this development logic by offering a single platform with different applications for different business functions and a single reference database, transforming IT in a fundamental driver for value creation rooted in new intelligence built in the software (Gable, Scott, & Davenport, 1998; Micelli, 2017; Nevo & Wade, 2010).

The introduction of these integrated management solutions triggers a profound change in the functioning of the organizational dynamics of large multinational companies, through a deep transformation called Business Process Reengineering (BPR). This transformation coincides with a substantial change in the way organizations are managed, going beyond the functional organization to adopt a model structured by processes thanks to technology (Hammer & Champy, 2001). This literature explicitly highlights the radical dimension of change imposed by new technologies and proposes methods of intervention that aim to implement radically new forms of process organization.

Information technology (IT) supports coordination within and among organizational units, where the BPR logic transforms the firm's approach toward activities by overcoming function boundaries to stress the interconnectivity among them. IT becomes relevant in the BPR during different phases of BPR (Attaran, 2004): in the design phase, technologies enable collecting, codification, and transfer of knowledge related to the different activities, actors, and locations involved in the process to be redesigned; in the implementation phase, IT allows gathering and analyzing the information concerning the performance and structure of the processes, where codification of the process is intertwined with the codification of the knowledge related to it; after BPR is implemented, IT monitors and sustains coordination also at distance.

ERP represents the technological dimension of the firm processes and its implementation is connected with the adoption of a BPR logic within the firm. “The key underlying idea of ERP is to achieve a capability of planning and integrating enterprise-wide resources” (Xu, Wang, Luo, & Shi, 2006, p. 148). Especially in geographically dispersed enterprises, ERP has been used for knowledge management purposes, by coordinating the connection between the core and the periphery of actors in the network (Lipparini, Lorenzoni, & Ferriani, 2014). ERP provides a large amount of data and information related to multiple processes and actors through a unified view, thus becoming a channel for knowledge management strategies. At the same time, clear knowledge management strategies the firm aims at developing have also an impact on ERP adoption and functioning within the organization (Xu et al., 2006). Within the ERP framework, much attention has been given to knowledge codification within the company. Tacit knowledge challenges ERP implementation, pushing firms to consider also the relevance of individuals within the organization. Codification and socialization approaches have to be coupled to benefit more from this intersection between knowledge management and IT systems (Apostolou, Abecker, & Mentzas, 2007), taking into account that knowledge creation and transfer can rely on sharing the same practice among individuals of the same organization (communities of practice) (Brown & Duguid, 2000).

2.2 Knowledge Management and the Web

A second important revolution in the application of digital technologies in firms is related to the Web. Since the end of the 1990s, the spread of the Internet and the changes that Internet would have triggered were thought of as the beginning of a real “new economy,” with its own rules, specific and different from those that have governed the economy of the past (Kelly, 1998; Porter, 2001). There is little doubt that the rapid spread of the Web has constituted a substantial revolution in the way of doing business, particularly with regard to the relationship between business and consumer. The latter, far from being alone and isolated in its decision-making processes, can leverage digital social connections allowing a previously unknown capacity for evaluation and proposal. This knowledge contribution represents an opportunity for companies to grow and innovate (Armstrong & Hagel, 1996). At the same time, the Web strongly impacts on the traditional distribution channels, toward a larger variety of e-commerce strategies (Gulati & Garino, 2000).

A growing body of studies have explored the involvement of customers into the firm’s innovation processes. Starting from the seminal contribution by von Hippel (Von Hippel, 1978), scholars stress how lead users and customers may bring their knowledge into the dynamics of product development internal to the firm and more in general into the firm's activities (Cova & Dalli, 2009; Gruner & Homburg, 2000). Digital technologies and the rise of distributed, open, communication infrastructures reduce barriers and costs for customer participation (Bagozzi & Dholakia, 2006; Galvagno & Dalli, 2014). With respect to the mass production paradigm, the Web opens new trajectories in the relationship between the firm and its customers, shifting the power from the firm to the customers. More importantly, customers (users) define different forms of aggregation—the communities—which can also become autonomous actors in the process of innovation and knowledge management (Baldwin, Hienerth, & von Hippel, 2006; Boudreau & Lakhani, 2009; Di Maria & Finotto, 2008; Sawhney, Verona, & Prandelli, 2005).

In order to create a more stable and interactive relationships with customers, the firm may develop specific toolkits for innovation (Franke & Piller, 2004; Von Hippel, 2001). Through the Web, the firm creates virtual spaces to exchange knowledge with its online communities (Armstrong & Hagel, 1996; Füller, Jawecki, & Mühlbacher, 2006; Kozinets, 1999). Specifically, firms with strong brand invest in order to gather knowledge from specialized customers and lead users (Marchi, Giachetti, & De Gennaro, 2011) within a new scenario of co-creation also of the intangible dimension of the brand perceived as shared asset with customers (Fueller & Von Hippel, 2008; Schau, Muñiz, & Arnould, 2009). Virtual Customer Environments become the digital channels for knowledge management (Nambisan & Nambisan, 2008): customers are involved in new product development through idea generation; in product testing through collection of feedbacks; and in product marketing through electronic supports to other customers based on the individual experience and knowledge.

The business scenarios generated by ICT show a transformation in firm's internal processes as well as in the connection with the market. In this perspective, they have prepared the basis for the new revolution related to Industry 4.0.

3 Opportunities and Challenges for Knowledge Management in the Industry 4.0 Context

The "Industry 4.0" label includes a large variety of technologies with different characteristics and domains of applications (Reinhard et al., 2016). Connected robotics, advanced automation, and sensors may transform the firm and specifically operations, driving toward the rise of a smart factory (Büchi, Cugno, & Castagnoli, 2020; Mittal, Khan, Romero, & Wuest, 2018). Not only manufacturing processes can be enhanced in terms of efficiency, but also new extended and detailed control opportunities may rise. A challenge is connected to the exploration of relationship between the implementation of Industry 4.0 technologies and lean management strategies (Kamble, Gunasekaran, & Dhone, 2020; Sanders, Elangeswaran, & Wulfsberg, 2016), where lean management has been one of the key new managerial practices developed during the 1990s that strongly impacted on manufacturing organization (and beyond) (Womack & Jones, 1997). In this perspective, learning processes occurring in relation to lean and operational excellence practices may benefit from digitalization and the implementation of Industry 4.0 technologies. At the same time, however, because of lean experience the firm may implement and exploit such technologies better (Rauch, Dallasega, & Matt, 2016).

Moreover, a growing body of research is exploring the consequences in terms of job metamorphosis connected to automation (and also artificial intelligence; see below) (Autor, 2015; World Economic Forum, 2016). On the one hand, studies highlight the reorganization of manufacturing activities toward the decrease in jobs in operations, while on the other hand research explores also the opportunity of skill redesign due to new forms of interaction and collaboration with technologies (Bakhshi, Downing, Osborne, & Schneider, 2017). In terms of knowledge management, this opens challenges in the types of knowledge firms and workers have to invest in: from substitution of jobs in more routinized activities toward new roles that workers can play going beyond specialization to include a more interdisciplinary approach (Pfeiffer, 2016). In this perspective, scholars are also investigating the geographical implications for manufacturing location related to Industry 4.0 (Dachs, Kinkel, & Jäger, 2019; Rehnberg & Ponte, 2018; Strange & Zucchella, 2017).

This transformation in the factories is also more and more connected to the environmental sustainability side of production, where circular economy framework calls for a better understanding and measurement in the use of resources (Tseng, Tan, Chiu, Chien, & Chi, 2018). The factory is not only smart, but through such technologies may also become green (Bonilla, Silva, Terra Da Silva, Gonçalves, & Sacomano, 2018). Scholars and practitioners are exploring how to use digital technologies as a means of achieving better environmental goals, in particular within the circular economy framework (Lacy & Rutqvist, 2016; Webster & MacArthur, 2017). The need for new circular-oriented innovation and the collaborative dimension of eco-innovation (Brown, Bocken, & Balkenende, 2019; De Marchi, 2012) push firms to exchange knowledge within the value chain—both upstream and downstream.

Industry 4.0 technologies open interesting opportunities of controlling use of resources and sustain knowledge exchange with the actors involved (Tseng et al., 2018).

This issue is related to studies on 3D printing. On the one hand, this technology is linked to the rise of the new paradigm of mass customization, where the firm can mix variety of products with efficiency in small-scale production also with the involvement of customers (Bogers, Hadar, & Bilberg, 2016). Such approach is considered a form of direct digital manufacturing, involving customers in the production (Holmström, Holweg, Khajavi, & Partanen, 2016). The maker movement is becoming protagonist of this revolution (Anderson, 2012), where customers have a new tool—3D printing—they can use not only to design, but actually to physically produce the product (Kalva, 2015; Laplume, Anzalone, & Pearce, 2016). On the other hand, 3D printing is considered a driver for new business models, also in relation to the circular economy framework (Despeisse et al., 2017; Unruh, 2019).

In addition to the above mentioned technologies, scholars and managers devoted much attention to big data and artificial intelligence. Such technologies can revolutionize the way through which firms collect and manage data, but also control learning processes and develop business scenarios (Boden, 2016; Kaplan & Haenlein, 2019; Ransbotham, Khodabandeh, Fehling, LaFountain, & Kiron, 2019). The debate concerning the relationship between knowledge management and artificial intelligence (AI) is not new (Wiig, 1999). However, compared to previous forms of AI, in the present scenario such cognitive processes are not only automated but also augmented such as the definition of Analytics 4.0 (Davenport, 2018a).

From a knowledge management perspective, the first opportunity connected to Industry 4.0 technologies refers to the fact that new processes and tools are available to acquire and elaborate distributed knowledge. Through IoT the firm is able to obtain a growing, constant (ongoing), detailed, customized set of data both from internal sources (i.e., smart machines enacted by sensors) and from external ones (smart products used by customers) (McKinsey Global Institute, 2015). Such data integrated within ERP and more in general the firm information systems can be analyzed through advanced processes of data analysis related to big data analytics and AI (Liebowitz, 2001). In this perspective, the firm may know more about its processes and products from multiple perspectives—marketing, innovation, operations, administration (i.e., Paschen, Kietzmann, & Kietzmann, 2019).

A big challenge refers to the ability of the firm to translate data into knowledge (Pauleen, 2017; Tian, 2017): it is not an automatic process the learning dynamics that an organization can develop through big data. In order to obtain answers from problem-solving situation and take decisions and actions, the firm applies analytics to big data databases to extract information and identify new knowledge also based on—and in coordination with—contextual knowledge inputs (Pauleen & Wang, 2017). Through AI and big data analysis, the firm could be able to augment its strategic vision as it may rely on new resources to strengthen its competitive advantage (Davenport, 2018b). As in the case of automation (robotics), also for AI new open questions refer to the kind of competences required within the firm to exploit such technologies, but also the implications in terms of job transformation (Daugherty & Wilson, 2018).

The second opportunity is linked to the actors that can be involved in the knowledge management dynamics. New actors are producing knowledge within open (autonomous) innovation processes. As mentioned, makers are customers that exploit 3D printing to create and produce new products, customized on their desires and needs, independently or through makerspaces (Halbinger, 2018; Kohtala & Hyysalo, 2015). From this point of view, firms able to connect to those customers for innovation purposes could benefit from their knowledge from a user-driven perspective, beyond the digital tools offered by the Web (Von Hippel, 2001). With the rise of big data and AI a new question arises and it is related to the level of exploitation of data generated by customers. More generally, scholars suggest the positive impacts of Industry 4.0 technologies in the customer relationship management: through smart products (Porter & Heppelmann, 2014) and digital ubiquity

(Iansiti & Lakhani, 2014) the firm may gather more fine-grained knowledge on the use of the product constantly. This approach asks for explicit knowledge management strategies to be adopted in the new digital scenario, since it is still not clear to what extent additional large amount of new knowledge is really relevant or how to defend the firm's competitive advantage on it (Hagiu & Wright, 2020).

A new actor that should be included among the knowledge sources are the machines themselves. As claimed by studies on artificial intelligence (Boden, 2016), machines can be seen as new digital agents who may act independently from the human inputs. According to Floridi "Artificial agents are not science fiction but advanced transition systems capable of interactive, autonomous and adaptable behavior" (Floridi, 2005, p. 416). Through AI, machine learning processes can generate additional knowledge as inputs for strategic developments. Within the theoretical debate on AI (and IT more in general) and knowledge management (Liao, 2003), the novelty of the present scenario refers to the availability of big data, improved computational power, and a system of interconnected technologies that enhance the production of "autonomous" knowledge to be used at the firm level (Yao, Zhou, Zhang, & Boer, 2017; Zhuang, Wu, Chen, & Pan, 2017). This scenario is connected to the problem of control and validation of the new knowledge created through AI outputs with respect to emerging processes such as AI-driven design processes (generative design). By combining multiple perspectives and tools, knowledge-based engineering improves product development through the autonomous inputs of technology, where the focus is on repetitive and non-creative design tasks but also to support multidisciplinary design optimization (Rocca, 2012). Even if the relationship between AI and creativity (and design) is not new (Boden, 1998), new approaches in product design are connected to the opportunity of sustaining the competitiveness related to mass customization within the Industry 4.0 framework (Zawadzki & Żywicki, 2016).

It emerges also a potentially reduced problem of exploration (March, 1991) in the Industry 4.0 scenario, where technological solutions connecting big data and advanced analytics increase the efficiency in gathering data and potentially transform them into knowledge—also overcoming the geographical limitations. However, also issues related to the control over such knowledge emerge. The rise of platform economy (Parker, Van Alstyne, & Choudary, 2016) and the disproportion of power between large firms and SMEs (Wu & Gereffi, 2018) may reduce especially for the latter opportunities of knowledge creation and exploitation. At the same time, firms with prior IT investments and experience in previous revolutions—the EPR/BPR and Web ones mentioned above—can benefit more from the fourth industrial revolution, with respect to firms that have neither clear digital strategy nor past experience on how to effectively introduce technologies within the organization, irrespective of the size. It is not a matter of investing in all the Industry 4.0 technologies available simultaneously (Reinhard et al., 2016), rather to choose the right, appropriate technologies for the product and the processes that characterize the firm and its strategy (Bettiol, Capestro, Di Maria, & Furlan, 2019; McAfee, 2004).

3.1 *Managing Knowledge Within the Industry 4.0 Scenario: Contributions of the Book*

In line with the theoretical picture depicted above, the book aims at exploring the relationship between Industry 4.0 technologies and knowledge management dynamics from different perspectives.

The contribution by Capestro and Kinkel (Chapter "Industry 4.0 and Knowledge Management: A Review of Empirical Studies") provides insights of the linkages between the fourth industrial revolution and knowledge management issues through a literature review aiming at identifying how scholars have explored empirically this topic. The authors analyze about 50 empirical studies focused on the implementation of a set of Industry 4.0 technologies to explore their relationships with knowledge management. They emphasize the knowledge implications related to processes, products, and people, suggesting the need for manufacturing firms to develop clear strategic orientation toward knowledge management. Moreover, firms should invest in order to upgrade human resources' competences to also include digital skills.

The analysis on the implications of Industry 4.0 technologies on value chain activities and their geographical location has been explored by Fratocchi and Di Stefano (Chapter "Do Industry 4.0 Technologies Matter When Companies Backshore Manufacturing Activities? An Explorative Study Comparing Europe and the US"). A growing number of studies—especially recently with the rise of attention and the diffusion of Industry 4.0 technologies—are evaluating the transformation in the location choices of manufacturing activities of firms from advanced countries. The theoretical premises suggest the cost advantages of the new technological landscape, pushing manufacturing firms in redesigning their offshoring strategies across countries, also considering the home country as an option (compared to the past decades). Fratocchi and Di Stefano developed an extensive structured literature review followed by an analysis of empirical evidence of backshoring decisions implemented by both European and US firms. The authors suggested that even if theoretically Industry 4.0 technologies have been identified as drivers for backshoring decisions, the empirical analysis identifies those technologies both as driver and as enabling factor. Among the many technologies, only automation (robotics) and 3D printing are cited as relevant in backshoring decisions. Moreover, there are differences in the way European vs. US firms adopt such technologies. Most importantly, it seems that automation per se is not necessarily related to decisions concerning backshoring from low-cost countries to high-cost country. This result is explained in terms of competences available and developed within firms adopting Industry 4.0 technologies. It is not a matter of technological investments, rather of coupling competences in the use of Industry 4.0 technologies with knowledge related to manufacturing processes. From this point of view, the adopting firm should develop appropriate learning dynamics in order to effectively exploit the advantages of Industry 4.0 technologies within its backshoring strategies.

In their analysis of knowledge management strategies in top performers, Bettiol et al. (Chapter "Knowledge and Digital Strategies in Manufacturing Firms: The

Experience of Top Performers") suggest that Industry 4.0 technologies may have different impacts in terms of how knowledge is created and shared at the firm level. Compared to previous scenarios, the emerging new technological one has potential implications on the knowledge related to products, but also on the knowledge related to Industry 4.0 technologies themselves (new potentialities that have to be fully discovered in their synergies yet) as well as knowledge of the management of the firm (learning on how to exploit Industry 4.0 technologies, also in connection with prior ICT revolutions). On the one hand advanced, interconnected technologies generate new knowledge autonomously, but on the other hand, in order to really deploy the value connected to data produced by such technologies, firm should also rely on the social dimension of knowledge management dynamics. The empirical analysis on *Champions* shows how specifically AI is intertwined with other data-driven technologies—cloud, big data, and IoT—in addition to prior ICT investments, where skills and competences related to Industry 4.0 are critical in order to manage effectively the implementation and use of digital technologies.

Blasi and Sedita study the implications on knowledge management and innovation of adopting Industry 4.0 technologies in firms specializing in the creative industries. In such industries knowledge management is characterized by the relevance of interaction between the firm and its suppliers and customers, in relation to business innovation processes. The focus of the empirical analysis in Chapter "Industries 4.0 and Creative Industries: Exploring the Relationship Between Innovative Knowledge Management Practices and Performance of Innovative Startups in Italy" is Italian startups in creative industries in general and ICT specifically. Within the Industry 4.0 scenario, startups not only can benefit from being early adopters but also can play a role as promoters of Industry 4.0 technologies in their markets (as creative industries). Three clusters of firms emerged with respect to the adoption of Industry 4.0 technologies (taking into account specifically IoT and big data) as well as their turnover: smart adopters, regular adopters, and laggards. Through a deep analysis of factors characterizing the three clusters—specifically as far as funding sources are concerned—the authors suggest that adopting Industry 4.0 technologies can be an opportunity, but also a challenge in particular for the first two clusters of startups. In fact, strong innovators (Industry 4.0-wise) have different funding forms of sourcing and a reduced portfolio of resources with respect to laggards. Such results highlight the need to further explore the consequences of innovation (and knowledge management) in advanced technologies for startups and their sustainability over time.

The interrelation between innovation and Industry 4.0 technologies can be explored also by examining organizational innovation and specifically the redesign of production processes connected to the achievement of operational excellence. With respect to startups described above, in this perspective established manufacturing firms may decide to adopt Industry 4.0 technologies to obtain benefits of efficiency and better control on operations, considering the opportunities connected to the smart factory. However, such relationship is far from being exhaustive in its implementation and it is the content of the contribution by Miandar, Galeazzo, and Furlan (Chapter "Coordinating Knowledge Creation: A Systematic Literature

Review on the Interplay Between Operational Excellence and Industry 4.0 Technologies”). The authors develop a systematic literature review in order to evaluate the interplay between these two new sources of knowledge. Four different paths emerge taking into account the direction of relationships between Industry 4.0 and operational excellence. Most of the studies stress that such technologies are enablers of lean manufacturing, where firms can exploit the technological potentialities to obtain results of operational excellence. By considering the knowledge management framework proposed by Nonaka and the Thompson’s inputs on task coordination, the results of the analysis suggest that Industry 4.0 and operational excellence should be coordinated sequentially. Moreover, not all Industry 4.0 technologies support those dynamics. Limited evidence is related instead of other forms of connections between Industry 4.0 technologies and operational excellence.

The last two chapters of the book study Industry 4.0 technologies in relation to environmental sustainability strategies of firms. In Chapter “Achieving Circular Economy via the Adoption of Industry 4.0 Technologies: A Knowledge Management Perspective”, De Marchi and Di Maria show the presence of relevant differences between green and non-green adopters when Industry 4.0 technologies and sustainability are concerned. Through an empirical analysis of Italian manufacturing firms, the authors analyze how the adoption of Industry 4.0 technologies supports the achievement of green outcomes, with special attention to the circular economy framework. It emerges that those technologies support manufacturing adopters in obtaining sustainability outcomes, in case of both proactive, circular-oriented firms and firms that discover sustainability as a non-intended consequence of technological investments. In general, green adopters have a higher investment rate of Industry 4.0 technologies. Moreover, despite the theoretical expectations on 3D printing, specifically robotics and augmented reality are the technologies where there is a statistically significant difference between green and non-green adopters. The focus is specifically on manufacturing activities as domain of investments—confirming the strong connection between circular economy and production and the importance of Industry 4.0 technologies in this relationship. From a knowledge management point of view, technologies help firms in supporting the achievement of sustainability outcomes based on collaboration within the firm boundaries (among workers and functions) as well as in the value chains.

In the conclusive Chapter, Tolettini and Lehmann grounded such theoretical discourse within the steel sector (Chapter “Industry 4.0: New Paradigms of Value Creation for the Steel Sector”) in Germany and Italy. Through a deep and extensive study of the industry, the authors focus on the Feralpi case study to explain the strategic potentialities of Industry 4.0 technologies in renovating competitiveness of firms in the steel sector. With particular emphasis on environmental (and social) sustainability, the authors show the advantages steel firms may achieve through technological investments in terms of resource efficiency and product and process innovation, up to more flexible supply chain and more reactive market response. The case study of Feralpi—as innovative leading company in the industry at the national and international level—suggests that many Industry 4.0 technologies can be adopted by a steel company in multiple steps of the value chain and for multiple goals. In particular, technological investments increase the ability of the firm in knowing operations better (especially in most critical phases) through data-driven approach, allowing the firm in reducing risks and negative outputs for workers and the local community among the many stakeholders considered. Moreover, Industry 4.0 technologies support strategic decisions for firm's evolution within the industry.

To conclude, theoretical and empirical studies included in the book further advance knowledge on knowledge management implications of the adoption of Industry 4.0 technologies. Our book suggests that there is a strong impact of such technologies in the processes of knowledge creation and transfer, but also that the fourth industrial revolution should be interpreted as a long-term transformation, where the implementation of technologies itself generates learning processes which do not lead only to immediate results. Further research on this issue is also required in the forthcoming years to have a more complete picture of the strategic consequences of Industry 4.0.

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