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1 Introduction

Small and medium-sized enterprises are the backbone of the Italian and European economic structure due to the strong presence of active firms, high level of employment and value added to the economy. Small and medium-sized enterprises (SMEs), according to EU Commission recommendation 2003/361[1], are defined as those firms which have less or equal to 250 employees, €50m of turnover and €43m of balance sheet total to be considered medium sized while small sized are those which have less or equal to 50 employees, €10m of turnover and €10m of balance sheet total. In Italy, the economic heart is represented by the population of SMEs. In fact, the Rapporto sulle imprese 2021[2], developed by ISTAT, identified that, in 2019, the Italian's SMEs count for the 99.4% of overall amount of active Italian firms, contributed with 63.4% of employment and produced up to 47% of the overall Italian value added. The European Union is characterized by the prevalence of SMEs, in which, in 2018, the Italian's contribution is 16.3%, while France contributed by 12.6%, Germany and Spain contributed by 11,5-11,7% of the Eu27 total amount.

The current historical period is characterized by the fourth industrial revolution that is shaping the economic environment with strong impacts on firms, territories, and Countries. The digitalization is one of the challenges imposed toward firms, especially towards SMEs. The Covid-19 crisis, which had devastating negative impact, has accelerated the times and fuelled the sense of urgency about the need for a transition towards digitalized technologies, processes and systems.

The adoption of digital technologies represents new opportunities for firms to improve their competitiveness, even if, this process lead to the arise of new difficulties and barriers, determining new room for the intervention through public policies. In fact, it is important that the EU, and consequently the Italian government, have provided, respectively €806.9 billion (in current prices) through the Next Generation EU[3] and €191.5 billion through the National Recovery and Resilience Plan (PNRR)[4] and €30.6 billion Complementary Fund approved by

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[1] http://data.europa.eu/eli/reco/2003/361/oj
[2] https://www.istat.it/storage/rapporti-tematici/imprese2021/Rapportoimprese2021.pdf
[3] https://ec.europa.eu/info/strategy/recovery-plan-europe_it#i-beneficiari
[4] https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility/italys-recovery-and-resilience-plan_en

the Italian government for a total of €222,1 billion[5]. The PNRR's aim is to build the basis for the sustainable long-term development of the economy with positive impacts toward the productivity, supporting the economic recovery from the pandemic crisis and stimulating the development of digital projects and green projects with investments quote of 20% and 37% respectively that are in line with the Next Generation EU's pillars.

The PNRR's resources are allocated into six missions. The first is Digitization, innovation, competitiveness and culture with 40.32 billion, the second is Green revolution and ecological transition with 59.47 billion, the third Infrastructure for sustainable mobility with 25.40 billion, the fourth is Education and research with 30.88 billion, the fifth is Inclusion and cohesion with 19.81 billion and the sixth is Health with 15.63 billion.

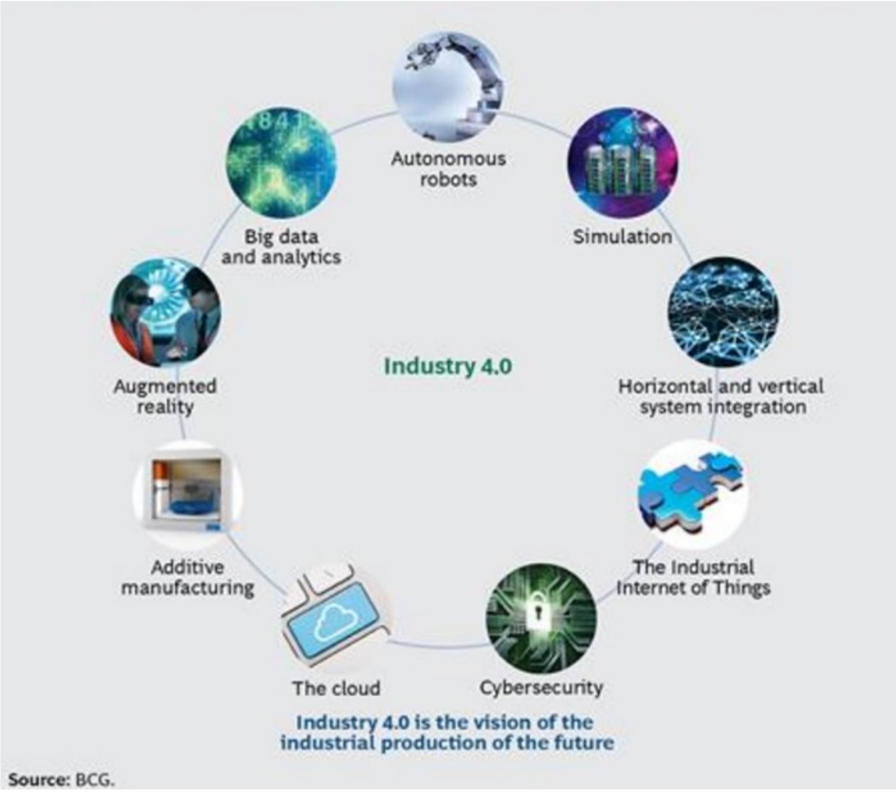
The first mission of the PNRR focuses on relaunching the productivity of the country's system through the strategic levers of innovation and digitalization in the sectors of public administration, culture and tourism, and in general in the Italian productive system. One of the main objectives, set out in the document approved in Parliament, is to make production realities more competitive through digital innovation, which necessarily requires significant investments in different areas. One of the most relevant first mission's investment is on Cybersecurity. The amount of expenditure dedicated to it is expected to be (amounts are in billion euros); 170 in 2021, 190.4 in 2022, 174 in 2023 and 88.6 in 2024 with a total expenditure of 623 for the entire period which is the 6.4% of the total of first mission dedicated to one of the nine Industry 4.0 technological pillars (Lasi et al., 2014).

The digitalization process of firms is characterized by the adoption and implementation of digital technologies leading to the creation of new business strategies. This process requires adequate firm's resources, especially human capital and financial resources, that leads to the reshape the firm's organizational structure, the firm's operations, and the relationships with external actors. These factors are supported by the PNRR's investments on digitalization's projects which are related to the adoption of Industry 4.0 technologies. The nine technological pillars of Industry 4.0, according to Rüßmann et al. (2015), are Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, IoT and IIoT, Cybersecurity, The Cloud, Additive Manufacturing, Augmented Reality and these are the drivers of the consequent business transformation, as shown in Figure 1. Industry 4.0 is essential because allows firms to connect their machines through sensors creating a system which gather data and information along the value chain going beyond a single firm,

[5] https://www.mise.gov.it/index.php/it/pnrr

collecting, organizing and analysing data with the aim to achieve different business goals as efficiency, flexibility and higher quality output, so essentially, increasing the competitive advantage.

Figure 1. The Industry 4.0: The nine technological pillars.



Source: adapted from Rüßmann et al. (2015, p.2).

The adoption of these technological pillars, typically, requires changes in the firm's business model and fundamental dynamic capabilities. Firms are not anymore standalone organization which are fully vertically integrated as described in the Ford-Taylor organizational model, instead, nowadays, firms leverage on suppliers and partners, so the network of actors, cooperating and collaborating to satisfy the firm's needs during the digitalization process.

The digitalization process requires knowledge, skills, and capabilities that are difficult to create and develop within the firm's boundaries due to their complexity and specificity. In fact, SMEs are the actors that majorly benefit from the implementation of these new technologies, even if, they encounter high barriers. These factors lead to the development of new firm's strategies focused on collaboration and cooperation with external actors. These new strategies aim to create, develop and acquire new knowledge from partners along the supply chain such as customers and suppliers. The research of new resources leads to the expansion of the relationships of firms including partners that are not directly connected along the value chain. Firms shift the perspective from the supply chain toward the ecosystem's approach including in the set of relationships new partners such as universities, knowledge intensive businesses services (KIBS), competence centers and Digital Innovation Hubs (DIHs). These actors enhance the capabilities of firms to increase their competitiveness through the adoption of industry 4.0 technologies and developing new business models, such as servitization. The geographical proximity among focal firm and partners composing the ecosystem enhances the capability of strengthening existing relationships and create new relationships determining positive effects over the territory in which these actors are locates. In fact, the geographical dimension is a driver for the technological development of economic actors due to the positive effects derived from the agglomeration and interactions among players determining a favourable environment for innovation and the competitiveness enhancing the attractiveness of the territory.

The present study will be composed by the theoretical part divided into three chapters and the empirical part. The three theoretical chapters will be composed by the first chapter in which will discuss and explain the relevancy of Industry 4.0, digitalization and the presence of barriers and opportunities for SMEs. The second chapter will present the need of collaborations, coordination, and partnerships for firms, and the relevancy of the territorial dimension as driver to foster the digitalization process. The third chapter will present the crucial role of partners in the ecosystem and their contribution to support the digitalization process, highlighting the benefits for firms and the territory. The fourth chapter of this thesis will present the empirical analysis. The aim of the empirical analysis is to better understand the digitalization process in the context of the North-East Italian firms, investigating the role of partners and territory in this process. The analysis is based on the database composed by the collection of survey responses, which is deepening studied through the hierarchical cluster methodology highlighting interesting differences and similarities among group of firms.

2 The evolution toward the future.

2.1 INTRODUCTION.

The fourth revolution is leading to the digitalization of firms. A comprehensive definition of digitalization is: "the use of computer and internet technology for a more efficient and effective economic value creation process" (Reddy & Reinartz, 2017). Industry 4.0 describes the digitization process though the adoption and implementation of novelty technologies to connect actors, objects and systems based on real-time data exchange (Spath et al., 2013). The digitalization is a transformation phenomenon that has great impacts toward firms, entire value chains and network of actors, industries and countries' economy and society(D. Horváth & Szabó, 2019). The digitalization penetrates each aspect of the firm, from the product, service and process development and implementation to the organisational structure, management and strategic aspects, affecting also the Business Model, and the external relations, creating several challenges (Bleicher & Stanley, 2017).

2.2 THE ROLE OF INDUSTRY 4.0.

The role of technology is shaping firms' competitiveness in B2C and in B2B contexts. The term "Industry 4.0" was coined firstly by the initiative of the German federal government with the collaboration of universities and private companies. This initiative was launched in 2011 and it was called "Industrie 4.0", this program was strategic due to the objective of developing advanced production system aiming to increase the national industry competitiveness through the efficiency and productivity increment (Kagermann et al., 2013). The fourth industrial revolution, so the industry 4.0, is the new shift that overwhelm the economic system, especially the manufacturing systems, which is focused on the combination of Information and Communication Technologies (ICT) with the traditional industrial processes and systems (BMBF 2012). Thus, this shift is characterized by the emergence and convergence of new technologies which are integrated creating additional value for the whole product lifecycle (Dalenogare et al., 2018; Frank, Dalenogare, et al., 2019). Industry 4.0 is the driver and enabler of the paradigm's shift from mass production, which is characterized by a manufacturing system focused on high volume of standardized products with the aim of cost reduction, to mass customization (Modrak et al., 2014). The mass customization is referred as the manufacturing strategy of producing high customized and personalized products, in which often the source of the customization is the customer itself, with similar production costs of the mass production system and this is possible only through new manufacturing system based on flexibility, efficiency and automatization which are the core characteristics of Industry 4.0. Thus, this new paradigm is based on manufacturing and logistics systems that are reliable, flexible and reconfigurable due to the combination and inclusion of ICT technologies allowing to achieve mechanisms for the decision-making process that are interactive and collaborative (Spath et al. 2013).

In the recent years, the trend of innovative and digital technologies, represented by industry 4.0, is considered crucial to achieve the long-term competitiveness (Michael Porter & Heppelmann, 2015; Porter & Heppelmann, 2014). The process for firms, especially manufacturing one of adoption of these digital technologies is named "digization" which allow to connect people, systems, companies, products and services (Hsu, 2007). Digitalization is the transformation process that impact firms changing the business' offer, internal roles and the working methodology due to the adoption of digital technologies with changes that refers primarily to changes at process, organization, business and society level (Parviainen et al. 2017).

In the new industry 4.0 era, physical and virtual world are growing together. The integration of Information Communication Technologies (ICT) and the industrial technologies has the aim to create a digital smart and sustainable factory (Zhou 2015). The key role of this growth and integration is played by CPS which realize systems connected via Internet of Things and services (Schluse et al., 2018).

Cyber-physical system (CPS) is a system in which physical objects and devices interact, in a close connection, with software, and more broadly with cyber components, allowing the exchange of information in many ways. CPS is defined, according to Lee (2008), as: "integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa". The relationship between the physical components and computational components is enabled by embedded systems which allows to achieve high levels of coordination and combination of this relationship (Tan Y, 2008). The CPS to be developed requires two essential components, the first is related to the advanced connectivity technologies, in synergy with IoT and IIoT, which allows the communication and transmission of useful data in real time from the physical world and the second component is related to cyber space, which is characterized by the smart management of data, advanced analytics capabilities and elaboration-computational capabilities (Lee et al., 2015). The development and deployment of CPS is a complex process, due to the different interconnected components and the exchange of data. The CPS 5C Architecture framework defined by Lee et al. (2015) describes the construction of CPS, in a workflow management, from data creation and acquisition to value creation. The five Cs of this framework, that construct this architecture, are smart Connection, which is the level of creation of data from machines, sensors, actuators and internal components, Conversion of data to information, in which in this level the focus is on the conversion and inference from data to useful information, Cyber, in which this level represents the central information hub that collect massive information from the network over which specific analytics tools and techniques are applied, Cognition, this level is characterized by the presentation of the new created knowledge to users supporting their decision-making process and Configuration is the final level and it is characterised by the feedback from the cyber world to the physical space, as supervisory control, applying corrective and preventive decisions.

CPS allows the collaboration, hand-in-hand, between humans and machines.

2.3 THE NINE TECHNOLOGICAL PILLARS.

The Industry 4.0 is based on the nine technological "pillars" that form current technological scenario. These are Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, IoT and IIoT, Cybersecurity, The Cloud, Additive Manufacturing, Augmented Reality and these are the drivers of the consequent business transformation (Rüßmann et al., 2015).

1. Big Data and Analytics

Internet and IoT technologies lead to flourish the creation of massive quantities of data, from different sources and cheaply (McKinsey & Company, 2011). Big data is the collection of comprehensive data, which is continuously created from different sources which are both external and internal of the firm's boundaries (Rüßmann et al., 2015). The data's sources majorly refer to production equipment and system, IoT and IIoT devices, logistics system, ERP, customer's management system, social media through specific software and also from the customer's firm production system, collecting customer's process and product usage data (Frank, Dalenogare, et al., 2019; Paiola & Gebauer, 2020). The main big data's issue is related to its elaboration and analyses to extract meaningful information, for the right person and achieving a purpose in the right time. Technologies generates big data which are collected and stored in databases leading to the creation of complex datasets that are difficult to be analysed properly with traditional techniques, which have useful hidden information. The aim of advanced analytics is to analyses these datasets and discover theirs secrets as; hidden patterns, correlations, causalities, trends, customer preferences and other useful information (Zhong et al., 2017).

Nowadays, there is an increasing interest in Artificial Intelligence (AI) and its subfields of AI, such as machine learning (ML), natural language processing (NLP), image processing, and data mining. Artificial Intelligence is referred to the process in which the targeted machine simulates functions that are typical of humans such as sensing, comprehension, learning and problem solving (Cioffi et al., 2020).

Artificial Intelligence and Machine Learning are fundamental tools for the analysis of Big Data. The first reason is due to the improvements of predictions due to the learning process based on the depth analyses of past data contained in datasets allowing the improvement of the decision-making process for the future. Secondly, these technologies help to analyses complex databases extracting and discovering meaningful insights, information and patterns supporting the decision-making process (Kibria et al., 2018).

2. IoT and IIoT

Internet of Things (IoT) and Industrial Internet of Things (IIoT) are fundamental technologies to create an interconnected system to collect, organized and storage data and information with the aim of further analysis. This is possible only due to the inclusion of sensors, embedded computers and traditional communications technologies. The aim is to create a network of interconnected devices, through the inclusion of sensors, actuators and RFID to enable standalone machines into “smart” products (Al-Fuqaha et al., 2015) which create data and exchange data between them with the aim to be collected and elaborated(Xia et al., 2012). The elaboration is typically performed in a centralized way to achieve data storage with aim of improving the business strategy and Business Model, while decentralized way to reduce the time required to satisfy requests so achieving real-time responses (Rüßmann et al., 2015). IoT and IIoT are strictly connected with big data and analytics, because the first allows the transformation of the machines, products and, for manufacturing firms, the Installed Base (IB) into interconnected device communicating data and information to be collected and analysed, in real time, transforming the IB from standalone device into the wealth of information (Frank, Mendes, et al., 2019) in which, nowadays, is the unique asset that allows the differentiation of manufacturing firms through the access to data (Wise & Baumgartner, 1999).

3. Autonomous Robots

The usage of robots and automation in the manufacturing system is evolving. This technology is evolving and becoming more flexible, cooperative and increasing the interconnection between machines and devices. Autonomous robots are smart machines that can function independently in the real world without direct human supervision. They are typically connected through IoT and sensors and these robots are capable of collaborating with other machines and people providing benefits as precision, speed, durability, and adaptability. This technology helps to decrease the production costs, due to the automatization of repetitive operations and tasks, by enhancing the accuracy of the production process and so lowering down the number of defected products and parts leading to the increase of the overall efficiency of the production process and reducing the costs related to the management of waste products and, finally, it releases the human capital from the pursue of repetitive tasks in such a way to be dedicated to highly value-added activities. Generally, this technology is applied into factories to increase the automatization of the production and logistics system, achieving several benefits, as identified by Groover (2008), such as the increase of labour productivity, the reduction of labour costs, the mitigation of the negative effects of labour shortage, the reduction of repetitive manual tasks, the improvement of the workplace safety, the Improvement of product's quality, the reduction of the lead time and the realization of processes or task that cannot be done manually.

4. Simulation

Simulation is defined as:" the process of creating and experimenting with a computerised mathematical model of a physical system" (Chung C., 2004). Simulation reflects the physical world in a virtual model leveraging on the real-time data, including machines, products and humans. Simulation isn't a new technology, in fact, in the engineering phase is already used for 3D simulation of materials, prototypes, products, process and also whole production plants. The novelty is on the usage of this technology in the production areas allowing operators to optimize the machines and product lines setting, reducing the installing and setting of equipment, reducing the set-up time and optimizing the production schedule and providing simulation of these equipment with linked calculations of estimated benefits and Return on Investment (ROI) (Rüßmann et al., 2015). The virtualization of products, machines, production plants, also entire firms, lead to the generation of the "digital twin". The digital twin is the virtual replication of an existing physical asset based on the collection and analysis of data through mathematical models aiming to create the virtual copy imitating its characteristics, functionalities, behaviours and communication interfaces (Schluse et al., 2018).

5. Cybersecurity

The new firm's need that will arise due to the creation of an interconnected network of products is to ensure the safety of data transmission regarding cyber treats which target embedded systems and small devices (Gubbi et al., 2013). This interconnected network is built on several technologies, as IoT and Cloud computing, leading to the creation, communication and the exchange of a massive quantity of data and information that are sensible, personal, confidential and represent the intelligence's heart of the company (Poyner & Sherratt, 2018). The inclusion of IoT technologies, as sensors, Radio Frequency Identification (RFID), Bluetooth, and WiFi connection devices, will transform the standalone product into smart and connected one, leading toward several benefits even if, these technologies represent the access point to the network for cyber criminals changing the threat landscape (Zarpelão et al., 2017). Cyber-attacks and treats have the aim to cause the IoT systems to fail through several strategies as denial of Service, Data Type Probing, Malicious Control, Malicious Operation, Scan, Spying and Wrong. There are several already existing methods for the protection such as storage of information of attacks and safety checks at regular intervals, but these methods lead toward overhead in the processing and are still vulnerable. These are the reasons of the introduction of Advance data analytics, through the usage of Machine Learning to achieve the protection of the system, overcoming unknow threats, achieving efficiency and speed in the detections of vulnerabilities and, finally, supporting the system self-recovery (Hasan et al., 2019).

Nowadays, it is essential the protection of industrial manufacturing system from cybersecurity threats, achieving its reliability and security supported with the identity and access management systems of machines and users (Rüßmann et al., 2015).

6. The Cloud Computing

Cloud computing is fundamental in the Industry 4.0 paradigm. Cloud computing refers to the usage of Internet to delivery computational services based on visualize and scalable resources (Xu, 2012). The scalability of the resources over which is built this service, represent the key aspect of its attractiveness for the strategic-business purposes, allowing the creation and developing new and small projects with a limited investment and so containing the negative impacts in case of failure (Zhong et al., 2017). Cloud computing allows the decentralization of collection, storage and analysis of data, in real time, between machines and products, sites and firm, through online cloud-based software platforms, overcoming the limits of the firm's boundaries (Rüßmann et al., 2015). The benefits of cloud computing are related to the increase of reaction's speed, allowing more effective remote monitoring and control and the creation of the analysis on data which is the based to develop and implement service-oriented strategies.

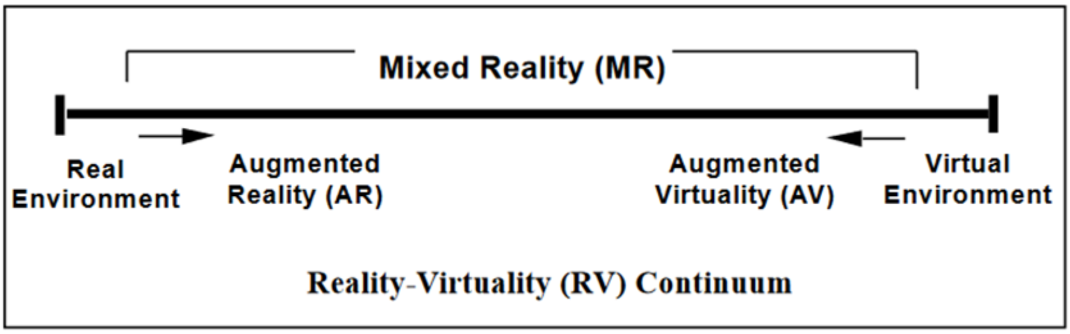
7. Additive Manufacturing

Industry 4.0 is the driver of the paradigm's shift from mass production to mass customization. In the manufacturing systems and production plants require technologies that have low set-up time, high flexibility, and low consumption of resources with the aim of achieving efficiency and effectiveness, in terms of customization. This is possible with additive manufacturing (AM) technologies which starting from a model created with three-dimensional Computer Aided Design (3D CAD) system allows the creation of objects without the planning of the production process (Gibson et al. 2010) and this is due to the process of adding layers by layers of materials, as powder, liquid, sheet and others, until the achievement of desired output (Kellens et al., 2017). This revolutionary technology is based on the additive process to create the desired output, and this is totally different to the traditional production process based on the subtractive and/or deforming methodologies in which this traditional production process starts from the raw material and then achieve the desired output by traditional techniques as, extracting, shaping, removing parts and cutting. This technology helps to achieve different positive benefits large for firms because it allows to create, prototype and produce singular components, useful to produce small batches of highly customized and complex products (Rüßmann et al., 2015).

8. Augmented Reality

Augmented Reality technology allow the communication, in real-time, of useful data and information toward operators incrementing the productivity and the quality of their decision-making process (Rüßmann et al., 2015). AR is a fundamental technology in the Industry 4.0 paradigm because it enhances the degree of human centricity in the industrial environment and this is one of the approach to augment the worker. This technology allows the user to experiment and get access to further and additional layers of digital information connected with the physical world. The spectrum of application of AR technologies goes from design and manufacturing, assembly operations, training, online guidance systems for operators and has high potential in the logistics as “pick-by-vision” indicating locations and quantities to be picked up (Masood & Egger, 2019). The Mixed Reality (MR), as shown in figure 2, is defined as that environment: “in which real world and virtual world objects are presented together within a single display” (Milgram et al., 1994). The Augmented Reality (AR) and Virtual Reality (VR) are both included in the definition of MR, but these are two different technologies as defined by Milgram et. (1994), in which the first increase and increment the information of the real world with information of digital space without replacing it, while the latter fully replace the physical world with the digital space.

Figure 2. Representation of the continuum of Reality-Virtuality.



Source: Adapted from Milgram et al. (1994, p.283)

9. Horizontal and Vertical System Integration

Information systems are able to be connected and to exchange data and information between them internally and externally to the firm’s boundaries. The full potential of Industry 4.0 can be achieved in the situation in which the information systems are fully connected among firms along the value chain, so including customers and suppliers, achieving the vertical integration and the full integration of Information systems within the same firm, which is define as horizontal system integration, connecting and allowing the flow of information among all the firm’s areas, such as, from inbound logistics, to warehousing, production, marketing and sales, ending with the outbound logistics. Industry 4.0 allows the communication of the right data and information toward the right area and department allowing to increase the cohesiveness of the firm, overcoming the silo-thinking mentality and achieving also the automation of the value chain, releasing the full potential at firm and industry level.

Nowadays, companies’ IT systems are not fully integrated, which is characterized by the lack of full integration and linkages along the value chain including firms, suppliers and customers and within the firm itself among different areas and departments. (Rüßmann et al., 2015).

2.4 SMEs AND INDUSTRY 4.0.

Industry 4.0 and the digitalization process create several opportunities for Small and Medium Enterprises (SMEs). The adoption of these technologies lead to the increase of flexibility, productivity, and the overall competitiveness (Kagermann et al. 2013). The adoption of these technologies necessitates of different requirements that, typically, SMEs suffer the lack of these. The challenges faced by SMEs are different from those of large companies leading to the need of creation of customized solutions to meet their specific needs (Bischoff et al, 2015). These differences between SMEs and large companies, defined as MNEs, are well identified by Mittal et al. (2018) in which compare seventeen generalized features derived from the literature review as shown in figure 3.

Figure 3. Comparison of features between SMEs and MNEs.

#	Features	SMEs	MNEs
1	Financial Resources	Low	High
2	Use of Advanced Manufacturing Technologies (AMTs)	Low	(Very) High
3	Software Umbrella (incl. Data Analytics)	Low (Often Tailored Solutions)	High (With More Standardized Solutions)
4	Research & Development	Low	High
5	Nature of Product Specialization	High	Low
6	Standards consideration	Low	High
7	Organization culture/ Leadership flexibility	Low	High
8	Company Strategy	Dictated by Instinct Of Leader (Owner)	Market Research & Accurate Analyses
9	Decision Making	Restricted to Leader/ Few Knowledge Carriers	Board of Advisors & (Int./Ext.) Consultants
10	Organizational Structure	Less Complex And Informal	Complex And Formal
11	Human Resources Engagement	Multiple Domains	Specialized Domains
12	Exposure to Human Resource Development	High in The Industry/ Low Outside The Industry	Low Within Industry/ High Outside the Industry
13	Knowledge and Experience Industry	Focused In A Specific Area	Spread Around Different Areas
14	Alliances with Universities/ Research Institutions	Low	High
15	Important Activities	Outsourced	Internal to The Organization
16	Dependence on Collaborative Network	High	Low
17	Customer/Supplier Relations	High (Strong)	Low (Not So Strong)

Source: Adapted from Mittal et al. (2018, p.195)

SMEs are characterized by similar needs, requirements, barriers and challenges. even if, present some differences and specifications (Masood & Sonntag, 2020; Raj et al., 2020). Masood & Sonntag (2020) carefully analysed the current state of the literature regarding the challenges and barriers faced by SMEs during the implementation of industry 4.0 technologies. The three main challenges that have been identified are financial resource limitation, knowledge resource limitation and technology awareness limitation (Orzes et al. 2019; Mittal et al., 2018; Horvath and Szabo 2019).

2.5 THE FINANCIAL CONSTRAINT.

A relevant requirement is the economic and financial capability of sustaining the efforts of these technologies due to the requirements of high level of investments, in which, generally SMEs lack of the abundance of monetary resources to sustain them, especially compared to big and consolidated firms (Müller, Kiel, et al., 2018). These technologies lead toward several benefits, even if, a related issue to this topic is the firm's capability to measure and capture these benefits, understanding the full economic and technologic potential deriving from the adoption of Industry 4.0 technologies (Koch et al. 2014). The need to assess and certified results connected with those benefits is a rising need for SMEs, in which they have to estimate the Return of Investments (ROI) of the above-mentioned investments due to the limited amount of economic resources and guiding the capital budgeting decisions toward the most remunerative investment opportunities (Liao et al., 2017). The calculation of the above-mentioned benefits includes the economic gains deriving from enhancing the productivity of manpower, as well as machine and plant productivity, reducing the lead time for the production phase, and time to market related to the launch on the market of innovation, enhancing the flexibility leading to reducing the production costs, by reducing the set-up time, and increasing of revenues by meeting the customer's need in time. These benefits have to be compared with the financial resources ready to be used, the financial need to sustain the investment, which has a medium-long term horizon, the costs of development, implementation and optimization of the technologies until reaching the optimal performance and system integration.

The lack of monetary resources is a relevant issue for innovative SMEs with a strategic orientation based on the new industry 4.0 technologies that are characterized to be disruptive and radical innovation rather to be incremental (Schröder, 2016). Generally, at the beginning SMEs and start-ups suffer of negative cash flows, meaning that cash outflows related to the payment and coverage of costs are greater than cash inflows connected to the collection of the revenue streams, leading to a short-term monetary unbalance that have to be covered through the consumption of economic and monetary resources, named capital. SMEs' capital is typically characterized by low amount compared to the big and consolidated firms, which the primary source of the capital is external. SMEs are young, small organisations characterized by small amount of resources provided by the founders, which determines the internal source of capital, disruptive strategies based on breakthrough innovative technologies. These characteristics lead SMEs to be perceived as a risky investment for banks especially due to the not fully comprehension of their new business models, their products and/or services and the lack of collaterals, leading to the provision of limited amount of financial credit. The second major actors that can coverage the gap between the collection and the need of resources are the venture capitalists, even if, these investors are specialized in specific branches and fields. This high specialisation is also a positive characteristic due to the possibility of transfer specific know-how to firms, introducing them to network of actors that can support the firms during the decision-making process, leading to the increment of the probability of success of SMEs. Finally, the provision of capital between banks and venture capitalist is totally different. Banks provide capital through a credit position which is characterized by the payment of interests and the return of the loan at the contract's deadline while venture capitalists provide capital through an equity position, with the aim to invest in share or quotes of the company and then to sell them, releasing their investment, obtaining a capital gain, after a period of between five to seven years (Schröder, 2016).

2.6 THE KNOWLEDGE CONSTRAINT.

The second major barrier refers to the need of knowledge, skills, and capabilities to lead to the success of SMEs.

The fourth revolution will have an impact toward the labour market changing the composition of the workforce. At the macroeconomic level, the industry 4.0 technology will have a substitution's effect toward the less specialized labour force, with negative impact on those tasks, jobs and occupations that are manual, repetitive and aren't high value-added. Simultaneously, this revolution leads to the enhancement of the firm's need of qualified workers, to the shift and creation of new jobs and enhancing the overall labour force occupation (Autor, 2015; Balsmeier & Woerter, 2019; Gregory et al., 2016). The digitalization will have a strong impact on jobs, skills and the overall occupation. Balsmeier et al. (2019) addressed this issue with an econometric analysis on firm-level dataset of Switzerland finding that: "investment in digital technologies is positively associated with employment of high-skilled workers and negatively associated with employment of low-skilled workers, with an overall positive net effect on employment.".

The adoption and implementation of these new technologies requires well prepared workers and qualified human capital, related to the ICT field, rising the need of investment in the skills, capabilities and knowledge by firms (Glass et al., 2018; Stentoft et al., 2019). Typically, qualified workers specialized themselves into MINT (Mathematics, Informatics, Natural sciences, and technology) academical subjects, which are fundament for the development toward relevant professional occupations, such as electrical engineer, software developer and engineer, and data scientist, for the implementation of Industry 4.0 technologies and supporting the firm's strategy (Schröder, 2016).

The firm's strategies to prepare the human capital for the implementation of industry 4.0 at strategic, organisational, and operational level (Parviainen et al., 2017) are of two types: Building in-house the required skills and capabilities through training and development process and/or the hiring process for the acquisition of talents and qualified workers.

The first strategy is related to the Human Resource (HR) activity of training and development. This process has the aim to prepare employees to release the full potential of these technologies, through the learning process of new digital capabilities, upskilling their skills, and, finally, infusing the digital culture. Building the digital culture is an essential pre-requisite of this process due to the relevance during the clear definition of vision, mission, and strategy of the company, even if, it is considered one of the major difficulties and challenges (Geissbauer et al., 2016). The strategic view will be communicated through the process of setting goals, objectives and Key Performance Indicators (KPIs) aiming to align and achieving the convergence of interests and goals between employees and the firm. A relevant step to enhance the success of development and training process, reducing the risk of turnover and low commitment of employees is to analyse and communicate success case studies, evaluate the quick wins during this process and strong commitment of managers (Müller, Kiel, et al., 2018).

The difference of the employee's qualification between large companies and SMEs, defined as lack of "employee participation" (Mittal et al., 2018). SMEs are small and flat organizations, which suffer of the financial constraint leading toward the focus on the most relevant economic and financial issues. The flat organisational structure is defined by low number of hierarchical levels leading toward a less vertical and specialized organisational structure, in which employees typically performs several tasks, regarding different firm's areas on a daily basis. This organisational characteristic allows the creation of teamwork environment and enhancing horizontal capabilities, even if, this is detrimental to the specialization of employees in a specific area. The development and training programs are costly activities which are limited due to the financial constraints, with negative impacts on the base of the future competitive advantage. The comparison with MNEs evidences the positive aspects of presence of established development and training programs, composed by mentorships, supervised training and workshops, leading to the higher specialization of employees in specific area, becoming experts of that area (Mittal et al., 2018). The issue related to the lack of knowledge, know-how and skilled workers is relevant for SMEs and Large companies. The difference is related to the already existing employees with the right competencies and qualifications, or ready to be quickly upskilled, to satisfy the short-term needs for large companies with respect to SMEs (Glass et al., 2018). Finally, both groups suffer from the shortage of employees specialised as young engineer and scientists and the lack of interdisciplinary courses for training.

The second strategy is based on talent acquisition and qualified workers. This strategy will achieve the human capital readiness supporting the firm's implementation process through the creation of the knowledge, skills and capabilities base. The success of this strategy depends on the attractiveness of the firm for potential candidates. Indeed, this strategy is closely related to the challenge for SMEs in the competition for the attraction of qualified workers. There is a strong competition due to the presence of high number of rivalry SMEs and the presence of big firms which are perceived with a higher level of attractiveness.

Finally, nowadays, the knowledge and know-how are strategic assets for the competition in the market, which sources are internal and external to the firm's boundaries. The external sources, as collaborations and alliances, are crucial to acquire new information and knowledge, related to the state-of-art of the field of interest, and staying updated with novelties related to new technologic and business opportunities. These benefits can be captured with networking activities with special partners as universities and research institutes. This is a smart solution to overcome the financial and technical constraints which lead to the difficulties on the R&D activities. SMEs are strongly focused on a single domain, on single or few products with related markets and technologies, leading to the focus on narrow field of knowledge. This emphasizes the knowledge constraint which limits the ability to learn about the firm's own experience due to the limited access of shared knowledge. SMEs are also strongly dependent on its own network of actors due the outsourcing strategy, leading to the specialization and focus on the core business area which determines the competitive advantage and externalize all the other activities to the network of suppliers (Mittal et al., 2018), aiming to overcome the financial, technological and knowledge constraints (Glass et al., 2018; Masood & Sonntag, 2020).

2.7 THE TECHNOLOGY CONSTRAINT.

SMEs suffer from the lack of financial resources required to invest on the new industry 4.0 technology. This will cause the financial constraint of the firm determining the limitation of the upgrading, developing, and implementing of these technologies which lead to the slowdown of the innovation process, and this is also emphasized by the lack of technical resources. The result is that SMEs, compared to large companies, generally lose the competition in the Research and Development race (Mittal et al., 2018). These constraints also limit the capability of the firm to acquire data, information and new knowledge (Julien and Ramangalahy, 2003) which represent the fuel for firms' engine to achieve the competitive advantage. Thus, SMEs suffer of technical issues related to data extraction, data management and data analysis (Haseeb et al., 2019).

The fourth revolution creates new opportunities for firms through new industry 4.0 technologies. The novelty of these technologies is perceived as a barrier, especially for SMEs. These technologies are developed and implemented with tailormade solutions to meet the needs and requirements of large companies that differ from the SMEs' specificities. This will enhance difficulties to the creation, adoption, and implementation of customized solution for SMEs to meet their specific needs, with negative impacts toward their digitalization process (Glass et al., 2018).

This issue is enhanced with the gap related to the missing standards which create a relevant barrier. The lack of standards is detrimental for the implementation of industry 4.0 for firms, especially SMEs, due to the enhancement of uncertainty, complexity, and difficulties in the integration process. The missing standards are defined in the missing of international regulation and norms, the missing compatibility of ports and interfaces, and the lack of data formats standardization (Ozkan-Ozen et al., 2020; Türkeş et al., 2019). The international regulation is fundamental to ensure the security of data management, with the aim of reducing the issue related to the data protection, referring to the liability, privacy, the consequences of data loss (Aggarwal et al., 2019; Glass et al., 2018; Kamble et al., 2018). The perception of the need related to the data protection, and, in general terms, cybersecurity is different between SMEs and large firms (Glass et al., 2018). The key aspect is represented into the new need of large firms to ensure the IT security, safety, protection of their network and so data transmitted. Large firms want to protect their vital strategic assets from cyber threats (Hasan et al., 2019), industrial espionage, sabotage, and the rising need to achieve higher transparency of the value streams. SMEs, differently to the rising needs of large companies, don't perceive these needs, even if, they aren't isolated to these negative issues. The possible cause of this missing barrier for SMEs could be the overestimation of their cybersecurity capabilities or the feeling of not being an interesting target for cybercriminals (Glass et al., 2018).

Finally, the infrastructure is necessary as the backbone for the fourth industrial revolution (Zhou 2015). This challenge is related to the development and implementation of the infrastructure that has to be supportive for the transmission of massive quantity of data, securely and quickly (Schröder, 2016). The communication infrastructure must allow the transmission of data, in terms of quantity and speed, creating the building block for the organization of the production on the internet basis, for the inter-firm connections and for the development and deployment of downstream services. A key role is played by the fibre optic cable connection which allows to overcome the negative aspects of the wireless connections as vulnerability, instability, and low speed. This solution can release the full potential of SMEs allowing them for the implementation of new technologies, even if, these are located in rural areas, determining the short-term need to increase the fibre optics coverage. The lack of broad band connections and the unclear definition of international regulation, norms and rules are slowing down the shift in the fourth revolution (Glass et al., 2018).

The consequence of the technological constrain and the difficulty of collecting information for SMEs is reflected on the quality of the decision-making process. Indeed, decisions in SMEs are built on a poor information base, often missing, and guided on ‘good feeling’ and intuition of whom take decisions such as managers and or entrepreneurs. These decisions are characterized by high levels of uncertainty and low level of confidence while in large companies, the decision-making process requires more time and complexity but is based on higher information pool deriving from analyses, as marketing analysis, in which the decision is discussed during management board’s meetings, and only after the approval of the board, the decision is taken. In this process the organizational culture plays a relevant role, as key element, in which SMEs have the advantage to take decision more rapidly, to be more flexible and to be able to adapt to the rapidly changing market needs which allow the reduction of the complexity and time required respect to large firms (Mittal et al., 2018).

The government activity is fundamental for the support of technology implementation, in which the lack of it is perceived as a barrier (Glass et al., 2018). Nowadays, several governments are developing and implementing supporting programs overcoming the difficulties and barriers of firms, especially the financial constraints (Kumar et al., 2020).

3 The role of collaborations.

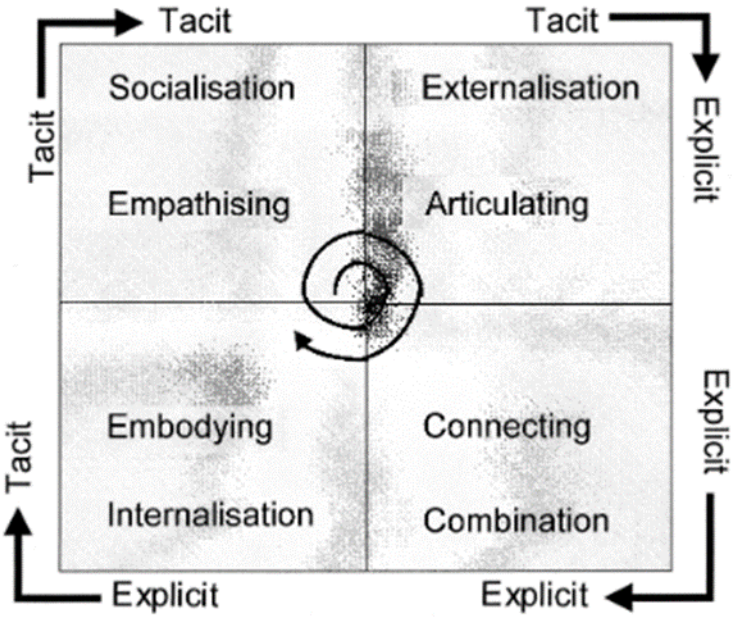
3.1 THE ROLE OF KNOWLEDGE IN THE DIGITAL ERA.

In the fourth industrial revolution, firms fight to acquire, absorb, and retain, key resources that are fundamental to achieve the competitive. The main reasons for which firms are interested into these intangible assets are related to the uniqueness, originality, and difficulties for competitors to copy or imitate them. These intangible assets are the new scarce resources strategically relevant in line with the Resource Based View theory. This explains the interest of firms in dealing with the process of acquisition, storage, analyses, and development of new knowledge starting from the data, in which the knowledge management sustains and drives the strategy (Götz & Jankowska, 2017; Kogut & Zander, 1996).

Knowledge is different and far more complex with respect to data and information but connected due to the process of analyses. Howells (2002, pag. 872) defined knowledge as: "dynamic framework or structure from which information can be stored, processed and understood.", meaning that has a social and relational dimension, characterized by communication and interaction between people, allowing to include the context and finally achieving the sense-making of those information toward knowledge. Nonaka and Takeuchi (1995) created the building blocks for the knowledge management literature stream defining the SECI model, which analysed the creation of new knowledge as a process characterized by the extraction, incorporation and recombination of information and knowledge, through and interactive process involving the socialization among individuals. This model is based on the concept of explicit and tacit knowledge and the relevancy of human interaction. In fact, knowledge isn't uniquely expressed in traditional means as documents, papers, books, manuals, and, after the ICT and Industry 4.0 revolutions, in files, codes, and other digital forms. These are expressions of explicit knowledge which main characteristics are related to be codifiable, objective, impersonal, independent to the context, and sharable (Nonaka et al., 2000). Nowadays, it is very easy and affordable to acquire, collect, store and share the explicit knowledge especially through the increased connectivity and communication developed in the ICT revolution, and the massive production of data, online storage and advanced analytics techniques for their elaboration emerged during the industry 4.0 era. Nonetheless, the distinctive ability of internalization and development of new knowledge by individuals is a key aspect, which leverage on the social dimension of the knowledge. This leads toward the development of tacit knowledge which has different representation forms as mental maps, know-how, expertise, trade secrets, skills-set, and the organizational culture. The tacit knowledge is difficult to share due to its characteristics, especially, the social interaction among people, difficult to codify, strongly personal and context specific (Nonaka et al., 2000). The main point is that these two types of knowledge are strongly interconnected and influence each other, where tacit knowledge is useful for the correct interpretation of explicit knowledge, through the application in the actual context which is influenced by the spatial dimension (Howells, 2002).

Nonaka and Takeuchi (1995) defined the process of knowledge creation as a dynamic process with a spiral form. The spiral process for the creation of knowledge, named SECI process, is based on four elements that are Socialisation, Externalisation, Combination, Internalisation, as shown in figure 4.

Figure 4. The SECI model.



Source: Adapted from Nonaka et al. (2000, p.9)

The SECI process is a spiral process that pass through all four conversion modes, and it is defined as a spiral conversion process due to the continuous interaction between the tacit and explicit knowledge without stopping after passing through all four steps.

The first mode of conversion is the socialisation, which is the conversion of tacit to create new tacit knowledge. This is a relevant mode for the creation of new knowledge due to the social interaction between people, in which they share their own tacit knowledge. This allows the exchange of ideas, opinions and experiences enriching people involved in the communication process. The exchange of tacit knowledge is difficult due to its own characteristics leading to overcome main issues as the absence of codification, the context specific dependency, and finally the strong individuality aspect of the knowledge exchanged. These reasons explain the main difficulties related to time, efforts, the presence of a relationship and closeness between people required for the accomplishment of the creation of new tacit knowledge. The socialisation takes different forms, such as apprenticeships, that has the aim to help the share and learn of tacit knowledge related to the context of the job and the tasks to be completed. It is also related to context outside the work environment such as meetings and events. Finally, the socialisation mode isn't related only to individuals inside firm's boundaries, in fact, the inclusion and involvement of actors along the value chain, both upstream and downstream, allow interactions with suppliers and customers in which the firm is able to collect ideas, experiences, requirements, needs and desires.

The second mode is the externalisation, which is the conversion of tacit to create new explicit knowledge. This conversion mode has the objective of converting unstructured, highly personalized, context specific knowledge, as experiences and ideas into codified, structured, and easily transferable knowledge. The mechanisms through which this conversion mode is carried out is related to the social interaction of people, in which they collaborate and discuss in meetings, with the purpose of defining symbols, codes and concept. This codified language is necessary in order to convert the tacit into explicit knowledge which can determine the opportunity to share knowledge, leading to the progression for the future knowledge development and improvement. This process leads to the creation of metaphors, analogies, theories, and models (Nonaka et al., 2000).

The third mode is the combination, which is the conversion of explicit to create new explicit knowledge. This conversion mode process has the purpose of combine explicit knowledge from different sources to improve, develop and create new knowledge. This process is defined according to Nonaka and Takeuchi (1995, p.67) as: "the reconfiguration of existing information through sorting, adding, combining, and categorizing of explicit knowledge can lead to new knowledge". As mentioned above, the explicit knowledge's sources are diverse and heterogeneous. The sources are related to the firm's boundaries, in which they can be internal or external. This heterogeneity of source's origin supports the acquisition of higher variety of information, leading toward high success rate of developing new knowledge. A relevant characteristic of this conversion mode is the opportunity to share, communicate and disseminate this knowledge inside the firm's boundaries toward all the individuals. This type of knowledge is easily sharable through technology allowing its diffusion rapidly, cheaply and overcoming spatial barriers.

The fourth mode of the SECI model is the internalisation, which is the "process of embodying explicit knowledge into tacit knowledge" (Nonaka & Takeuchi 1995, p.154). In this conversion mode the key role is played by individuals inside the firm's boundaries. They internalised the explicit knowledge created in the combination mode within the firm with the modalities described above. In this conversion mode, the objective is to let individuals learn, understand, contextualize, and embody the explicit knowledge converting it into tacit one. The learning processes are characterized by different means related both to reading, identifying relevant aspects, exercises and pursuing job-related activities and tasks, combining the interconnected learning process on- and off- job. The point is that individuals through these activities are able to capture the opportunity to improve their own knowledge, know-how and skills, leading toward higher level of productivity. This is the last step of the previous learning spiral process, which will fuel the beginning of the one through social interaction and sharing the new acquired knowledge and experience.

The SECI model defined by Nonaka and Takeuchi (1995) is fundamental to understand how organisations create new knowledge which is fundamental for the innovation process and for the competitive success in the fourth industrial revolution. In fact, the complexity characterizing the digitalization process faced by firms implies the development of strategies to acquire new knowledge assuring the success of implementation of the industry 4.0 technologies. The sources of knowledge are both internal and external to firm's boundaries leading to the creation of a strategy aiming to identify the sources and capture, extract, internalized and recombine the knowledge. In this process, firms have to identify internal excellence, supporting talented employees, involving them in the knowledge management strategy and leveraging on the accumulated knowledge and know-how. In order to ensure the development of new knowledge, firms should invest into a favourable environment which induce the communication, collaboration and exchange of information among employees, favouring the nurturing of relationships and creation of ideas. Nonetheless, firms aren't alone, in fact, they operate in a competitive environment, in which they are connected toward supplier and customer, along the value chain. Firms have the opportunity to leverage on these actors which are key external sources of knowledge through the creation and development of relationships supported by technology (Di Bernardo & Grandinetti, 2012; Bettiol et al. 2020).

Technology enables and boosts firm's strategies focused on the knowledge management. Firms from the beginning of IT era need to manage data, information and knowledge related to organizational functions in which the technological advancements allowed to reduce issues, like missing data, redundancy, and inconsistency, achieving benefits as reduction of time spent and increasing the efficiency of data managing. The software evolution follows the resolution of issues and application of new advanced technologies, in which, firstly, firms adopted IT software system helpful to manage single organizational function based on separated databases. The absence of a common and unique database over which different IT solutions for different business functions leads to coordination and integration issues strongly impacting the knowledge flow among different firm's area. This main issue was recognized by the actual leader SAP who provides a well-structured IT solution which is the Enterprise Resource Planning (ERP) based on a common shared database (Micelli, 2017; Bettiol et al. 2020). SAP's portfolio[6] of software solutions is developed with a modular integration strategy with the aim to satisfy the personalization requirements of customers in terms of functionalities to be achieved and nature of the system with the reference to Cloud or On-Premises solutions. These solutions had a strong impact on the knowledge management for firms, leading to reshape the internal organizational dynamics of the firm itself, defined as Business Process Reengineering (BPR) (Micelli, 2017). The traditional firm's organizational structure was characterized by the definition of different functions dedicated to different areas of the firm (i.e., Procurement, Production, Sales etc.). Many issues arose with this internal structure due to the specificity of knowledge, share codes, values, and practises, and, finally, goals and objectives. These specificities lead to the creation of the silo's mentality determining difficulties in communication and coordination problems, slowing down the decision-making process, increasing related costs and time spent. This revolution enhanced the opportunity for firms to overcome this issue through the management of the entire end-to-end flow of activities and related information, following managerial revolutions with reference to the Total Quality Management and lean management (Micelli, 2017). The ERP system allows inbound and outbound communications flow of data and information bidirectionally from the core firm's intelligence toward external actors along the value chain, supplier and B2B customers, in which it is possible to create a continuous end-to-end flow of knowledge passing through several economic actors, coordinating their activities with benefits of reducing costs, transactional, coordination and communication costs and reducing the time needed to the delivery of the products to the final costumers (Bettiol et al. 2020). In this context, firms had been focused on knowledge management strategies to convert tacit into explicit knowledge and configure the ERP system reflecting it properly throughout the deep parametrization and automatization of procedures, allowing the correct coordination with external parties (Apostolou et al., 2007; Bettiol et al. 2020).

[6] https://www.sap.com/products.html

The Information and Communication Technology (ICT) and Web era enhanced the availability and possibility for firms to manage knowledge from inside and outside the boundaries assuring the continuity of the flow of interactions through real-time communication and collaboration involving external parties (Kozinets, Hemetsberger, & Schau, 2008). This technological revolution provided several communication tools enabling and powering connections with external partners, with special attention toward costumers (Micelli, 2017; Bettiol et al. 2020). This era drastically changed firms' technological strategy which initial focus shifted from the IT managerial software system to the digital world. Firm's strategy changed and adapted toward the discovery of new potential Internet tools, with strong impacts on the distribution channel (e-commerce), sales and marketing functions, capturing the idea that customers desired to be involved in the innovation process creating an interacting bidirectional communication flow (Micelli, 2017). This technological revolution drastically changed firms' strategy, impacting on their business model and the competition. Firms increasingly focus on the collection, acquisition and elaboration of consumers' data, information, and needs, leading to the development of new business models enhancing the satisfaction of customers, while consumer's power increased due to transparency and availability of information online determining an increment of awareness and knowledge (Micelli, 2017). The consumer empowerment leads to the creation of Internet/Digital communities in which individuals share their information, opinions, suggestions, and experiences, which create an online social environment producing useful knowledge. Firms can benefit from the inclusion of digital communities and lead users in the innovation process, with positive impacts on the products development, company and brand reputation and consumer's engagement (Micelli, 2017; Bettiol et al. 2020). In this line, ICT and Internet technology enable new forms of collaboration and cooperation between companies and external parties, especially the demand side, due to the reduction of communication costs and barriers boosting the open innovation process of the firm by leveraging on digital social knowledge, with the result of the firm's overall growth (Hagel e Armstrong, 1997; Baldwin et al., 2006; Galvagno & Dalli, 2014; Micelli, 2017; Bettiol et al. 2020).

Nowadays, the Industry 4.0 change drastically the competitive and technological environment in which firms are located. These technologies have a strong impact inside the firm's boundaries reshaping process flows and activities, with the capability to achieve the smooth connection among different firm's areas as between engineering design and development activities (R&D) with the production floor activities. In fact, the novelty of Industry 4.0

revolution isn't related to the technologies involved in the firm's production, since these were already available previously, instead the novelty is related to the access and availability of them at low cost, reducing the investment risk, and determining the combination of different technologies together which are able to exchange information and coordinate themselves (Micelli, 2017; Bettiol et al. 2020). The reduction of costs related to these investments lead to the grow of adoption by existing players and new start-ups reshaping the competitive environment due to the decreased entry barriers related to capital intensive sectors (Anderson, 2012). The dissemination of affordable and advanced technology allows the interconnection of several actors boosting the process of development of new knowledge. The spectrum of actors includes the private sector, as firms, lead users and community of makers, accelerators and incubators, and the public sector, as institutions, universities, and research centres. The industry 4.0 arise several opportunities toward the improvement of the organisational learning process leveraging on the network of actors interconnected to the firm. New digital tools for complex analysis arisen powered by the increasing computational power, decentralization of the computational system, and advance analytics, specifically referring to Artificial Intelligence (AI), Big Data, Cloud Computing. AI plays a disruptive role toward the new era of the analysis and management of information, transforming the learning process toward a bottom-up process involving the firm's equipment, and, finally, changing the Knowledge Management strategy. In this line, AI is defined as: "a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation" (Kaplan & Haenlein, 2019, p.15). This means that there are new actors involved in the learning process that are machines, which work side by side, with humans and organisations (Pauleen & Wang, 2017; Bettiol et al., 2020). As described by Pauleen & Wang (2017), AI is strictly related to human knowledge and learning process, due to several reasons, specifically human's knowledge leads to the creation of new forms of algorithms, advanced analytics and AI, secondly, AI provides the useful elaborated information where individuals decide their utilisation in relationships with goals to be achieved, and, finally, AI can suggest decisions and actions to take but individuals have the responsibility for the decision-making-process regarding them and their actualization.

The combination of the industry 4.0 technologies within a business framework leads to the creation of knowledge, which end-to-end process of collection, elaboration, analysis of data, impacting and adapting the learning process and, creating new knowledge, automatically thought several interactions among these technologies without the need of human's intervention (Pauleen & Wang, 2017; Yao et al., 2017). Humans, individuals, and employees, will use their knowledge to set up these technologies, guide the process for the creation of new and/or enriching the already existing knowledge and, finally, managing and using this knowledge (Ramzi, Ahmad, & Zakaria, 2018). This requires the presence of human capital ready for the choice of the right combination of technologies in line with the business requirements, implementation of these technologies, assuring the end-to-end information flow, understanding, and managing the newly created knowledge (Schwab, 2017; Mittal et al., 2019; Dragicevic et al., 2020; Bettiol et al., 2020). These aspects reflect the complementarity of humans and technology in the fourth industrial revolution.

3.2 THE RESHAPE OF VALUE CHAIN.

The fourth industrial revolution impacts on the firm's organizational structure and on the relationships along the value chain. The digital technologies shape the relationships with customers and suppliers, also known as downstream and upstream links, enhancing the interconnectivity and integration among them (Schmidt et al., 2022). The adoption of these technologies determines difficulties for their implementation along the value chain due to the existing relationships with customers and suppliers. Thus, digital technologies will shape the traditional interactions among actors in the value chain toward higher degree of coordination and integration required by these technologies leading to the creation of building elements related to the social capital with particular interest to the strengthen trust among actors (Müller et al., 2020; Schmidt et al., 2022). The industry 4.0 technologies release their full benefits in the situation characterized by the exchange of data and information, systems communication and coordination, and the smooth interaction among all the actors in the value chain. This impact on the traditional relationship between buyer and supplier characterized by long-term time horizon, the alignment of interests and strategies, and cooperation among them, which lead to the creation and spread of common benefits among actors (Schmidt et al., 2022; Vanpoucke et al., 2017). In fact, these technologies enhance the inter- and intrafirm exchange and integration of strategic data, enabling the automation of key processes within the firm's boundaries and among actors. The strong collaboration between the buyer and supplier is sustained by the developed social capital which is the base for the long-term dyadic collaboration and supports the generation of network links with other actors (Belhadi et al., 2022; Schmidt et al., 2022). Thus, industry 4.0 shapes in several dimensions the relationships along the value chain. These technologies require the share of data and information determining the alignment of crucial processes related to the business intelligence, as forecasting and strategic planning, in which the artificial intelligence and advance analytics are the core technologies (Schmidt et al., 2022; Stank et al., 2019). These technologies improve the accuracy and the efficiency of data analysis, leading to the increasing of resilience of the entire supply chain in which firms are able to coordinate and adapt toward the environmental turbulence developing jointly new plans. In fact, the adoption of the digital technologies allows the connection of firms' processes developing end-to-end processes along the entire supply chain achieving the transparency of data and information usable in real time. These determine the shift toward the multi-actor's decision-making process involving the entire supply chain (Frederico et al., 2020; Schmidt et al., 2022; Stank et al., 2019). The increased exchange of data and information, transparency and coordination directly impact on the trust of supply chain actors strengthening the social capital. The increased trust has positive effects toward the strategies adopted by firms, in which the collaboration, integration and partnerships will be involved as new strategic pillars to achieve the competitive advantage. In this context, the knowledge is the crucial asset for the implementation and utilization of the digital technologies, enabling the new collaborative strategies among players (Stank et al., 2019).

The supply chain is characterized by a heterogenous composition of firms involving large companies and SMEs, where SMEs are supplier of large companies and vice versa. In the first scenario, large companies due to their power can affect SMEs in their strategy, activities, and on the implementation of digital technologies. Small and medium enterprises face difficulties in the involvement in new collaborations and partnerships due to the lack of specific assets. In this situation, the technological development of SMEs is the result of a reactive strategy toward the market pressure derived from new requirements and changes by their large customers. The reactive strategy for the satisfaction of new market requests is the consequence of costs and time required for the implementation of industry 4.0 technologies and risks related to the adoption of technologies that are not aligned with the customers' requirements. SMEs are more fragile compared to the other firms determining their perception that industry 4.0 creates benefits from its implementation, even if, it is perceived as a requirement for the satisfaction of market pressure derived by MNEs rather than an opportunity to be captured (Müller, Buliga, et al., 2018). Thus, firms, especially SMEs, benefit from the supportive collaboration with several actors sustaining the digital transformation and the integration within the value chain based on new value cocreation strategies.

Firms adopting the industry 4.0 technologies can obtain the full benefits through the strategic shift from the transaction perspective toward the value cocreation among partners. In fact, digital technologies will profoundly shape the traditional supply chain toward new forms of collaborations among firms leading to the creation of networks and ecosystems with internal and external supply chain's actors (Benitez et al., 2020). The industry 4.0 requires deep collaborations, integrations and cooperations among partners leading to transformation of the perspective adopting the holistic view (Schmidt et al., 2022). The transformation toward new forms of architectures, as network and ecosystem, will increase the complexity of relationships among actors, achieving the opportunity for the exchange of resources and value cocreation strategies (Benitez et al., 2020). In this context, firms require support to be able to cooperate in the ecosystem determining the involvement of new actors such as Knowledge intensive business services (KIBS), technology providers, universities, and public institutions. Thus, in the fourth industrial revolution the competition shifts from the micro level, focused on the single company, toward the meso level which is focused on network and ecosystem (Benitez et al., 2020; Schmidt et al., 2021, 2022).

3.3 SOCIAL CAPITAL AND RELATIONSHIPS.

Firms encounter several challenges and obstacles in the digitalization process, which determine the increment of the risk, reduction of the speed of implementation and adoption of these technologies, reducing the overall firm's capability to capture the related benefits. Firms have to overcome three main barriers that are the financial constraint, lack of knowledge and limited technology awareness (Orzes et al. 2019; Mittal et al., 2018; Horvath and Szabo 2019; Rüßmann et al., 2015). These barriers are amplified for SMEs, requiring different strategies compare to large companies for the successful implementation of digital technologies. In fact, according to Sommer (2015) SMEs are less likely to be ready for the digitalization compared to large firms, even if, SMEs understand the potential benefits of this transformation process. The solution is achieved through the implementation of public policies since "SMEs have to be supported separately as they are less capable of coping with the financial, technological and staffing challenges than large enterprises." (Sommer, 2015, p.1528). Currently, Governments foster the opportunity for firms to enrich their set of existing relationships and creating new ones with relevant actors such as universities, knowledge intermediaries and technologies providers through public policies (Agostini & Nosella, 2020). The contributions of public institutions, especially universities and research centres, have positive impacts toward the economic development of firms, leading to the enhancement of the overall technological and productivity level of the country. In this line, in the 2010, the Italian Government, through Presidential Decree no. 76/2010 (under art. 3, paragraph 1) and ANVUR (Italian national agency for the evaluation of universities and research institutes) defined the new third mission as “the openness of the university towards the socio-economic context through the valorisation and transfer of knowledge.”[7]. The new Third Mission is operative since 2013, enabled by the evaluation system AVA (Self-assessment, Periodic Evaluation, Accreditation)[8], aiming to connect the first two traditional missions of university that are teaching and research, to the economic sphere, aiming to become powerful engines for geographical development of territories in which they operates with technological and knowledge transfers, leading to positive impacts at micro level, firms, meso level, territories and clusters, and macro level, with development of the whole country on the social, economic and cultural dimensions (Agasisti et al., 2019; Compagnucci & Spigarelli, 2020).

The successful digitalisation process is based on the firm’s capability to acquire, elaborate, and manage high level of knowledge, expertise, know-how of different domains, which determine the enormous internal difficulties to pursue an in-house strategy. These affect the firm’s strategy shifting the focus toward coordination, collaboration, and partnerships with key stakeholders, managing relationships with the goal of building a network of actors. Firms leverage on the network to get access to external assets, knowledge and expertise, involving new external actors, covering missing firm’s resources and obtaining the competitive advantage, as showed by Moeuf et al. (2018, p.628): “connecting with partners, achieving autonomous processes, synchronizing flows and customising products”. The digital revolution showed the necessity, particularly for manufacturing firms, to collaborate with external actors of different domains, also far from the firm’s core domain, related to the IT domains, such as technology and infrastructure providers (Agostini & Nosella, 2020; Davies, 2015). The study of McKinsey&Company (2016) showed that firms suffer due to the lack of expertise on the IT domains, which create several doubts and unclarity about the source to be addressed with respect to the firm’s boundaries, the type and number of external actors to be involved, and which types of relationships to be created between the firm and them. This study showed the relevancy of the adoption of a portfolio management strategy and applying it toward the network of external actors coordinated by the focal firm. The aim is to manage the set of firm’s relationships, shifting from a single provider to a set of external providers, getting access of several source of knowledge of different domains, identifying key resources to support the strategy, and which are the providers who hold them and to capture these resources through the collaboration and cooperation. Thus, firms have to develop new capabilities to support this strategy, which are the capability of research of new partners,

[7] https://www.anvur.it/en/activities/third-mission-impact/
[8] https://www.anvur.it/en/activities/ava/

assessing their quality, potential, and contribution to the firm's mission, and the ability to manage and orchestrate several actors aligning them to firm's goals. The aim is to manage the set of partnerships adopting the portfolio strategy, in line with the resource management perspective, extracting the maximum benefits from these relationships. Finally, a crucial aspect of the partners' portfolio management strategy is identified on ownership and control of data and information among firms and the set of partners. Nowadays, data, information and knowledge represent a strategic asset for the firm's competitiveness, and this clarify the need of contractualization of these relationships, in order to avoid issues related to loss of control of shared data, unwanted share of sensitive data and information, and malicious uses of those data with detrimental effects on the firm (McKinsey&Company, 2016).

Firms to achieve the potential benefits deriving from the adoption of digital technologies have to change their internal organisation and strategy favouring the collaboration, coordination, and cooperation between internal and external actors regardless of the firm's boundaries. This requires an advanced firm's human capital related to hard, technical, and soft skills. The latter are essential elements of the new collaborative strategy for the digitalisation process in which enhance the ability "to communicate, cooperate and to establish social connections and structures with other individuals and organizations" (Erol et al., 2016, p.14). The coordination of experts among several firm's specialisation areas is a crucial driver of the digitalisation in which managers play a key role defining a clear digital strategy guiding investment choices and as orchestrator of several actors, favouring the decrease of the communication barriers among functions which are, typically. affected by the traditional issue of silos thinking (Agostini & Nosella, 2020; McKinsey&Company, 2016). Firms need a set of knowledge in order to be prepared toward this technological revolution. This requirement has a strong impact on their management strategy with external providers, shifting from a unique to a set of technology providers (McKinsey&Company, 2016).

The fourth industrial revolution requires a set of knowledge, capabilities, and resources, that, typically, firms suffer their lack. In this context, firms can leverage on the social capital with the aim to embrace these new technologies. The Social Capital (SC) is broadly defined as: "the relationships between individuals and organizations that facilitate action and create value" (Hitt and Duane, 2002, p.5). The concept of Social Capital is defined according to Nahapiet & Ghoshal (1998, p.243) as: "the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit", thus, including the network and all the assets and resources that can be transferred within the network (Nahapiet & Ghoshal, 1998). The social capital is structured in three dimensions which are structural, relational, and cognitive. The structural dimension of social capital refers to the structure of connections between actors. This dimension describes the existence of ties between actors, which are the actors involved in the network, the different types of ties between nodes and the configuration of the network. This dimension describes the nodes of the network, characterizing who are the involved actors, which are the resources and information that are accessible through the relationships, and the relevancy as strategic position within the network as access to further nodes and for the overall firm's strategy. Finally, it also describes the relationship between the firm and node, defining it as ties, in terms of frequency of interactions between the nodes and the strength of this relationship. This dimension determines the location of key assets, knowledge, and resources, hold by nodes, the connections and related distance among nodes and the pattern to follow to get access to strategic nodes. The relational dimension is the crucial aspect of the network based on "trust, norms, obligations and identification" (Nahapiet & Ghoshal, 1998, p.255). The time determines the opportunity for the shift from simple interactions to long-term relationships, in which norms and trust arise, enhancing the reciprocity, influencing the relationships' nature and quality, based on the history of past interactions among nodes, determining a strong influence toward the expectations and behaviour of nodes within the network (Lefebvre et al., 2016; Mazzucchelli et al., 2021). The cognitive dimension refers to the cultural closeness between nodes leading to the common meaning and understanding within the network. This dimension describes the shared code, symbols, and language, as means to determine common base for the day-by-day communication among nodes, and, finally, shared narratives (Nahapiet & Ghoshal, 1998). This dimension has been enrich including shared values, vision, goals, objectives, and culture among the network's actors, which determine the bases for the development of a shared system of meaning, interpretation, sense-making and representation within the network (Lefebvre et al., 2016). The social capital is fundamental to enhance the firm's innovative capability, referring to the ability to create new services, products, or a combination of them, discovering new markets and business opportunities, and, finally, improving the already existing firm's portfolio (March, 1991).

The relational dimension of Social Capital is analysed as two interconnected dimensions referred to the firm's boundaries, with reference to the intra- and inter firms' relationships with stakeholders (Adler and Kwon, 2002), in which "internal SC will refer to the linkages among individuals or groups within the organizations, while external SC will represent the external linkages to other firms and institutions" (Cuevas-Rodríguez et al., 2014, p.267). The collaboration with external partners is a powerful instrument for the knowledge and technology transfer, in which the consultancy activities based on a trust relationship enhance to search and find new potential solution to address specific issues and speeding up the digitalization process (Erol et al., 2016). Partners are fundamental actors for the firm's digitalisation process impacting toward internal organisation, reshaping and preparing it for collaboration and cooperation and the development of new business models for the value creation along the entire value chain (Kiel et al., 2017; Michael Porter & Heppelmann, 2015; Porter & Heppelmann, 2014).

The Social Capital is strictly related to firm's capability to identify, capture, elaborate, recombine, and integrate knowledge, with internal and external source enhancing the competitive advantage defined as Absorptive Capacity (AC) (Cohen and Levinthal, 1990; Zahra and George, 2002; Agostini & Nosella, 2020). The firm's Absorptive Capacity leverage on the existing human capital and, especially, on knowledge, enhancing the capability to acquire external knowledge, embedded it internally, and increasing the potential success of adoption and implementation of new technological solutions (Liao et al., 2010). This concept stresses the relevancy of the firm's ability to be able to internalize and use the external knowledge, acquired through value relationships with key partners. SMEs suffer of lack of internal resources of different nature which has detrimental effects over the knowledge bases on which the absorptive capacity lays determining difficulties and challenges to release the full potential deriving from the usage of external knowledge (Agostini & Nosella, 2019, 2020). The firm's absorptive capacity, driven by the already existing knowledge and the positive environment which enhance individual's capability to communicate and collaborate, decrease the difficulties and increase the speed of adoption and implementation of digital technologies and improving the ability to internalize and implement external acquired knowledge, enhancing the organizational knowledge (Nonaka and Takeuchi, 1995), with positive effects over employees through the dissemination effects, enhancing their skills and competences, with particular interests toward the digital abilities related to technologies (Agostini & Nosella, 2020; Sousa & Rocha, 2019). Firms, with particular attention to SMEs, to exploit the full potential of digital technologies during the implementation process have to increase their ability to create and manage relationships with external actors, collaborating with them, aiming to acquire new knowledge and strategic resources, skills and capabilities, which is the role played by social capital which trigger the technology's adoption (Agostini & Nosella, 2020). The firm's absorptive capabilities, define as the ability to absorb, acquire, evaluate, adapt, and apply external knowledge (Cohen & Levinthal, 1989, 1990), have an intermediate role connecting and releasing the potential of social capital in favour of the digitalisation process. These aspects support the continuous flow of knowledge among individuals within the firm and with external actors, improving the firm and employees' ability to elaborate, internalize and implement the new external knowledge enhancing individuals' digital skills and capabilities and the organization readiness (Agostini & Nosella, 2020; Sousa & Rocha, 2019; Xiong & Bharadwaj, 2011; Yu, 2013).

3.4 INNOVATION ECOSYSTEM.

In the fourth industrial revolution era, the innovation process is crucial to understand the competitiveness, which is no longer focused on a single actor activity, but it comprehends multiple collaborations with actors leading to the innovation ecosystem concept (Adner, 2017). The new technological advancements have strong effects toward firms and industries leading to deep transformation processes as digitalization process, blurring the industrial boundaries and the overall industrial transformation. These phenomena require firms to quickly adapt and innovate through new collaborative strategies looking for long-term competitiveness within the innovation ecosystem. Industry 4.0 technologies are based on the evolution of the previous technological stage, the Information and Communication Technology (ICT), through the enhancement of the connectivity based on the Internet of Things (IoT). These technologies are interconnected and combined among them for the creation, development, and provision of digital solutions enhancing the value generated. The complexity deriving from the combination and adoption of these technologies influences the relationship between the firm and supplier for the development of new solutions, in which, previously the situation was characterized by each technology provider develops the modular unit required without integration with other parts (Benitez et al., 2020; Yin et al., 2018). The new digital solutions created from the fourth industrial technologies requires high level of interdependence and complementary of human capital, in terms of knowledge, skills, capabilities, and competences and technologies, in terms of connection infrastructure, process and elaboration information systems. The characteristics of these complex systems require the shift of perspective from a dyadic relationship between firm and single technology supplier, toward the concept of innovation ecosystem (Benitez et al., 2020; Schmidt et al., 2021).

The concept of innovation ecosystem is based on the notion of ecosystem adopted from biology and adapted in the business context by J. F. Moore (1996). The initial concept is related to the expansion of the view referred to the firm's strategy in which introduced the role of interactions among firms and other actors along the process of value creation. In the digital era, the set of collaborations and interactions for the acquisition and implementation of digital technologies, requires the inclusion of several actors toward the creation of partnerships due to the growth technological complexity that cannot be addressed by the value chain perspective which examines the interfirm links without addressing the focal firm's innovation process (Adner & Kapoor, 2010; Rong et al., 2015). The ecosystem is defined according to Adner (2017, p.40) as: "the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize". The definition of ecosystem as structure focuses on the comprehension of the composition of interconnected actors that interacts and collaborate aiming to cocreate value (Adner, 2017; Russell & Smorodinskaya, 2018). The number and variety of actors involved in the ecosystem through collaborative and supportive relationships enhance the positive effects in terms of value generation compared to the situation of isolated actors due to the creation of synergies (Benitez et al., 2020). In fact, the innovation process within the ecosystem environment is not linear and isolated, but it is complex, characterized by relationships among actors and the focal firm aiming to cooperate as mean to achieve a common and complex value proposition (Adner, 2017; Adner & Kapoor, 2010). The set of relationships in the ecosystem determines the interdependence of individual legal entities which integrate complementary resources and solutions toward the common shared interest (Benitez et al., 2020; Dattée et al., 2018). Thus, firms focus on the core business expertise and capabilities following a specialization strategy and adopting an outsource strategy involving multiple actors for the innovation process in order to capture and integrate fragmented knowledge, know-how and expertise dispersed among network's nodes, in line with the open innovation paradigm (Adner, 2017; Adner & Kapoor, 2010; Chesbrough, 2003).

The innovation ecosystem is described as the network of actors, including individuals, firms, regions, and nations, in which the creation of partnerships among them determines the cooperation and cocreation of value, aiming to appropriate of gains received in a turbulent and uncertain economic environment. Economic actors enhance their competitive advantage embracing the horizontal collaborative network structure through the interaction and cooperation with other network actors combining and integrating complementary resources achieving technological development and innovation (Kahle et al., 2020; Reynolds & Uygun, 2018; Russell & Smorodinskaya, 2018; Walrave et al., 2018). The innovation ecosystem determines a flourish environment in which economic actors, including universities, research centers and regulators, can benefit due to the creation and circulation of knowledge, capabilities, and know-how, and the establishment of network of relationships which boost the value cocreation process enhancing the benefits of the adoption of industry 4.0 technologies (L. A. de V. Gomes et al., 2018). In fact, nowadays, the firm's capability of introducing innovations and technological developments integrating with the business context determines the source of competitive advantage (Adner & Kapoor, 2010). The key element for the sustainability of innovation ecosystems is the relationship among actors. The complexity of the industry 4.0 technologies requires the exchange of complex set of knowledge and competencies of different domains, in order to be combined to create value for the actors. These relationships are not simple transactions coordinated through market mechanisms, instead, they are long-term relationships characterized by the accumulation of several interactions, in which the reciprocity and trust arise among parties, determining the generation of expectation of mutual benefits deriving from the collaboration (Tanskanen, 2015). These cooperation dynamics among actors is essential for the cocreation of innovative solutions due to the high technological interdependency. In fact, the dyadic relationship between firms and technology provider fitted the development of isolated solutions characterizing the previous technological stage, while, in the current stage, the need for integrated, smart, and complex digital solutions rises the need for integration and interconnection of several domain's knowledge (Benitez et al., 2020).

The notion of ecosystem is centered on the overall goal to be achieved defined as value proposition. This is fundamental for the economic actors to assure the alignment of interests within the ecosystem toward the same objective. The value proposition influences the composition of the ecosystem in terms of actors, interactions, and activities defining the boundaries of it. In fact, changes of the value proposition will result in changes of ecosystem's elements and boundaries in order to accomplish the newly defined goal (Adner, 2017; Walrave et al., 2018).

Small and medium-sized firms to achieve these complex digital solutions have the opportunity to join and integrate in innovation ecosystems. In fact, SMEs can benefit from the coordination and exchange of resources, capabilities, and knowledge leading to the creation and development of new solutions thought joint efforts with key stakeholders connected based on social interactions (Ardolino et al., 2018; Müller, Kiel, et al., 2018). In the context of innovation ecosystem, digital capabilities refer to the capabilities of deploy resources in the ecosystem to achieve desired objectives arising from the digitalization process (Ardolino et al., 2018; Kahle et al., 2020). These capabilities belong to the ecosystem as result of combination and integration process among several actors or can belong to a single node of the network (Kahle et al., 2020; Reynolds & Uygun, 2018). The innovation ecosystem is crucial to address the needs of small and medium-sized firms for the creation and development of complex solutions, in which, the characteristics of interdependency and value cocreation among actors are crucial to overcome SMEs' barriers (Benitez et al., 2020; Boyer & Kokosy, 2022). The collaboration with a set of partners creates the opportunity for SMEs to acquire, internalize and implement new knowledge, competences and skills that belongs to different domains, overcoming the financial, knowledge, and technological constraints.

The study of Kahle et al. (2020) analyzed the role and effects of innovation ecosystem in the development process of smart products for SMEs. The study adopted a qualitative case study approach analyzing 120 SMEs located in the Brazilian electronic and automation industrial cluster. The results showed that the complexity related to digital technologies require the integration of several complementary digital capabilities owned by firms for the development of smart products, in which universities, and R&D centers support this process. Finally, the ecosystem provides positive effects toward the development and competitiveness at firm level and nation level creating room for supportive public policy. In line with these results, the study of Boyer & Kokosy (2022) analyzed the role of innovation ecosystem in the involvement of firms in the adoption of industry 4.0 technologies through technology-push and market-pull strategies. The results confirm the positive effects of innovation ecosystem for firms in the adoption process of digital technologies, in which a pivotal role is played by universities, incubators, and research centers. The study of Rocha et al. (2019) analyzed the role of collaborations in the ecosystem setting for Brazilian start-ups along the digitalization process, adopting a qualitative multiple case study analysis. The results show that the ecosystem is fundamental source for the firm's digitalization process, due to the creation of knowledge and collaboration among actors, including established firms, universities, incubators, and government agency, leading to the promotion of technological development in the industry 4.0 context. Finally, the study of Benitez et al. (2020) analyzed the role and evolution of innovation ecosystem along the process of integration and value cocreation of SMEs based on industry 4.0 technologies. The results show that the lens of ecosystem is more suitable than the supply chain analysis due to the complexity of relationships among actors coupled with the technological complexity. The innovation ecosystem evolves changing the mission, shaping the network of relationships, and the role of internal actors. Finally, this study shows the opportunities for SMEs to participate in innovation ecosystems boosting the digitalization process.

3.5 Regional Innovation System.

In the context of industrial developed countries, the technological and economic regional development is influenced by several factors determining inhomogeneity across regions within the country impacting on the diffusion and adoption of industry 4.0. The heterogeneity of regional development can be described through the lens of Regional Innovation System approach highlighting the reasons of different development paths among regions. The concept of Regional Innovation System (RIS) emerged in the 1990s with the studies of Phillip Cooke (1992). The regional innovation system is described as a system of multiple actors of different nature which are interrelated and connected along the process of learning within the regional territorial context. The characterizing dimensions of the system encompass the economic, institutional, and technological nature.

The RIS approach is based on the National Innovation System (NIS) concept, in which this approach analyzed the phenomena of innovation and learning processes at national level assuming the internal homogeneity in the system. These phenomena shown peculiarities at regional level, suggesting that the development of the RIS concept as the result of subsystem level of NIS which is supported by the social and cultural territorial environment (Cooke et al. 1997; Doloreux & Parto, 2004). The RIS focused on the interactive learning process at regional level of the category of player of NIS which are universities, public research institutions and economic organizations (Chung, 2002). The RIS approach is preferred to the NIS approach in the situation characterized by high regional heterogeneity avoiding the misunderstanding of uniformity at national level. In fact, the regional peculiarities determine the fragmentation of the national system toward multiple regional systems that are different among them. The source of this heterogeneity is related to the presence of different actors and the interactions among them influencing the innovation process, the technological development and the territorial specialization. The Regional Innovation approach is particularly useful to capture the territorial dimension of the process of creation, absorption, and elaboration, in line with the exploration and exploitation strategies, of new knowledge and innovations. RISs are influenced by specific regional characteristics, that are the industry specialization, the technological evolution trajectories, the existence of entities dedicated to the provision of supportive activities, the location of institutions and the characteristics of the network among these actors, leading to the rise of regional differences (Isaksen et al., 2018a). The RIS approach enhance the understanding of the development and the growth path in a region in which it is established a network of interconnected firms that use and share complementary knowledge and technology, facing an already existing or newly arising market demand and, finally, firms have access to inputs within the RIS and to external network in relation to production and knowledge factors (Binz et al., 2016; Isaksen et al., 2018a). Thus, the regional growth paths require the combination and interconnection of the entrepreneurial, institution and supportive organization activities in a systemic view.

According to Isaksen et al. (2018, p. 224-225) differentiates five forms of regional development paths. The first form is defined as 'path extension' referring to the development path characterized by the situation in which firms use the already present knowledge determining incremental innovation based on establish technological domain. The 'path modernization' refers to dominant changes within the region, that could be caused by new changes and innovation in the technology and organization domains, determining new path directions. The 'path branching' implies new development of the industrial region diversification based on related existing knowledge, competencies, and capabilities. The 'path importation' refers to the process of setting up new industries to the region, based on the external influence such as the location of foreign firms, the importation of new skills and competences to the region. Finally, the 'path creation' is the most radical and disruptive form that determines the rise of new industries in the region due to new disruptive technologies, scientific discoveries, and business innovation.

The heterogeneity of growth path depends on the type of RISs that can be separated, according to Isaksen et al. (2018), in organizationally thick and diversified RIS, organizationally thick and specialized RIS, and organizationally thin RIS. The organizationally thick and diversified RIS describe industrial regions characterized by high variety and diversity of industries, supporting organizations in the knowledge and innovation process, within wide spectrum of technology domains. This environment favors the fertilization among industries' boundaries, supporting the circulation and recombination of knowledge, based on open knowledge networks. In this context, university and research centers play a crucial role in the development path. This RIS's type can lead to the evolution forms of "path modernization, path branching and the creation of new paths" (Isaksen et al., 2018, p.228). The second RIS's type is the organizationally thick and specialized RIS. The region is characterized by a narrowed and specialized industrial based in which clusters are focused on one or limited number of industries, and the institutions and supportive organizations are aligned to the specialization strategy of the area. This RIS's type, differently to the previous form described, is strongly focused on the specialization strategy leading to the lack of variety in the knowledge, technological and industrial domains. In this context, networks are stable and focused on the industrial specialization of the region, determining low opportunities for the recombination process of new knowledge. This RIS's type favors the development of incremental innovations, rather than disruptive ones, leading to potential evolution forms of path extension and modernization. Finally, the organizationally thin RIS is characterized by the presence of low number of higher education active firms and low circulation of knowledge due to the presence of few and low developed clusters. This context faces the prevalence presence of SMEs active in traditional sectors with few large firms, that are branch of externally owned firms. In this context, local actors tend to cooperate and exchange knowledge without questioning the established values and norms, leading to the rise of the 'bonding social capital' that could reduce the innovativeness due to the enhanced conformity among actors. These RIS types differ in the development path and innovation potential determining specific policies based on the combination of actor and system-based elements to address their peculiarities aiming to enhance the innovativeness (Isaksen et al., 2018a).

The study of Hervas-Oliver et al. (2021) showed the positive effects of the European innovation policy program, specifically the EC RIS-3 DIH program, which aim to reduce the difficulties of the adoption of industry 4.0 at regional level in Europe. This study showed that DIHs are based on the RIS perspective involving key elements such as the collaboration among regional actors and institutions, including the network complexity within a well-defined spatial territory. This study enhanced the comprehension of the digitalization process at regional level in which the regional system is the ground for the technological evolution of firms and, consequently, territories.

3.6 CLUSTERS IN THE FOURTH INDUSTRIAL REVOLUTION.

The knowledge creation and innovation processes are characterized by high level of complexity, due to the intrinsic nature of novelty. The spatial dimension is crucial for the process of creation, transformation, and diffusion of these novelties, favouring the interaction of actors which boost the flow of knowledge. This dimension is fundamental for continuous interactions between several types of actors with their different roles, enabling the regional learning process through the recombination of know-how and competencies of closely located actors (Götz & Jankowska, 2017). The regional collective learning is defined as the learning process that arise from interactions that are related to the regional sociocultural and institutional relationships among territorial actors (Keeble & Wilkinson, 2000; Götz, 2021; Götz & Jankowska, 2017; Hervas-Oliver et al., 2019b). This creates a flourish environment characterized by actors which share common values, backgrounds, vision toward problems and creating the ground for trust relationships. These evolve into collaborations allowing the exchange of precious tacit knowledge which attracts firms for the development and implementation of new technologies (Agostini & Nosella, 2020; Götz & Jankowska, 2017).

The activities related to interaction, communication, coordination and collaboration among employees, firms, and external actors is enhanced by the geographical proximity, which is relevant to understand the location strategy of economic actors to capture key resources and assets. Proximity is deeply defined and articulated in several dimensions that are linked to the geographical proximity, which are institutional, cultural, organizational, social and technological dimensions that are complementary among them (Knoben & Oerlemans, 2006). The geographical dimension of the proximity concept, including the territorial, spatial, local and physical aspects, is a key factor influencing the knowledge transfer and technology acquisition among actors (Gertler, 1995). The reduction of geographical distance has positive effects toward the ability of actors to communicate, sharing common values, norms, building a shared vision and culture, creating trust relationships, which are the building blocks for the creation of the social capital (Nahapiet & Ghoshal, 1998). The human touch, characterizing the face-to-face interactions, allows to transfer and exchange of complex information and knowledge, which nature is both explicit and tacit, enhancing the likelihood of the comprehension and absorption between the involved parties (Shaw and Gilly, 2000).

The fourth industrial revolution is reshaping the firm's business strategy and organizational structure, enhancing the collaboration with external partners, and creating a well-structured network of value relationships. These aspects impact on the geographical location strategy of economic actors which are influenced to capture the full potential deriving from these relationships, determining, as consequence, the modification of the geographical distribution of these actors, impacting on the spatial agglomeration, and the economic structure of entire countries (Schwab, 2017). The spatial agglomeration of actors within a define territory determines the creation of positive effects for these actors. The first studies focused on the competition between firms of different size and the adoption of agglomeration strategies were promoted by Marshall (1979). These studies focused on the phenomenon of spatial agglomeration of small and medium firms as an alternative strategy adopted toward large firms, analysing the effects and peculiarities influencing local firms. Firms located in industrial districts increase their competitive advantage through the rise of positive externalities. These are defined as positive effects that are external to firms but internal to the industrial district, creating the opportunity to capture them by the strategic firm's location choice. The main four externalities, which favour local firms, are the access of specialized labour, specialized inputs, knowledge spillovers and greater demand due to the reduction of the search costs of customers (Marshall, 1979; McCann & Folta, 2008; Grashof et al., 2019).

The presence of specialized pool labour market has a crucial role due to the connections with the knowledge creation process, the share of tacit knowledge and the innovation process. The agglomeration of firms enhances the geographical attractiveness for specialized employees and employers due to the positive effects impacting the local labour market, in terms of reducing the time and search costs for the employment, increasing the quality of the match between firms and employees, and, finally, increasing the labour mobility between close firms. The increased labour mobility is the key element of the labour specialization which is crucial for the knowledge spillovers and innovation process (Otto & Fornahl, 2010; Grashof et al., 2019). The geographical closeness of firms and individuals enhance the distribution and dissemination of embodied tacit knowledge through the socialization process, such as conversations and meetings, and through the process of changing firms for employees (Nonaka and Takeuchi, 1995). In fact, the high geographical proximity enhances the possibility to create one of the best ways to share tacit knowledge which is the face-to-face contacts (Daft & Lengel, 1986). This will boost the dissemination process of knowledge within cluster that is required for the collective learning process and innovation activities in which the human capital is the driver for the adoption of new technologies and innovations (Otto & Fornahl, 2010; Braunerhjelm et al., 2017; Grashof et al., 2019). Firm's location is a strategic choice which is carefully made aiming to improve the innovativeness and competitiveness. In fact, firms to support their main strategy, choose to locate in a favourable geographical region characterized by high innovation propensity, patents activities, presence of institutions and research centres for the development of breakthrough innovations (Castaldi & Los, 2012; Castaldi et al., 2015; Grashof et al., 2019).

In line with the Marshallian's definition of industrial districts, further authors analysed the agglomeration phenomenon identifying different peculiarities, with the focus over two main studies. The first study is related to analysis by Becattini (1979) who identified similar characteristics related to the economic environment, even if, the key role played by the social dimension and interaction of the community of people and businesses in a limited area as critical aspect. The second main study refers to Porter (2000) in which analysed the interesting behaviour of firms defined as coopetition and the presence of specific actors within the spatial concentration that are firms, specialized suppliers, service providers and institutions. The coopetition is characterized by the competitive firm's behaviour, aiming to increase revenues, profits and acquiring new customers and the cooperative firm's behaviour, aiming to share ideas, information and knowledge, collaborate and creating partnerships. The combination of cooperation and competition allows the creation of synergies, increasing the innovation process and the competitiveness at both firms and cluster level (Porter, 1990; Götz, 2021). The overall benefits of being located within a district refers to knowledge spillovers' effect, the improvement of the social capital and, finally, the key role played by local institutions (Capello & Lenzi, 2014). These studies are complementary between them due to the focus on different peculiarities that allows the comprehensive understanding of this complex phenomenon.

Most of the European Countries are characterized by the phenomenon of spatial agglomeration of firms, determining the presence of industrial districts which positively affect the economic and technological development of countries, with particular interest to the interrelated effects with the fourth industrial revolution. The adoption of digital technologies requires the firm's development of internal human capital with particular interest to skills and competences of workforce, and the readiness for the inclusion in the firm's strategy. These needs are satisfied through the strategic location within a fertile economic environment able to enhance the firm's innovation, creativity, and adaptability capabilities. The positive externalities of industrial districts favour the digitalisation process of firms due to the presence of the high knowledge specialisation and the enhancement of the firm's capability to create relationships with other actors, boosting the knowledge creation process (Burlina & Montresor, 2022; Ortega-Colomer et al., 2016; Xavier Molina-Morales et al., 2013). The study of Grashof et al. (2019) confirmed the positive effects of the firm's location within an industrial district. The empirical analysis occurred on 8404 firms active in patenting activities, located in Germany, in the period 2012-2014. The main evidence of this study is related to the positive association between the development of radical innovations and the firm's strategic location choice, in which the position within the industrial district affects the innovation propensity, where the peripherical location enhances it while the central position reduces it. Finally, the opportunity to create and develop new relationships with other actors has a positive effect toward the enhancement of the innovation propensity, as well as the capability to capture and implement new technological developments (Grashof et al., 2019).

The agglomeration effects, arising due to the spatial concentration of firms, enhance the attractiveness of the geographical location and the territorial's competitiveness leading to positive influence toward the spread and adoption of the new technologies (Burlina & Montresor, 2022; Gugler, 2019; Götz, 2021). In fact, these environments allow firms to enhance the adoption of digital technologies, overcoming several firm's specific barriers affecting SMEs, with positive impacts toward firms related strategy and business processes that are favoured by industrial policies and inclusion of specialized actors to support the digital transformation (Burlina & Montresor, 2022). The industrial district drives the process of adoption and implementation of the Industry 4.0 for firms which are located in it with respect to whom are outside it due to its own peculiarities deriving from the agglomeration effects. The study by Bettiol et al. (2021) analysed the relationship and effects of the geographical agglomeration and the adoption of Industry 4.0 technologies. The study was carried out through the analyses of about 1400 Italian manufacturing firms belonging to 12 industries. The interesting result is the strong and positive relationship between the firm's strategic choice to be located within the industrial district and the related increased speed of digitalisation compared to firms outside industrial districts. The firms' behaviour toward the digitalisation path changes in relation with the location choice, in which firms in the industrial district are influenced by the surrounding environment characterized by the coopetition mechanism, leading to a mutual influence among actors, especially on the investment choices. Finally, the firm's technological investment choices change accordingly, where local firms adopt digital technologies which favour flexibility, collaboration and customization while firms located outside focused on efficiency and productivity.

The digital transformation process of firms is enhanced due to the location within industrial districts in which the dissemination process of knowledge is favoured by the gatekeepers (D. Horváth & Szabó, 2019; Pagano et al., 2021). The gatekeepers are crucial actors which has the "ability to access external knowledge and construct a conversion process which deciphers external knowledge and turns it into something locally understandable and useful" (Hervas-Oliver & Albors-Garrigos, 2014, pag. 431). The need of external knowledge for firms located within the industrial district, which are typically SMEs, cannot be satisfied by themselves due to the lack of financial resources, strategical focus on core business activities, the lack of capabilities to search and internalized external knowledge, and, finally, these activities carried out by multiple firms lead to redundant expenses that can be avoided. The role of gatekeeper acts as a knowledge broker covering this relevant activity, in terms of research of external knowledge, acquire, elaborate, create new knowledge, and disseminate it within the industrial district (Hervas-Oliver & Albors-Garrigos, 2014; Pagano et al., 2021). The role of gatekeeper can be covered by several type of actors, which nature can be private or public, such as cluster lead firm, institutions, research centres, knowledge providers, universities, and business association (Gradinetti 2011; Pagano et al., 2021). In line with the Third Mission promoted for universities and research centres, local institutions address the new digitalization issue faced by firms, through the development and implementation of projects and services which leads to the final results of knowledge and technology transfer, such as the Digital Innovation Hubs (DIHs) and competences centres (Rissola & Sörvik, 2018). The study by Pagano (2021) analysed the dissemination process of knowledge related to digital technologies in the industrial district environment. The study focused on the Pesaro industrial district located in Italy and more precisely in the Marche Region, carrying out a qualitative analysis based on 18 in depth interviews. The results of this analyses shows that traditional and specific dissemination mechanisms of industrial district take place among actors enhancing the collaboration and cooperation, in which both firms and institutions develop and implement projects related to Industry 4.0 determining "new interaction processes, combining formal and informal exchanges" (Pagano et al., 2021, p.46). These initiatives related to the digitalization process allow new forms of collaboration with crucial partners which promote the creation and dissemination of knowledge and technology, enhancing the overall industrial district learning capabilities, improving firm's absorptive capacity, and nurturing the relationships expanding the network to actors within and outside the industrial district (Pagano et al., 2021). In line, the study of Götz (2021) analysed the impacts of the industrial district in relationship to the promotion and dissemination of knowledge related to Industry 4.0 and relative benefits for firms along the implementation journey of these technologies. The exploratory analysis carried out through case study and survey analyses focused on 36 German clusters for the population descriptive statistical analyses and 9 clusters, with a single participant per cluster, for the survey analyses. The composition of these clusters, in terms of economic actors, is "59% share of SMEs; 13% share of research institutions' and 16% share of large firms" (Götz, 2021, p.72) which confirm the presence of majorly SMEs. The main results of this study are that clusters contribute to create a favourable environment for the development and implementation of digital solutions, enhancing the opportunity to foster the creation and dissemination of knowledge, with positive effects toward the internal business processes enhancing their efficiency and simplifying them. Finally, firms, especially SMEs, obtain benefits through the combination of the industry 4.0 technologies and location within clusters due to their complementary nature, in which digital technologies foster new business models, new form of collaboration with external actors while clusters act as an environment which enhance the know-how, expertise and knowledge of firms located in that regional area, determining a source of competitive advantage on the location choice (Alcácer et al., 2016; Götz, 2021).

4 The relevance of partners.

Nowadays, firms face several difficulties on the competition due to several factors. Firms are challenged to compete on a global scale, where actors are interconnected in real time through the utilisation of digital technologies, in which the innovation strategy is essential due to the decreasing product lifecycle and enhancing the efficiency of production's process, and, finally, firms are innovating their business model toward more complex and hybrid models including offers of services. These factors challenge firms to build, create and develop new knowledge to fuel these innovation strategies, based on the collection and interpretation of data and information allowing the adoption of digital technology with virtuous effects of the business. Firms, especially SMEs, face several barriers toward the implementation of these activities, requiring the support of KIBS (Knowledge-Intensive Business Services), which are specialised firms focused on the creation of new knowledge useful for innovation purposes and implementation of new technologies.

4.1 THE ROLE OF KIBS IN THE DIGITAL ERA.

In the industry 4.0 revolution, firms are demanded increasing capabilities to innovate their products and production processes, useful to compete in markets characterized by mature products, and business models, enhancing the firm's strategy to capture value. These requires the capability of firms to innovate investing in R&D activities and developing a network of actors which can provide strategical assets for the firm. The R&D activities are expensive and high-risk activities which innovative results are characterized by uncertainty determining difficulties for their implementation in the firm's environment, with particular interest to SMEs which suffer from the lack of financial resources. The complexity of developing new knowledge and the costs related to innovation activities shift the focus toward the adoption of the open innovation paradigm (Chesbrough, 2003). The aim is to develop a network of relationships with key stakeholders leveraging on their specific knowledge, supporting the firm's innovation process and the adoption of new technologies (Di Bernardo & Grandinetti, 2012). In this context, firms approaching the digital transformation needs to overcome the adoption and implementation barriers of these technologies, being able to create new strategies to compete (Fitzgerald et al., 2013). Firms need support from specialised actors which act as knowledge brokers that interconnect and create relationships between other actors that are not connected, which is fundamental for the flow of knowledge (Burt, 2007). The firm's opportunity to get access to vast number of external sources of knowledge foster the internal capabilities to develop innovation in the collaboration with those actors, following the open innovation paradigm, sustaining the firm along the digital transformation process (Allameh, 2018; Bogers, 2012). Knowledge brokers support their customers in the exchange of information and knowledge useful for their business through the interaction of external sources of knowledge where customers barely have interactions and communication with them. Thus, knowledge brokers usually identify the relevant actors who possess key knowledge, create relationships with vast number of actors, acquire and recombine the complex knowledge in which the recombination process include the internal existing knowledge and promoting the formation of network of actors (Haas, 2015; Olejniczak et al., 2016). In the knowledge economy, the building blocks of this network are actors involved in the knowledge creation process, with special attention toward KIBS.

KIBS are defined as: "firms performing, mainly for other firms, services encompassing a high intellectual value-added" (Muller, 2001, p.2). Knowledge-Intensive Business Services (KIBS) are private actors with the aim to create, develop and share new knowledge with other actors that are private or public such as firms and organizations (Muller and Zenker, 2001). This definition is broadly defined including a wild spectrum of actors involved in the knowledge-creation process, which are separated in two main categories, in line with the study of Miles et al. (1995), that are "traditional professional services" (P-KIBS) and "new technology-based services" (T-KIBS) (Muller and Zenker, 2001, p.1503). The main goal of KIBS is the provision of a highly customized service, through the main activities of creation and transfer of knowledge, where the first type of KIBS (P-KIBS) provide highly professional services designed for heavy users of new technologies, such as accounting and consulting, while, the latter (T-KIBS), provide services related to software development, which are related to R&D and engineering (Miles et al., 1995; Muller and Zenker, 2001; Bettencourt et al. 2002; Cabigiosu & Campagnolo, 2019). The relevancy of these actors is related to their strategical focus on the internal innovation activities, with the goal to be part of a network acting as crucial node to support the externalisation strategy of other nodes regarding the innovation process and knowledge management activities. KIBS distinguish themselves from other types of suppliers due to services provided characterized by high intensity of knowledge, the role played as consultancy company supporting firms in the resolution of problems and the high suitability of service provided to the needs of client. The study of Muller and Zenker (2001) identified the knowledge flow between the client and KIBS is not a linear knowledge transfer rather than interactive process composed by three phases. The first phase of the process is related to acquisition of knowledge, which occurs in the interactive process with the client during the problem-solving activities. The second phase is characterized by the recombination of already existing and newly obtained knowledge useful for the relationship with the client. The last phase is the provision of the high knowledge intensive service which embed the knowledge created in the previous stages of the process (Muller and Zenker, 2001). The main object of the KIBS offer is related to knowledge, which is embedded in services and transferred to customers though them. These services aren't standardized rather than highly personalized to fit the customer's needs, which requires high levels of interaction of both sides (Bettencourt et al. 2002; Cabigiosu & Campagnolo, 2019). The customer actively participates in the development and provision of this services, leading to the co-production of this service and, consequently, determining the interactive learning process of both partners, where the service is the result of the effort of both firms together (Leiponen, 2006; den Hertog, 2000).

The relationship between the customer and KIBS is fundamental for the deep understanding of the customer peculiarities in terms of business, strategy and organisational structure, enhancing the opportunities for the correct customisation and adaptation of the service features aiming to the satisfaction of customer's needs. These two elements, the interaction between firms and the customization, determine crucial variables for the identification of KIBS, in terms of services and the company which provide them (Bettencourt et al. 2002; Freel 2006; Cabigiosu & Campagnolo, 2019). This relationship is characterized by intense level of interactions and knowledge content in which KIBS can play different roles along the innovation process, according to the customers' needs (den Hertog, 2000; Smedlund e Toivonen, 2007). The study of den Hertog (2000) identified three main roles covered by KIBS. The first role is defined as facilitator in which they support the customer in the innovation process of product and production process, where the innovation process is carried out by the customer without being created or transferred by KIBS. The second role is the broker, in which KIBS act as knowledge and innovation intermediaries to transfer them between several actors and industries, without the necessity of the creation by KIBS. The last role is the source, in which they start and develop the innovation process, creating customized solutions for the customer, requiring the active and close participation of KIBS along the process. Along the relationship, KIBS are considered as "bridge for innovation" (Muller and Zenker, 2001, p.1503) due to their interactions within the network. They act as purchaser of tangible and intangible assets, as knowledge, from other actors, as supplier, through the provision of services to manufacturers and service companies and as partners, in which they provide complementary information, knowledge and services to their customers (Muller and Zenker, 2001).

KIBS have the opportunity to grow through the management of the depth relationship between the customer and KIBS which offers several benefits. This relationship represents the opportunity to expand KIBS's knowledge base, through the acquisition of new specific knowledge from its portfolio of customers, being able to expand the knowledge base related to several firm's aspects, best practices, and sectors. The relationship is the vector of relevant data, information and knowledge related to several firms, sectors, market trends, needs and opportunities that create new possibilities for KIBS for the expansion of the business and development of new services (Cabigiosu & Campagnolo, 2019; Campagnolo & Cabigiosu, 2015). The development of the service to be provided to the customer determines the knowledge creation process through the recombination of newly acquired and existing knowledge, enhancing the quality of the service and the success rate of the service. This learning process fuel the competitive advantage of KIBS, enhancing the capability to diffuse the knowledge through the provision of services, solving customers problems, helping them on the innovation process and in the implementation of new technologies (Muller and Zenker, 2001). The growth is achieved through the assessment of the right level between the satisfaction of a single customer's requests, leading to high level of its satisfaction, even if, it will require high level of customisation determining high level of connected costs, and to satisfy several actors, increasing the volume of services provided by KIBS, requiring higher levels of standardization with possible detrimental effects on the level of customization and, consequently, the customer's satisfaction (Sundbo 2002). The level of customization of the service is the critical part that enhance the possibility for KIBS to grow through the prope management of the traditional trade-off between standardization and customisation along the path of definition and provision of services. The solution of this dilemma is through the adoption of a modular strategy, in which each module is standardized, and the customization is obtained by the configuration agreed among parties involving the selection and combination of modules. This strategy allows KIBS to achieve the extraction of economic benefits, customisation, customer satisfaction, and the replication of knowledge and innovation, enhancing the absorption by the customer (Pekkarinen and Ulkuniemi 2008; Cabigiosu & Campagnolo, 2019).

The disaggregation of KIBS into the two categories defined by Miles et al. (1995), respectively P-KIBS and T-KIBS, confirms the relevancy of the collaboration and customization characteristics as fundamental to the success of the service for the innovation process (Hu et al. 2013; Freel 2006). The collaboration in the relationships between KIBS and customers is the key success factor for arising the innovativeness of both firms through the

adoption of a cooperation strategy (Freel 2006; Cabigiosu & Campagnolo, 2019). KIBS have the advantage of acquiring knowledge related to the needs and opportunities of their customers and sector to which they belong. This element enhances the opportunity for KIBS to successfully innovate due to the reduction of risks and uncertainty related to investments and increasing the success of first move strategy capturing its advantage enhancing the competitive advantage (Massini, Lewin, and Greve 2005; Cabigiosu & Campagnolo, 2019). The cooperation with the set of several customers with different characteristics in terms of business strategies, technologies and industries determines relevant sources of external knowledge that are fundamental for the development of competitiveness of KIBS leading to their growth (Laursen and Salter 2006; Cabigiosu & Campagnolo, 2019). The cooperation is characterized to be closely related relationships that is necessary to communicate, coordinate and transfer valuable intangible resources which are mostly knowledge, in tacit form, skills, competences and ad hoc solution for customer's problems (Muller and Zenker, 2001; Leiponen, 2006; Campagnolo & Cabigiosu, 2015; Cabigiosu & Campagnolo, 2019).
Finally, the innovativeness of KIBS depends on the value of the relationships with their customers in terms of opportunity to extract favourable resources. KIBS must assess the value of each existing and new potential relationships, in order to estimate the potential contribution to the internal innovation process and calibrating accordingly the effort in the provision of services (Cabigiosu & Campagnolo, 2019).

4.2 COMPETENCE CENTERS.

In the fourth industrial revolution, small and medium sized firms suffer from the lack of resources, competences, and culture. In this context, SMEs can be facilitated in the digitalization process through the support of external actors, as institutions, universities, research centers. The role of competence centers is crucial in the innovation ecosystem supporting SMEs in the adoption of industry 4.0 technologies. The competence center is a research initiative based on the collaboration between the public and private sectors including the set of innovation ecosystem's actors (Ietto et al., 2022).

In 2016, the Italian government introduced competence centers[9] as partnerships among the public and private sectors which main goal is to support the digitalization process of firms, in particular SMEs, through the activities of training and knowledge sharing, and sustaining projects related to the implementation of new innovations, R&D activities, and experimental development. These structures are the result of synergic unions of heterogenous innovative

[9] https://www.mise.gov.it/it/incentivi/centri-di-competenza-ad-alta-specializzazione

actors, involving public institutions, universities, research centers and firms which allows the combination of complementary resources and facilitating the digitalization process of supported companies. In fact, competence centers sustain firms on technical aspects related to the adoption and implementation of digital technologies and as consultancy structure sustain the internal firm reorganization process and the adaptation of business strategy. The financial funds dedicated to the constitution of competence centers and execution of projects amounted to 73 million euros. The competence centers play a crucial role for the adoption of digital technologies in which their activities promote and support firms in this process. The competence centers carried out, up to 31 December 2022, over 2000 demonstrations of industry 4.0 technologies mainly to SMEs (73%), 420 workshops, 511 free training events involving 29000 employees from 12000 firms, 370 paid training courses involving 22000 employees from 1800 firms, the provision of 330 consultancy services mainly for SMEs and, finally, the selection and funding of 211 of innovation projects.

In Italy, there are eight competence centers situated in Turin, Milan, Bologna, Pisa, Padua and Triveneto, Naples-Bari, Rome and Genoa, that are characterized by the guidance of its lead university. The eight competence centers share the common mission of sustaining the digitalization process of firms, even if, they are specialized on different areas. The "CIM 4.0 - Competence Industry Manufacturing 4.0" [10] is in Turin and specialized on additive manufacturing and digital factory, "Made - Competence Center Industria 4.0"[11] is in Milan and focuses on digital technologies, "BI-REX - Big data Innovation-Research Excellence"[12] is in Bologna and focuses on big data, smart city, and traceability, "ARTES 4.0 – Industry 4.0 Competence Center on Advanced Robotics and enabling digital TEchnologies & Systems 4.0"[13] is in Pisa and focuses on advance robotics and enabling digital technologies, "SMACT Competence Center"[14] born in Triveneto situated in Padua and focuses on digital transformation balancing the technological, strategical, social and environmental dimensions, "MedITech Competence Center I 4.0"[15] is located in the region of Puglia and Campania, and focuses on the vertical and horizontal integration of industry 4.0 technologies, "START 4.0– Sicurezza e ottimizzazione delle Infrastrutture Strategiche Industria 4.0"[16] is located in Genoa and focuses on diffusing the adoption of digital technologies specializing in physical security,

[10] https://cim40.com/chi-siamo/
[11] https://www.made-cc.eu/it/
[12] https://bi-rex.it/
[13] https://www.artes4.it/
[14] https://www.smact.cc/
[15] https://meditech4.com/
[16] https://www.start4-0.it/

people safety and cyber security, "CYBER 4.0 – Cybersecurity Competence Center"[17] is in Rome and focuses on cybersecurity.

The study of Ietto et al. (2022) analyzed the impacts of Italian Competence Centers (CC) on the digitalization process of SMEs. The results showed that CCs have positive effects on SMEs due to several support activities, as the enhancement of firm's human capital based on training courses, reducing the cultural barriers through the enhancement of familiarity to digital technologies and supporting the planned implementation of these technology shaping the manufacturing operations.

4.3 DIHs and European dimension.

The fourth industrial revolution has profound impacts on the digitalization process of firms and the geographical territory in which they are located. This is particularly true for SMEs which face several barriers toward the implementation of industry 4.0 technologies (Raj et al., 2020).

The implementation barriers of industry 4.0 technologies affect the firms and, consequently, the spatial territorial competitiveness, determining an opportunity for actions of public policy makers. In 2016, the European Commission launched the "Digitising European Industry" (DEI) initiative[18], with the aim to support with over €50 billion of investment between 2016 and 2020. The DEI initiative is part of a broader strategy named Digital Single Market (DSM) and its launch was supported by the Council of European Union[19]. This policy sustains and complements several initiatives at regional and national levels in Europe with the final goal of favouring the digital transformation.

The DEI initiative is built on five main pillars (see Figure 5):

1. European platform of national initiatives on digitising industry

   This aim to ensure coherence among Member States initiatives for the digitalization process. This will assure the alignment of commitments and investments of Member States achieving the DEI objectives.

[17] https://www.cyber40.it/
[18] European Commission (2016), COM(2016) 180 final of 19.4.2016, Digitising European Industry; Reaping the full benefits of a Digital Single Market, Brussels.
[19] Council of the European Union (2015), 9340/15, Conclusions on the digital transformation of European industry, 29.5.2015.

2. Digital innovations for all: Digital Innovation Hubs

   Digital Innovation Hubs (DIHs) are one-stop-shops where firms obtain support in the process of adoption and implementation of digital technologies. The DEI goal is to spread the creation of DIHs and support the development of a network of DIHs.

3. Strengthening leadership through partnerships and industrial platforms

   Relationships are crucial for achieving the implementation of digital technologies and competitiveness growth with positive effects from micro level to macro level including the overall EU's competitiveness. DEI initiative supports the creation and the development of digital industrial platforms and large-scale piloting and Public-Private Partnerships (PPPs).

4. A regulatory framework fit for the digital age

   the presence of the favourable regulatory framework is fundamental for nurturing the growth of EU'S industry and economy. In the Digital Single Market strategy, the European Commission has proposed several measures to update regulations in key digital fields.

5. Preparing Europeans for the digital future

   The European citizens are the heart of this revolution, and their readiness is necessary for the success of the digital transformation. This requires the adaptation and reskilling of the workforce and transformation of education and learning systems. This gap is addressed by European initiatives such as the digital skill and jobs coalition and the digital opportunity scheme.

Figure 5. Pillars of DEI initiative.

Source: European Commission adapted from Digitising European industry (2019 p.6[20]).

The European Commission utilizes several funds to financially support European initiatives to develop and diffuse digital technologies. The European fund for strategic investments (EFSI) is the fundamental part of the European investment plan, which goal is the sustain and development of the long-term economic growth and competitiveness in the EU. This fund was extended to 31 December 2020 raising the **investment target** to €500 billion, aiming to financially cover projects belonging to several areas such as infrastructure, R&D, ICT and others[21]. The Horizon 2020 (H2020) programme was the financial instrument for the funding of EU Research and Innovation programme during the period from 2014 to 2020. This programme sustained the research and innovation activities in digital technologies, foster their

[20] https://www.eca.europa.eu/lists/ecadocuments/ap19_13/ap__digitising_industry_en.pdf
[21] https://www.consilium.europa.eu/en/policies/investment-plan/strategic-investments-fund/

dissemination and sustain the digitalisation process of firms, with a budget of €80 billion[22]. The H2020 has been succeeded by Horizon Europe[23], which is the funding programme until 2027 allocating €95.5 billion to cover projects related to the climate change, Sustainable Development Goals and enhancing the EU's competitiveness. European Regional Development Fund (ERDF)[24] is a financial tool to sustain the European cohesion policy, aiming to reduce the differences in the development levels of European Member States and enhancing the life quality standards. The two main goals are the investment in for economic growth and sustaining jobs, strengthening the labour market, and achieving the European Territorial Cooperation among European Member States. In the period from 2014 to 2020, the EU allocated around 350 billion euros and in the period from 2021 to 2027 has been allocated around 200 billion euros maintaining both goals. Finally, The Competitiveness of Enterprises and small and medium-sized enterprises (COSME)[25] programme aim to support SMEs in different areas such as get access to finance, acquisition of skills and competences, get access to markets and technology providers, supporting entrepreneurs and boosting the competitive advantage with a budget of €2.3 billion during the period from 2014 to 2020. These are some examples of funds used by European Commission to promote its initiatives sustaining the development and diffusion of digital technologies, favouring the digital transformation of firms, with special regard to SMEs, sustaining the economic competitiveness and labour markets of European Members States.

In this scenario, new actors arise in support of the technological and economic development of actors and territory. Digital Innovation Hubs (DIHs) are organisational structures which goal is the provision of one-stop-shops services that support firms in the digital transformation, with special focus on SMEs (Dyba et al., 2022; Rissola et al., 2019). DIHs provide different types of services according to their mission of supporting single actors and the region. In fact, DIHs' core activities are related to one-to-one services, addressing the firm's needs and challenges, with particular focus on strategic aspects of the business, including digital assessment, advisory and consultancy activities. DIHs provide one-to-many services, organized as events, such as seminars, webinars, training, and workshops with the objective to spread the digital culture, increase the awareness of digital technologies and their benefits, increasing the knowledge, skills, and competences, favouring the digital

[22] https://cordis.europa.eu/programme/id/H2020-EC
[23] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
[24] https://www.europarl.europa.eu/factsheets/en/sheet/95/il-fondo-europeo-di-sviluppo-regionale-fesr-
[25] https://single-market-economy.ec.europa.eu/smes/cosme_en

transformation of the industrial region. Finally, investments in digital technologies are characterized to be difficult to assess their potential benefits, determining high risks and uncertainty, especially in relation to the integration with the existing firm's organisational structure. Thus, DIHs provide the infrastructure, which is specialised for testing different technological solutions, supporting actors for determining optimal investment choice based on their peculiarities and they support the creation and development of ecosystems enhancing the opportunity of interconnections among actors (Dyba et al., 2022; Rissola et al., 2019). DIHs support the implementation journey of digital technologies, the development of digital competencies and business strategy for companies determining positive effects on the territorial dimension in terms of innovativeness, competitiveness, and attractiveness. The activities and positive results achieved by DIHs determine the reason for which these actors are included as a type of Knowledge-Intensive Business Service (KIBS) (Opazo-Basáez et al., 2020).

In the industry 4.0 revolution, firms approaching the digital transformation needs to overcome the adoption and implementation barriers of these technologies, being able to create new strategies to compete (Fitzgerald et al., 2013). In this context, firms need support from specialised actors which act as knowledge brokers that interconnect and create relationships between other actors that are not connected, which is fundamental for the flow of knowledge (Burt, 2007). The firm's opportunity to get access to vast number of external sources of knowledge foster the internal capabilities to develop innovation in the collaboration with those actors, following the open innovation paradigm, sustaining the firm along the digital transformation process (Allameh, 2018; Bogers, 2012). Knowledge brokers support their customers in the exchange of information and knowledge useful for their business through the interaction of external sources of knowledge where customers barely have interactions and communication with them. Thus, knowledge brokers usually identify the relevant actors who possess key knowledge, create relationships with vast number of actors, acquire and recombine the complex knowledge in which the recombination process include the internal existing knowledge and promoting the formation of network of actors (Haas, 2015; Olejniczak et al., 2016).

The European Commission recognized the positive impacts of DIHs in fostering the digital transformation of firms and industrial region and achieving great results over the climate challenge which establish the Digital Europe Programme. The Digital Europe Programme[26] is the new programme actives in the period from 2022 to 2027. The aim of this programme is to sustain selected European DIHs[27] enhancing the EU digital capabilities toward specific areas of interests as Artificial Intelligence (AI), cybersecurity, improving the computational, processing and governance capabilities of data. The accomplishment of the programme's objectives is through the creation and development of a network of interconnected European Digital Innovation Hubs (EDIHs), which will support the digitalisation process for European organisations of private and public sectors (Dyba et al., 2022).

The geographical location of actors matters favouring their relationships, the exchange of knowledge, particularly the tacit type, enhancing the opportunity for introduction of novelties, leading to acquisition of the competitive advantage through the aggregation of several actors and the arise of external spillovers. The European policy makers, coordinated at national and regional levels, aims to support firms, especially SMEs, through the introduction of DIHs leveraging on the location choice as critical variable to reduce the geographical distance (Rissola & Sörvik, 2018). The inclusion of the perspective of multiple actors enhances the comprehension of the knowledge circulation, creation, and recombination phenomenon that arises within a limited geographical area and involves several different actors as DIHs, universities, local policy makers and technology transfer offices (Hervas-Oliver et al., 2021; Trippl et al., 2018). The cooperation dynamics characterizing the relationships among actors influence the technological development process determining the enhancement of complexity of the adoption path, even if, the inclusion of them favour the firm and regional's innovativeness (Hervas-Oliver et al., 2021; Isaksen et al., 2018b). The study of Hervas-Oliver et al. (2021) focused on the analysis of Spanish DIHs' impact through qualitative-based empirical analysis of 10 DIHs, and their secondary data. The authors interviewed managers and principal researchers during the period from July to November 2019. The results showed that DIHs policy promoted by European Commission have positive impacts on collaboration and open innovation strategies favouring the bottom-up approach among actors, promoting the exchange of resources for the resolution of problem internal to the spatial area (Hervas-Oliver et al., 2021). The positive effects of DIHs are recognized by the study of Crupi et al. (2020) focused on the Italian DIHs analysing the impact on the support of digital transformation of SMEs as the result of their activities as knowledge brokers. The analysis involved 11 DIHs applying the qualitative methodology using surveys and interviews during

[26] https://ec.europa.eu/newsroom/dae/redirection/document/80907
[27] https://digital-strategy.ec.europa.eu/en/activities/edihs

the period from March to June 2019. The analysis identified that main activities provided by DIHs are related to integration and exchange of knowledge, which effects the flow of knowledge among external actors, with particular interest to ecosystem building (89%) and collaborative research (87%) activities as shown in figure 6.

Figure 6. Service offered by DIHs to SMEs in the Italian context.

Source: Adapted from Crupi et al. (2020, p.1272)

The results confirm the positive impacts of DIHs' activities supporting SMEs through the creation and management of relationships and partnerships with "universities, research centers, service providers and corporations" (Crupi et al., 2020, p.1276). Furthermore, the DIHs' characteristics, the knowledge's type shared, and the existing set of relationships and partnerships deeply influence the digital transformation process of SMEs. Finally, the relationship between DIH and SME is characterized by the bi-directional influence in which both parties gain benefits due to this collaboration based on the exchange of knowledge (Crupi et al., 2020). Finally, the study of Dyba et al. (2022) focused on the impacts of three European regions on the digital transformation process of manufacturing firms. The analysis focused on Italy, Germany, and Poland, implementing the case study analysis method based on in-depth interviews investigating the actions and strategies of regional authorities and their impact on the implementation process of digital technologies. The results confirm that these actors, including DIHs, are fundamental to foster the digitalization of organisations, especially SMEs, increasing and sustaining the knowledge related to digital technologies, supporting the creation and development of digital strategy, covering the financial gap for digital investments and, finally, the development of human capital, in terms of skills and competencies of workers, enhancing the firm's digital readiness and overcoming the barriers toward the digital transformation (Dyba et al., 2022).

4.4 TERRITORIAL SERVITIZATION.

The technological evolution has a strong impact on actors shaping the territorial dimension of the economic structure of countries. The structure of economic regions heavily based on traditional manufacturing suffers on the transition and implementation of the digital technologies during the industry 4.0 revolution. The digital transformation impacts on the capability of economic regions on the adaptation of the existing capabilities and skills required, which technological and knowledge space are unrelated. The economic region's ability to adapt and diversify into new and unrelated technological and knowledge spaces without the intervention of specific actors reduce the success rate of the digital transition (Vaillant et al., 2021). In fact, the economic region extracts positive effects due to a diversification strategy in the situation characterized by closeness and relatedness between the existing and new set of knowledge, skills and capabilities. Thus, the existing knowledge base characterizing an industrial region strongly influence the adaptability during the process of digital transformation, favouring those regions characterized by high (Vaillant et al., 2021; Whittle & Kogler, 2020)., 2021; Whittle & Kogler, 2020). The presence of specific actors in the territory enhances the innovation capability of the region through the positive effects of deriving from the dyadic relationships with local firms. In this context, KIBS improve the implementation of the digitalisation from the micro levels to the meso level sustaining the competitiveness at both levels also with impacts on the development of new business and favouring the knowledge management practices (De Propris & Storai, 2019; K. Horváth & Rabetino, 2019; Lafuente et al., 2019; Vaillant et al., 2021).

Manufacturing firms struggle to compete, especially in developed regions characterized by mature markets, due to the reduced profitability caused by the competition at global scale with several actors located in developing and emerging economies which are favoured by costs advantage (Crozet & Milet, 2017). The strategy to escape the competition based purely on products is through the integration of services in the firm's offer, enhancing the value offered to the customers and escaping the pure price competition, called servitization (Baines & Lightfoot, 2013; Vandermerwe & Rada, 1988; Wise & Baumgartner, 1999). The servitization strategy is spreading into several firms and sectors, enhancing the capabilities of actors to generate additional value for customers, increasing the profit margins, stabilizing the fluctuations of revenues and cash inflows, increasing the growth rate, creating strategic lock-ins and, consequently, enhancing the competitive advantage (Cusumano et al., 2015; E. Gomes et al., 2019).

The adoption of the innovation strategy based on the combination of products and services is increasing over manufacturing firms due to several opportunities to be captured. This strategy is enhanced by the rising of the knowledge-based economy favoured by the Fourth Industrial Revolution. The implementation of this strategy demands the development of the necessary firm's internal conditions, as capabilities, culture and knowledge, which has the potential to benefit the firm's technological infrastructure supporting the adoption of the industry 4.0 technologies. These requirements determine several challenges to be accomplished leading to choose between different strategies for firms. Firms has to assess the opportunities and cost of achieving them internally, using the firm's resources, or based on external collaboration, involving value chain's actors and territorial partnerships (Vaillant et al., 2023). The innovation of product and service offered as a solution system requires critical investment for the development and integration of digital technologies, existing IT infrastructure, organizational firm's structure and the readiness of the human capital which imply the firm's choice for external collaborations, with specialized actors, boosting the territorial local network. These effects favour the reconfiguration of the local value system, the integration of new actors and the knowledge flow supporting the development of the territorial servitization and the digital transition of the region (Lombardi et al., 2022; Vaillant et al., 2023).

Nowadays, the exploitation of this strategy requires the firm's readiness to adapt its strategy, leverage on his product's culture and knowledge, implement the digital technologies, and improve the internal skills and competencies to be able to manage and use the data and information collected to develop and offer services satisfying the customers' need. The servitization is a reactive strategy for firms to reduce the competitive pressures and sustain their growth. SMEs are the majority of active firms which face several constraints during the implementation of this strategy compared to big companies that are favoured due to financial and human capital (Huikkola & Kohtamäki, 2017). The industry 4.0 technologies provide several benefits that can be exploited favouring the servitization strategy as the facilitation of the interconnection among actors, exchange data, information, and knowledge, the creation of relationships boosting collaboration and cooperation of actors that is enhanced by the proximity and affecting the competition strategies, enabling servititzation and business model innovations (Capestro et al., 2022; Chiarvesio et al., 2022; Kohtamäki et al., 2020). Thus, the application of servitization strategy is supported by relationships among local firms and KIBS for collaborative partnerships, leading to the application of the network approach enhancing the regional competitiveness of the territory, favouring the territorial servitization (Bustinza et al., 2019). The study of Chiarvesio et al. (2021) analysed the effects of Industry 4.0 on the mechanical cluster located in the Friuli Venezia Giulia Italian region. The results showed that local firms adopt new digital technologies in function of their existing strategy through a careful selection based on their potential contribution. The adoption of them boosts the competitiveness, in terms of higher customer's value through the offer of hybrid products and services. Among the cluster's population analysed, some manufacturer firms change disruptively their business model and value proposition pursuing a strong servitization strategy which bases on the manufacturing capabilities and knowledge. Thus, the digital transformation encompasses the local manufacturing SMEs determining the enhancement of higher value proposed, based on increments of productivity, flexibility, and customization, leading to the innovation of their strategy and, finally, sustaining the cluster competitiveness. In this study, local institutions are identified as crucial actors for their contributions in terms of facilitating the adoption of industry 4.0 technologies, favouring the share of knowledge and experiences, enhancing the awareness of potential benefits of the adoption and boosting the development of collaboration and cooperation strategies among local actors with the aim to strengthen the local network.

The fourth industrial revolution has positive effects toward firms through the adoption of digital technologies and the geographical location which is affected by both technological development and the spread of servitization strategies, leading toward the modern phenomenon of territorial servitization. The Territorial servitization is defined as: "the symbiotic relation between knowledge-intensive service (KIBS) sectors and manufacturing firms as an engine for enhanced territorial resilience, manufacturing renaissance and competitiveness, as well as regional development" (Lafuente et al., 2017, p.20). The territorial servitization phenomenon is characterized by the relationships between local actors and KIBS which lead to the strategic change of manufacturing firms determining the focus on core business activities, sustained by the rooted culture, competences and knowledge and the adoption of outsourcing strategies based on these relationships to overcome challenges and barriers characterizing the process of digital transformation, servitization and innovation. These relationships increase the competitiveness both at firm and regional level determining the enhancement of territorial's attractiveness for new manufacturing firms which will choose to locate in that region to gain benefits of being part of the network and attracting new KIBS which will locate there supporting the local industrial environment, creating a virtuous spiral (Lafuente et al., 2017). The result of this process is the development of the economic region through the evolution of the local network of actors characterizing the economic environment in which the strong connections and interactions is the condition for the economic and technological advancement and resilience of the territory and the aggregation of located firms, characterized by most SMEs (E. Gomes et al., 2019). In fact, the presence of KIBS, measured as the number of KIBS active over the population of firms, in a particular territory and period (Lafuente et al., 2017), is positively related to the territorial servitization of a specific region due to their supporting activities and the positive impact on the contribution of productivity level within the network. Thus, the higher presence of KIBS positively affects the implementation of servitization strategy by local firms supporting their economic growth which leads to the enhancement of competitiveness at meso level of the entire region enabling and sustain the territorial servitization driven by the geographical proximity of actors within their networks (E. Gomes et al., 2019). The geographical region benefits from KIBS' presence due to their capability of identifying, extracting and acquiring new knowledge of several industries which sustain the effect of accumulation of knowledge. This implies that local firms benefit from the access to new knowledge of different and complementary industries which rise the opportunity for development of innovations sustaining the territorial development (E. Gomes et al., 2019). In this context, KIBS are key players supporting firms, especially SMEs, for the creation of advance services pursuing the servitization strategies filling firms' gaps related to internal knowledge and capabilities (Lafuente et al., 2019; Vaillant et al., 2021). Thus, KIBS act as driver and supporter of those strategies enabling local manufacturers to achieve superior competitiveness through the solution of their needs, leading to the propagation of this effect in the network becoming the driver of the territorial servitization (Vaillant et al., 2021). The study of Vaillant et al. (2023) analysed the effects of already existing industrial territory characterized by the presence of active incumbent firms and KIBS on the development of Product and Service Innovation (PSI) ecosystem performance based on the manufacturing employment growth. The paper analysed 17 Spanish regions during the period from 2006 to 2012. The results showed that territorial servitization and the development of PSI ecosystems enhance the territorial competitiveness in terms of higher manufacturing employment (34.4%) compared to other regions. The presence of strong existing manufacturing incumbents located within a territory is a positive pre-determinant, creating the stimulus for the territorial servitization process, based on the flow of knowledge which determines the enhancement opportunities for the local development of PSI ecosystems.

KIBS play a crucial role in the new Fourth Industrial Revolution, even if, their contribution to the technological readiness of customers and, consequently, of economic regions depends on their specialization into T-KIBS or P-KIBS (Vaillant et al., 2021; Miles et al., 1995). Technology-based KIBS focus their core activities on exploration and identification of new knowledge, acquisition, absorption and recombination of existing knowledge, and distribution of new knowledge through the provision of services supporting the implementation of new digital technologies and enhancing the innovation propensity of customers (Vaillant et al., 2021; Miles et al., 1995). The core activities of P-KIBS are focused on the provision of professional services based on accumulated expertise and know-how, which degree of technological innovation and knowledge creation is lower compared to T-KIBS (Vaillant et al., 2021). Thus, the impacts on the regional diversification strategy is influenced by the heterogenous presence of the two categories of KIBS, in which T-KIBS majorly support the creation and development of knowledge and skill base, reducing the cognitive distance and enhancing the adoption of digital technologies, leading to the development of new business strategies leveraging on d(de Propris & Storai, 2019; Lafuente et al., 2019; Vaillant et al., 2021; Whittle & Kogler, 2020)., 2021; Whittle & Kogler, 2020). The activities of KIBS increase the rate of development and spread of servitization and territorial servitization phenomena, in which the separation of KIBS into the two categories of T-KIBS and P-KIBS is relevant with particular interest toward the contribution to firms. T-KIBS are focused on the acquisition, development and creation of knowledge related to industry 4.0 technologies which determines the crucial building block for the enrichment of internal resources for the provision of comprehensive solutions tailored to customer's needs. In fact, T-KIBS sustain and increase the speed and success rate of digital transformation of their customers enabling new business models focused on the hybrid solution in the spectrum of product and service combination. Thus, T-KIBS are characterized by the alignment of interests and goals with local firms sustaining the cooperation through activities which positively affect the development of network among local actors enhancing the digital development of the regional area enhancing the territorial servitization (Vaillant et al., 2021). The study of Vaillant et al. (2021) analysed the role played by T-KIBS in 121 European regions located in 24 countries. The results of this study showed that local firms obtain incremental benefits from the presence of T-KIBS compared to P-KIBS, in which they help to increase the development of region innovation systems facilitating the adoption of digital technologies and their implementation in new business models, determining positive impact on the enhancement of territorial servitization.

The evolution trajectory of the industrial region, in which the territorial servitization is rooted, affect the development patterns of local manufacturing firms, shifting from the traditional focus on the main sector of specialization, toward the iterative synergic collaboration between firms and KIBS, which favour cross-industry fertilization and expansion of the territorial industry knowledge base (Lafuente et al., 2017; Lombardi et al., 2022). The human capital is fundamental for the evolution and growth of firms and the industrial region following the territorial servitization path. Manufacturing firms need to be ready for the relationship with KIBS in order to be able to deeply comprehend the new knowledge, understanding the integration opportunities and generate value from this relationship (Doloreux & Frigon, 2020). Human resources are critical for the successful implementation of new digital technologies and the implementation of new business model, as the servitization. In this line, manufacturing firms can capture the maximum benefits from the relationship with KIBS in the presence of highly level of education workforce. Indeed, the educational level, especially qualifications and university degree, is positively related to manufacturing firm's ability to increase the competitiveness through the interactions with KIBS, achieving positive effects on the territory (Doloreux & Frigon, 2020; K. Horváth & Berbegal-Mirabent, 2022). In this line, universities enhance the quality of human capital, boosting the innovativeness of manufacturing firms and KIBS, enhancing the absorptive capacity of manufacturing firms releasing the potential of the knowledge acquired through the interaction of more advanced knowledge-based services. Thus, their presence in the local system enhances the opportunities to be capture leading to higher levels of territorial productivity (K. Horváth & Rabetino, 2019; Lombardi et al., 2022)no, 2019; Lombardi et al., 2022).

Finally, the process of territorial servitization suggests that local manufacturing firms increase their competitive advantage through the capture of opportunities and benefits deriving from the location of KIBS in same region, enhancing the competitive advantage at regional level. The firm's ability to extract those benefits is influenced by contextual factors, especially the local structure and setting, and the existing knowledge base. These factors determine that the process of territorial servitization isn't uniform, on the contrary, it is heterogenous due to the adaptation of contextual region's characteristics leading to differences across several industrial regions (Lombardi et al., 2022).

5 Empirical analysis: sample description and findings.

5.1 METHODOLOGY AND SAMPLE DESCRIPTION.

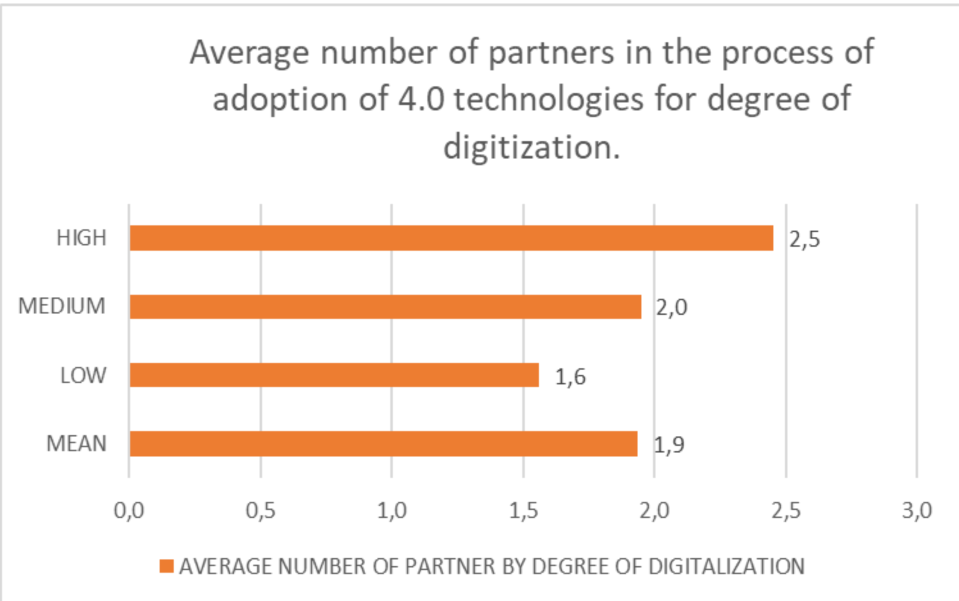
The topic of digitalization, collaboration, and the territorial dimension are extensively studied and analysed in the scientific research and literature, even if, the scientific studies on the relationship between these topics are quite narrowed. The novelty and complexity of this topic lead to choose an exploratory analysis carried out through survey analyses. This approach is suitable for new, unexplored, and not well-analysed topics. In fact, this approach enhances the comprehension of the relationships between firms and partners, the characteristics of them, and the impacts on the firm's digitalization process.

The database for the empirical analysis contains observations from the collection of survey responses, which was granted access for the development of the analyses thanks for the courtesy of professor Di Maria Eleonora. The survey was carried out by a working group of the Intesa Sanpaolo Studies and Research Department in collaboration with the researchers of the Universities of the Northeast who constitute the SMACT 4.0 Observatory. The selection of companies for the survey is based on active behaviour in the market, on the potential adoption of industry 4.0 technologies, the location within the Northeast area of Italy, specifically in the Italian regions of Veneto, Friuli-Venezia Giulia and Trentino-Alto Adige, belonging to agri-food, furniture and mechanical sectors. The initial sample identified included around 1400 companies, which 262 firms adhered to the survey research. The survey was conducted from September 2021 to November 2021. The survey is composed by structured questions addressing the digitalization process of firms, objectives achieved, identity of partners, characteristics of these relationships, in terms of knowledge management, frequency, content, geographical location and the presence of difficulties within the relationship. The sample and information deriving from the survey allow to achieve a more complete view of the phenomenon of the digitalization over the business performance, partners' relationships, and territorial diffusion.

The survey respondents were reduced from 262 to 169 to enhance the consistency of data and information for the analysis. The distribution of firms into the different sectors is heavily oriented toward the mechanical sector (52,07%) while the agri-food is 23,08% and furniture are 24,85%. The prevalent region in which respondents are located is Veneto (79%) followed by Friuli-Venezia Giulia (14%) and Trentino-Alto Adige (7%). The principal provinces are Padua (23%), Treviso (23%) and Vicenza (19%). The 56% of firms are small sized (defined as number of employees between 10 and 49), the 27% is medium-large size (defined as number of employees more than 50) and 17% is micro sized (defined as number of employees less than 10). The 31% of firms show good performance in terms of export over revenues above 65% while 21% of firms don't export. The digitalization degree is defined in four levels ranging from not adopter (level 0) toward high level of digitalization (level 4), in which the 44% of firms declare as not adopters (level 0), 19% as low intensity (level 1), 24% as medium intensity (level 3) and 13% as high intensity (level 4). This allows the differentiation between the not adopters (n. 75) and the industry 4.0 adopters, named 4.0 firms (n. 94), useful for further analysis.

Firms tend to collaborate with multiple partners determining a total of 182 partners belonging to 12 different categories that are machinery providers, technology providers, clients, raw material (RM) providers, university, competence center, digital innovation hub, chamber of commerce, innovative start-ups, competitors, no profit organizations and tecnopolis. The average number of partners involved in the collaboration with 4.0 firms is 1,9 but varies according to the degree of digitalization. Indeed, the high intensity firms collaborate with 2,5 partners on average, while medium intensity with 2 and low intensity with 1,6 as shown in Figure 7.

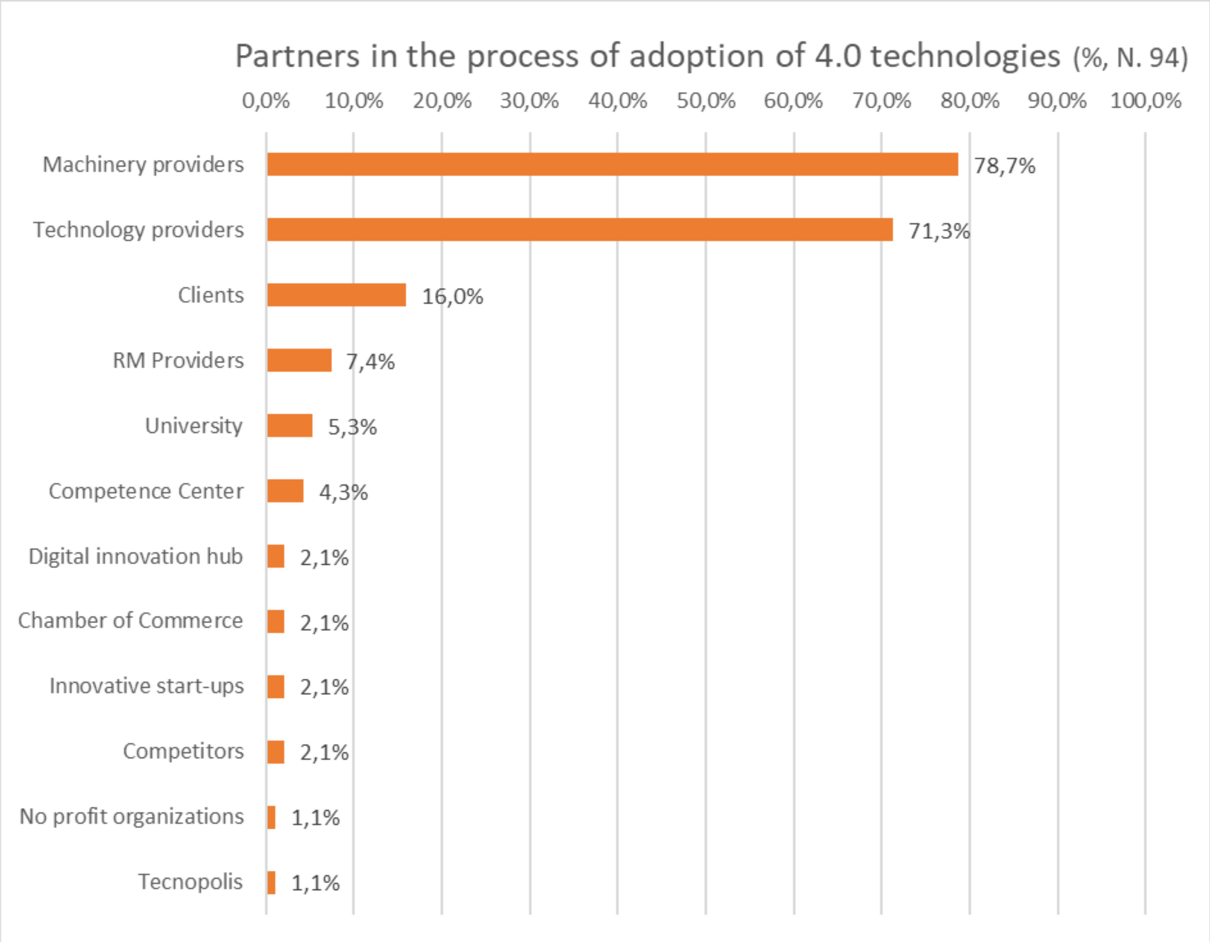
Figure 7. Average number of by degree of digitization.



Source: Personal elaboration.

The choice of partners isn't equally distributed among 4.0 firms as shown in figure 8. The main partners are machinery providers (78,7%) and technology providers (71,3%) followed by clients (16%), raw materials (RM) providers (7,4%), universities (5,3%), competence center (4,3%) and digital innovation hub (2,1%).

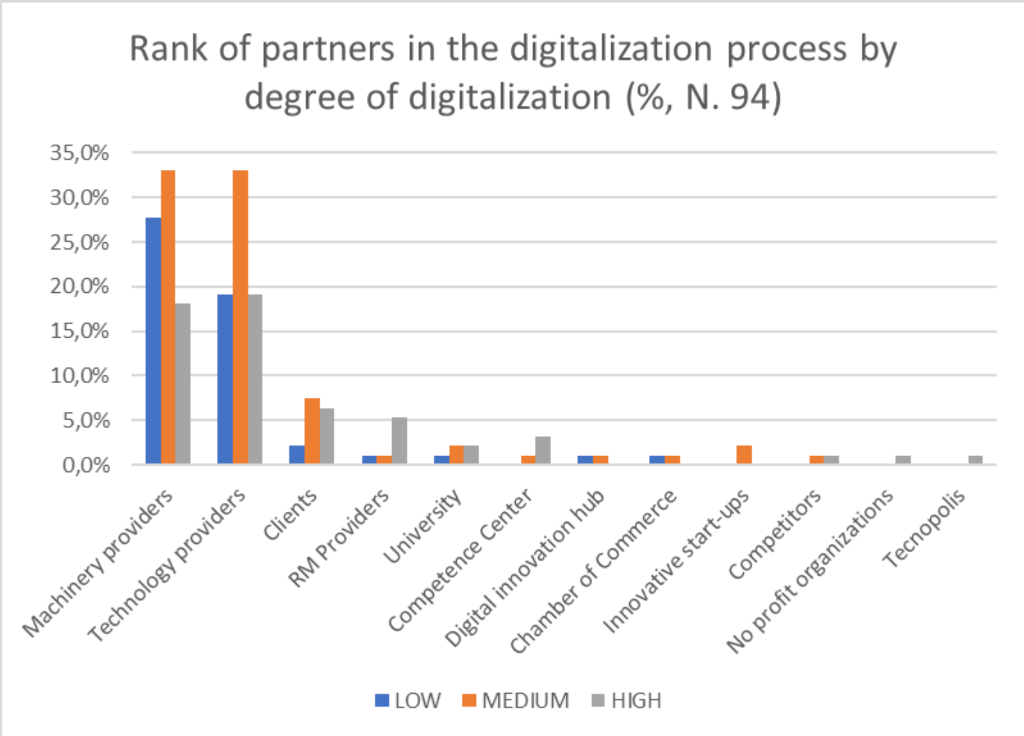
Figure 8. Average partners adoption



Source: Personal elaboration.

Firms based on the degree of digitalization show some similarities in terms of partners' preferences as shown in figure 9. Firms of all levels of digitalization prefer the machinery providers and technology providers, even if, the partner's rank is swapped for high intensity firms leading to technology providers (19,1%) as firstly preferred followed by machinery providers (18,1%). Clients collaborate mostly with medium (7,4%) and high intensity (6,4%) firms. Interestingly, raw materials providers, competence center, no profit organization and tecnopolis collaborate with the high intensity firms.

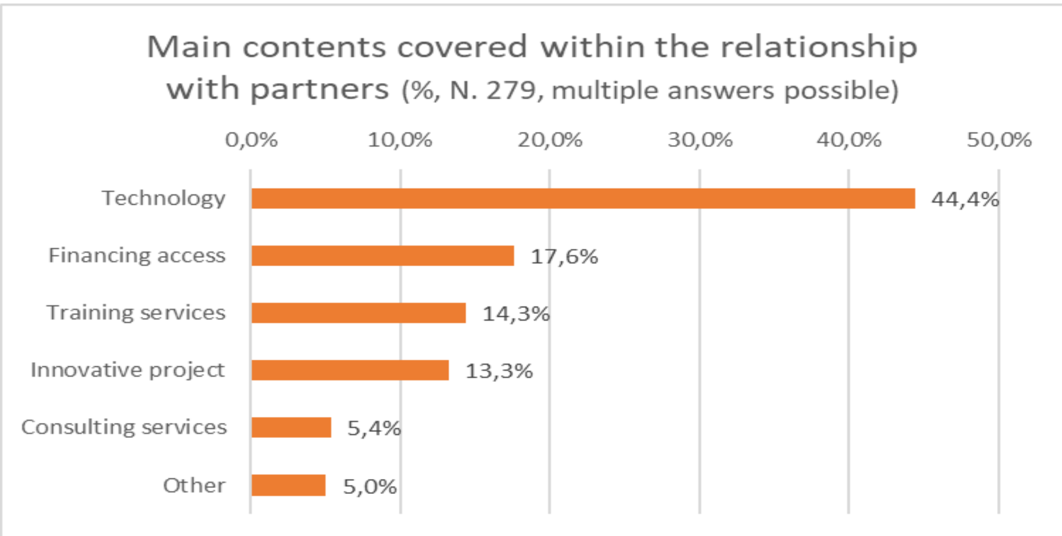
Figure 9. Partner choice by degree of digitalization.



Source: Personal elaboration.

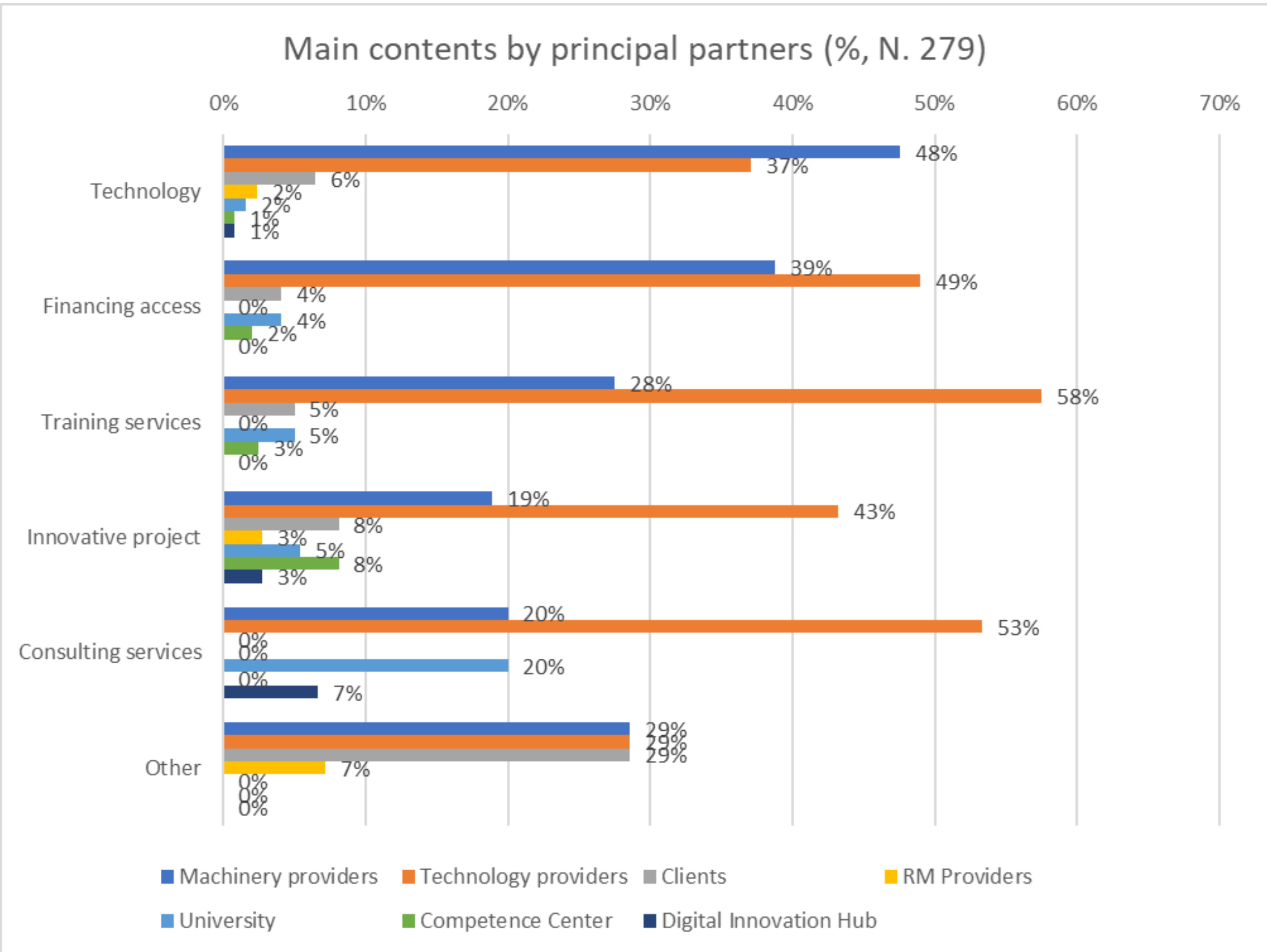
Firms can increase their competitive advantage based on the content exchanged within the relationship with partners. Main contents characterizing the relationship are technology (44,4%), financing access (17,6%), training services (14,3%), innovative projects (13,3%), consulting services (5.4%) and other (5%) as shown in figure 10. This is consistent with the interest of firms to increase the maturity in the industry 4.0.

Figure 10. Content within relationships.



Source: Personal elaboration. The contribution of partners within the relationship is different as shown in figure 11. In fact, the technological aspects are satisfied by machinery providers (48%), technology providers (37%) and, partially, by clients (6%). The technology providers are the most relevant partner in terms of contribution in financing access (49%), training services (58%), innovative projects (43%), consulting service (53%), highlighting its horizontal completeness. Interestingly, universities are focused on the content of consulting services and contribute to financing access, training services and innovative projects. The contribution of digital innovation hub is specialized on the consulting services and innovative projects. Finally, the contribution of competence center is majorly focused on the innovative projects.

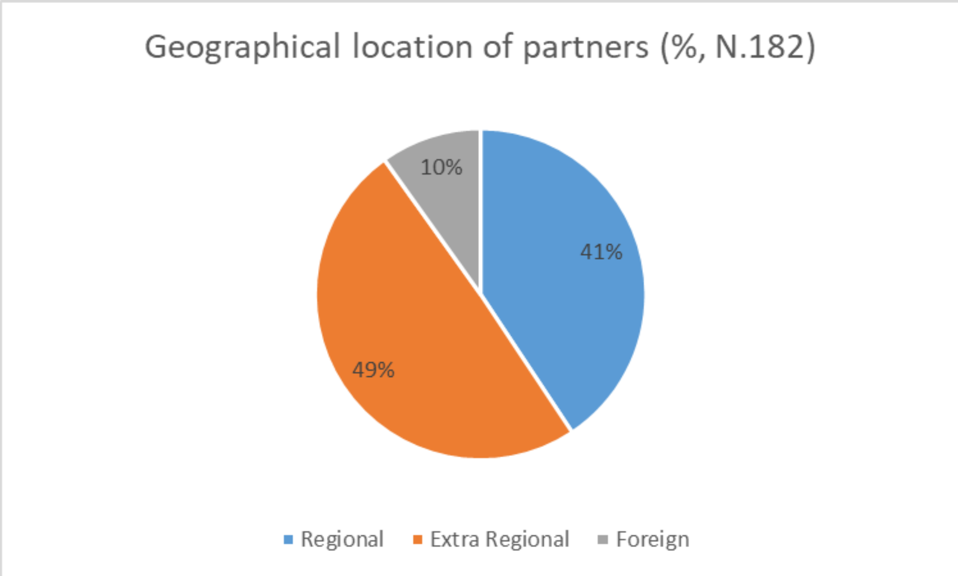
Figure 11. Main contents by partners.



Source: Personal elaboration.

The geographical location of partners is a key dimension to understand the role of proximity in the digitalization process of firms. The geographical location is divided into three categories, regional, extra regional, and foreign. The first category refers to partners located in the same region of firm, the second category refers to partners located in an Italian region different from the firm's region and, finally, foreign category refers to partners located in other countries. The geographical distribution of partners is almost evenly distributed between extra regional (49%) and regional (41%), and the presence of a minority of partners located in foreign countries (10%) as shown in figure 12.

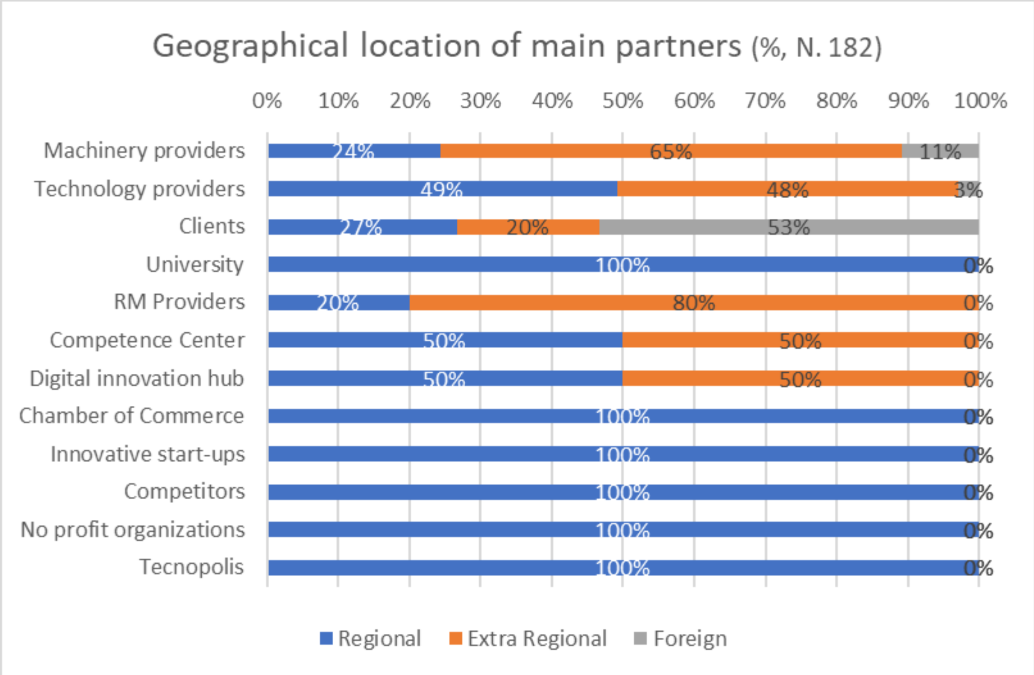
Figure 12. Geographical location of partners.



Source: Personal elaboration.

The analysis of geographical location distinguished by each partner evidence interesting differences as shown in figure 13. In fact, all partners identified as university, chamber of commerce, innovative start-ups, competitors, no profit organizations, and tecnopolis are entirely located within the same region of the firm with which they collaborate. The geographical distribution is evenly divided in regional and extra regional dimensions for technology providers, competence center and digital innovation hub, while the extra regional dimension dominates in the case of machinery providers (65%) and raw material (RM) providers (80%). The presence of foreign partners is identified in three categories that are machinery providers (11%), technology providers (3%), and clients (53%). The foreign location of partners is prevalent in a single category of partner that is client in which the remaining geographical distribution is divided into regional (27%) and extra regional (20%).

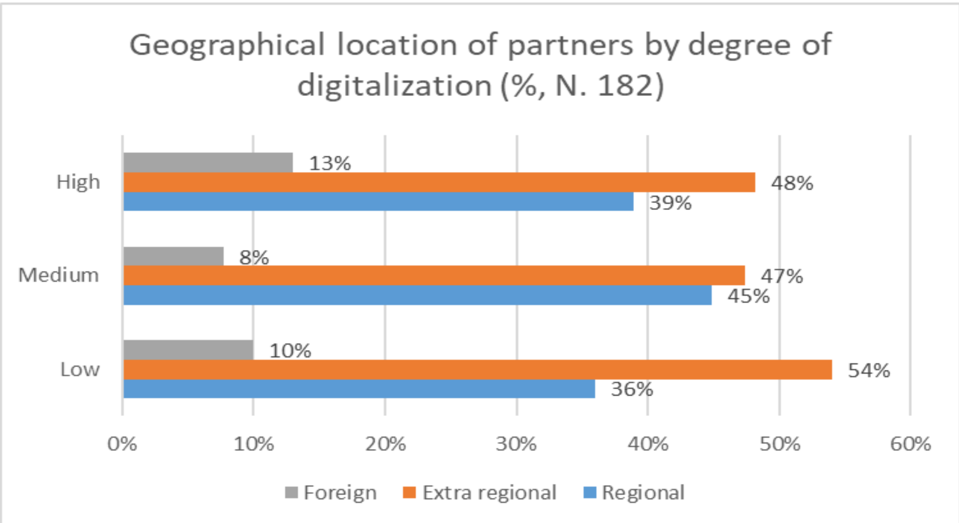
Figure 13. Geographical distribution of each partner.



Source: Personal elaboration.

The choice of partners is influenced by firm's digital maturity (figure 14) leading to interesting results in terms of geographical location differentiated by the degree of digitalization as shown in figure 18. The presence of extra regional partners is prevalent in all levels of maturity, in which for firms characterized by low level of digitalization contribute for 54%. The foreign partners collaborate mainly with highly digitalized firms (13%). Interestingly, firms in the medium level of digitalization collaborate almost evenly with extra regional and regional partners.

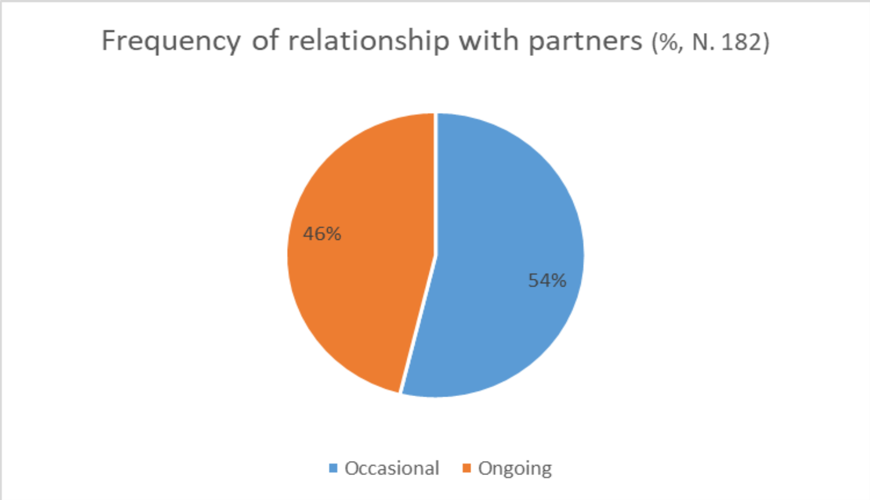
Figure 14. Geographical location by degree of digitalization.



Source: Personal elaboration.

The frequency of interactions between partner and firm is a crucial dimension to capture the value of the relationship. The frequency of interactions is defined into two levels that are occasional and ongoing. The frequency is evenly distributed between the two levels among all the firms as shown in figure 15.

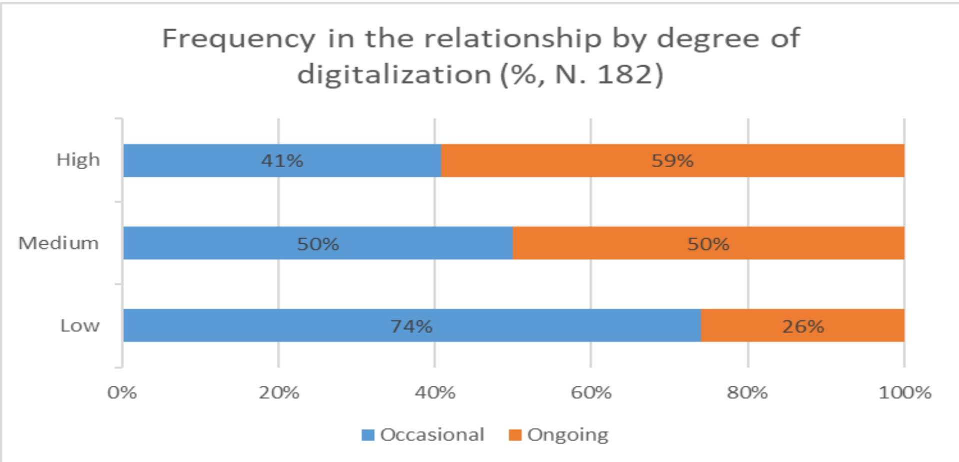
Figure 15. Frequency of relationship with partners.



Source: Personal elaboration.

The frequency of the relationship is influenced by the degree of digitalization of the firm as shown in figure 16. In fact, firms characterized by low levels of digitalization interact with partners mainly occasionally (74%) rather than on a continuous base (26%), while the opposite behaviour is shown by high digitalized firms which mainly interact on a continuous base (59%) rather than occasionally (41%). Finally, the medium digitalized firms tend to evenly split the frequency. These results are useful to understand the possible changes in the frequency of relationships linked to improvement of adoption of 4.0 technologies.

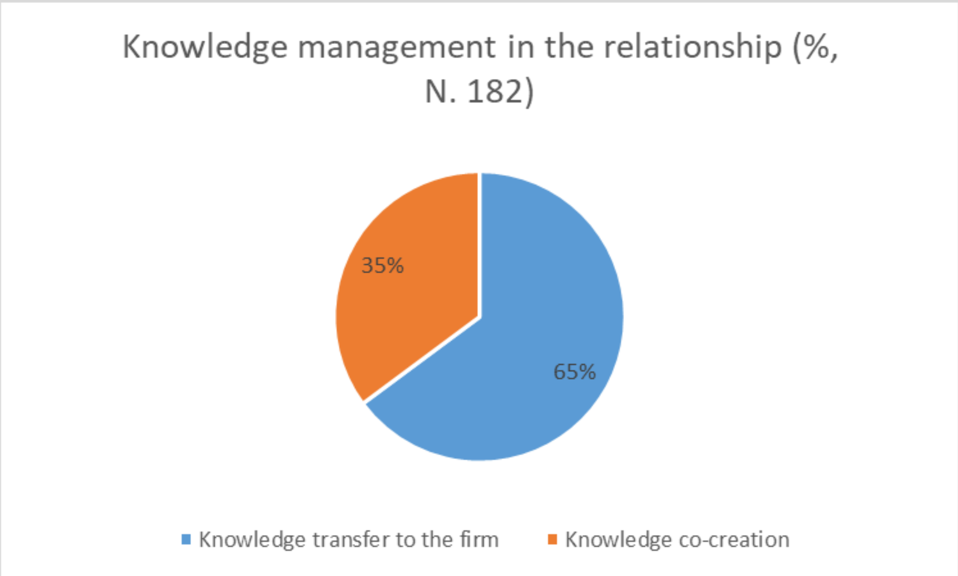
Figure 16. Frequency by degree of digitalization.



Source: Personal elaboration.

In the fourth industrial revolution, firms need to acquire and develop new knowledge to improve their competitiveness. The knowledge management strategies within the relationship with partners are identified as two main strategies that are, firstly, knowledge transfer from the partner to the firm and, secondly, knowledge co-creation. The first strategy allows quick access to new knowledge for the firm through its transfer between actors, in which it is already existing for the partner while, the latter implies the strong involvement of both sides influencing the horizon of the relationship due to the higher complexity of activities. In fact, firms majorly adopt the first strategy (65%) compared to the latter (35%) as shown in figure 17.

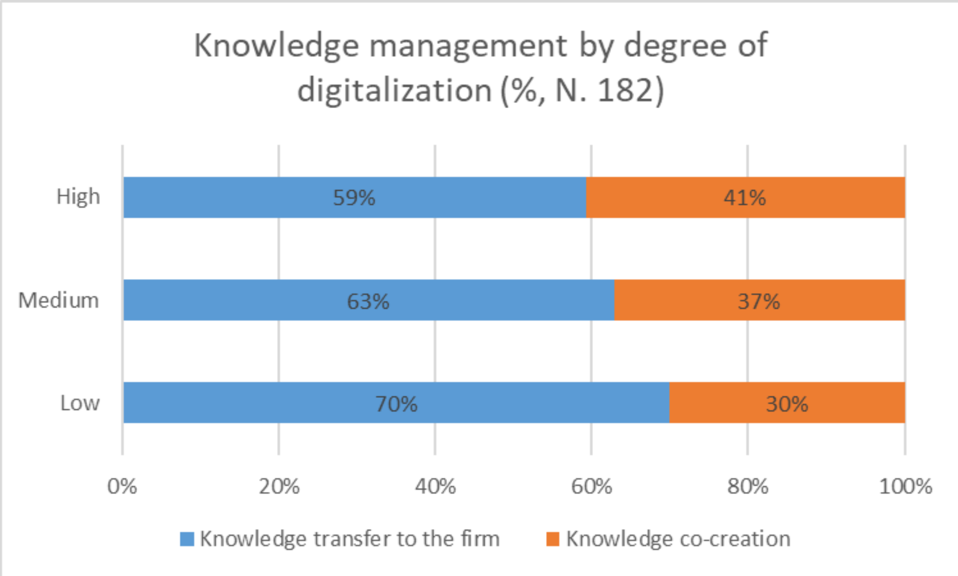
Figure 17. Knowledge management strategies.



Source: Personal elaboration.

The knowledge management strategies adopted by firms are distributed quite similarly among the different level of digitalization. In fact, the high level of digitalized firms adopts mainly the knowledge transfer strategy (59%) compared to the knowledge cocreation strategy (41%), the medium level adopts mainly the first strategy (63%) compared to the second one (37%), and, finally, the low maturity firms highlights the uneven distribution between the first strategy (70%) and the second strategy (30%) as shown in figure 18. The relationship between the digital maturity and the complexity of knowledge management strategies adopted shows a positive behaviour in which the higher level of digital maturity is related to higher level of adoption of knowledge cocreation strategy.

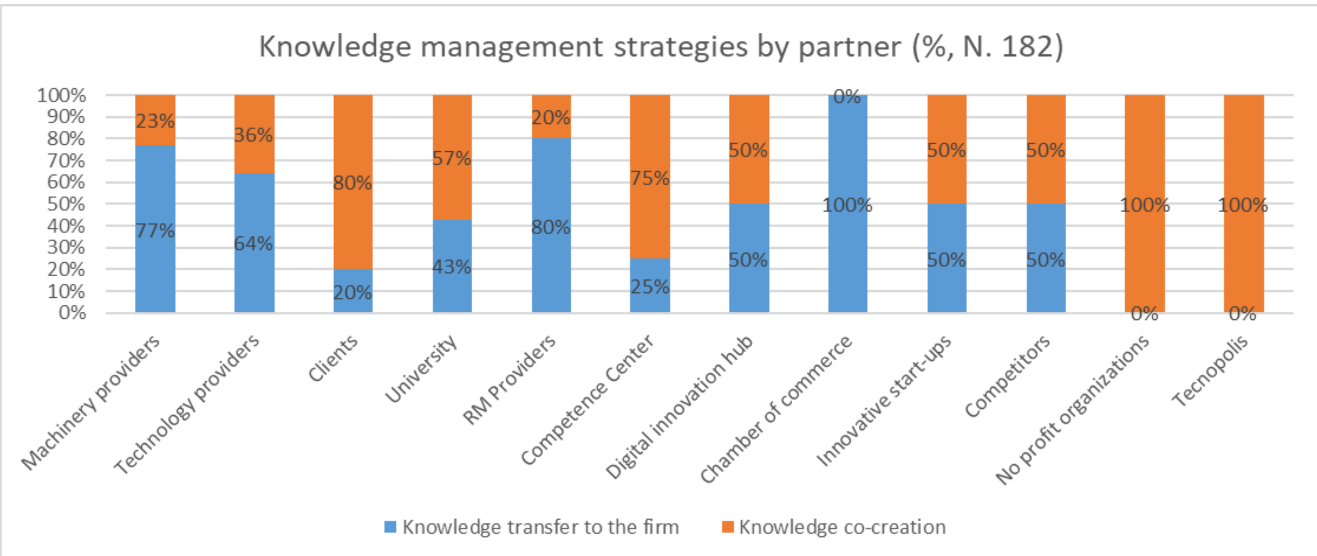
Figure 18. Knowledge management by degree of digitalization.



Source: Personal elaboration.

The adoption of knowledge management strategies is related to the partner involved in the relationship with the firm as shown in figure 19. The strategies adopted in relationship with machine, technology and raw materials providers show similar distribution to the overall population, in which the knowledge transfer (65%) prevails over the knowledge cocreation (35%). A balanced distribution between the two strategies is highlighted in relations to university, digital innovation hub, innovative start-ups, and competitors. Finally, the knowledge cocreation strategy prevails in relation to clients (80%), competence centers (75%), no profit organizations (100%), and tecnopolis (100%).

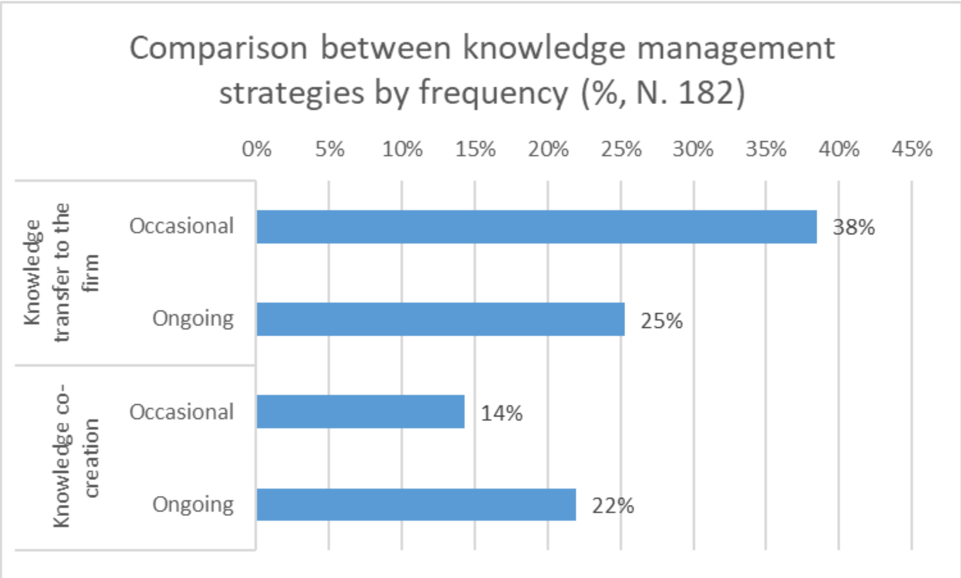
Figure 19. Knowledge management by partner.



Source: Personal elaboration.

The frequency of relationship is fundamental to enable the firm's knowledge management strategy as shown in figure 20. The two knowledge management strategies lead to different levels of risks, investments in the relationship, commitment, and trust between partners. For these factors, the adoption of the knowledge management strategy is strongly related to the frequency of interactions with partners. In fact, the occasional level of interaction between players is related mainly to the knowledge transfer strategy from the partner toward the firm (38%) rather than knowledge cocreation strategy (14%). The ongoing level is related evenly to both strategies, meaning that the knowledge cocreation strategy (22%) requires a well-structured relationship rather than the knowledge transfer strategy.

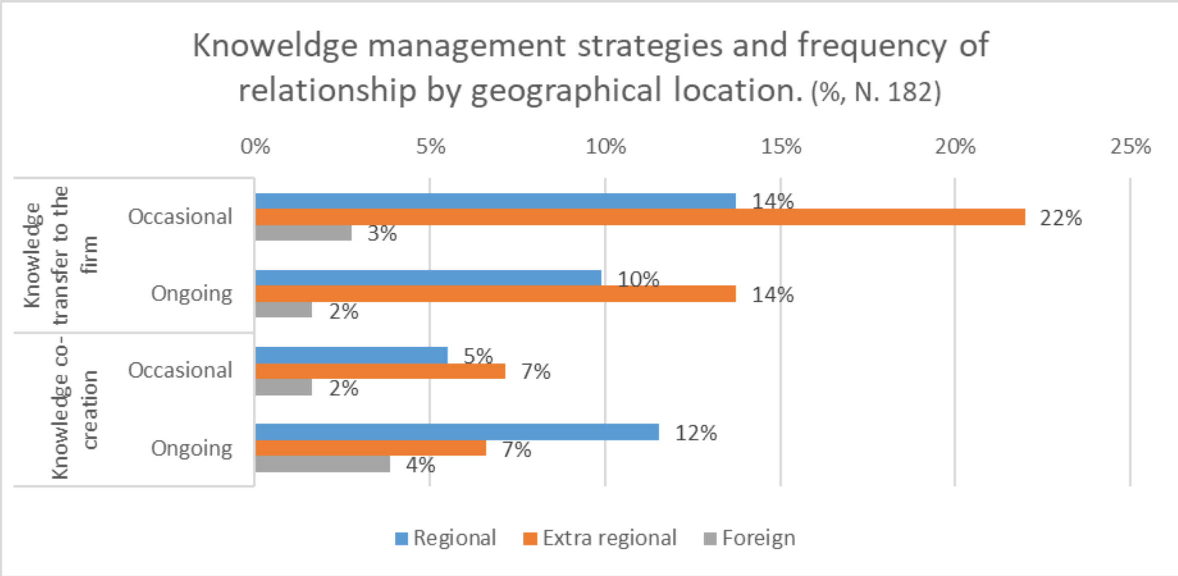
Figure 20. Frequency by knowledge management by partner.



Source: Personal elaboration.

The geographical proximity of partners is a driver for the creation and development of relationships between partners and firms, favouring the exchange and creation of knowledge. Figure 21 shows the relationship between the geographical location, the knowledge management strategies adopted by firms and the frequency of interactions with partners. The knowledge transfer strategy involves primarily partners that are in other Italian regions with occasional interactions (22%), followed by partners located in the same region (14%) and partners in other Italian regions in which the relationships is continuous (14%). The knowledge cocreation strategy is characterized by the prevalence of partners located in the same Italian region with an ongoing relationship (12%), followed by partners of other Italian regions characterized by occasional (7%) and ongoing (7%) relationships.

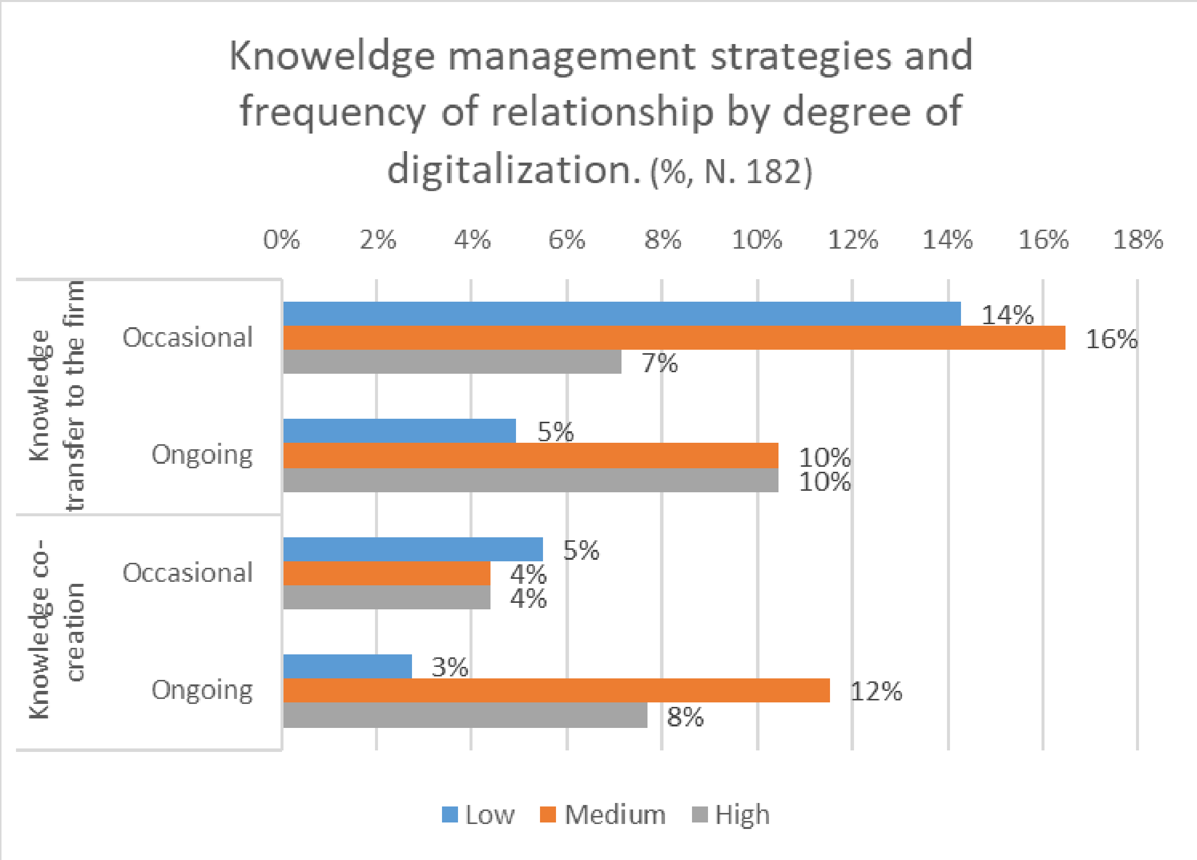
Figure 21. Knowledge management strategies and frequency by geographical location.



Source: Personal elaboration.

The relation between the knowledge management strategies and frequency of the relationship by degree of digitalization of firms is shown in figure 22. Low digitalized firms tend to build relationships with partners characterized by occasional interactions, focusing on the knowledge transfer from the partner to the firm (14%) with respect to the creation of relationships characterized by continuous interactions (5%). The knowledge cocreation strategy is the least preferred by low digitalized firms, in which, the relationship with partners characterized by continuous interactions is only 3% for the total. Medium digitalized firms create primarily partnerships characterized by low frequency of interactions pursuing the strategy of knowledge transfer to the firm (16%), followed the choice of knowledge cocreation strategy supported by the relationship characterized by continuous interactions (12%) and, finally, the knowledge transfer to the firm strategy supported by high intensity relationships (10%). Firms presenting high degree of digitalization focused primarily on the relationship characterized by continuous interactions with partners in which the knowledge management strategy preferred is firstly knowledge transfer to the firm (10%) and secondly knowledge cocreation strategy (8%).

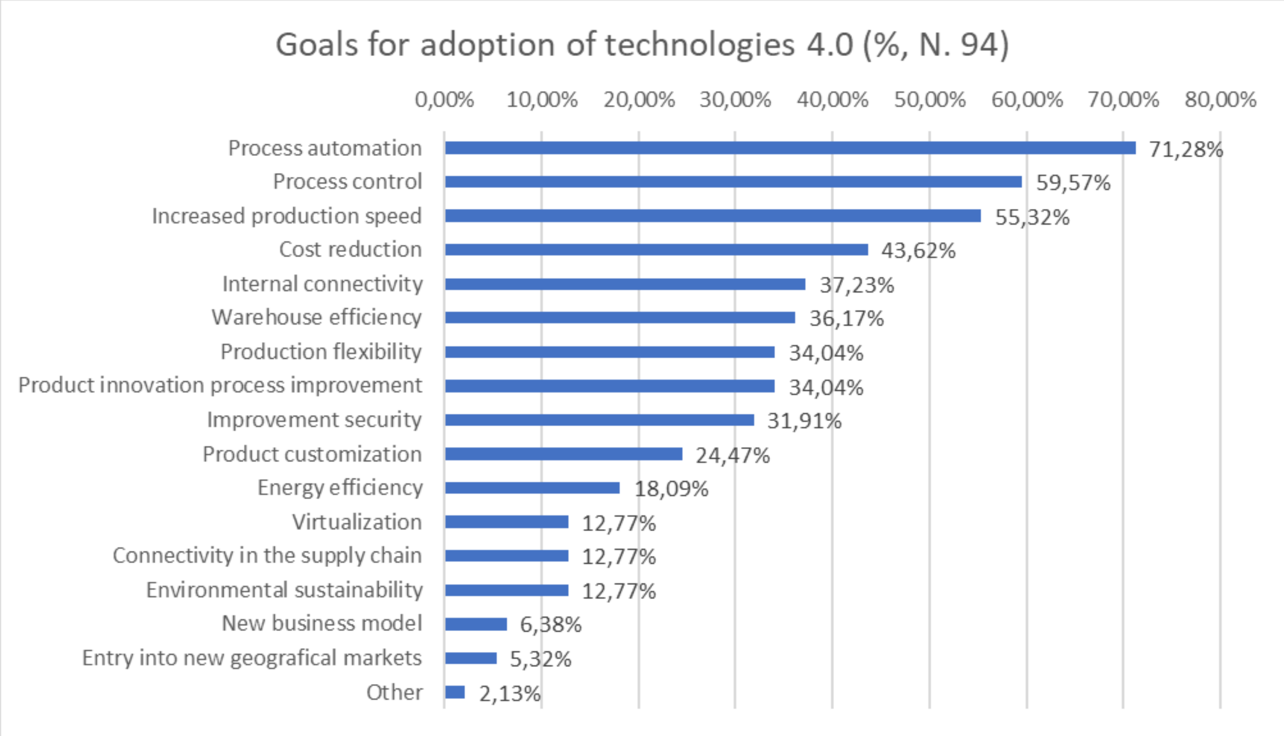
Figure 22. Knowledge management strategies and frequency by degree of digitalization.



Source: Personal elaboration.

The digitalization process allows firms to improve their competitiveness leading to improve and achieving new objectives. Firms can achieve more objectives due to the adoption of industry 4.0 technologies leading to identification of the total number of goals achieved up to 468. Figure 23 shows that main goals achieved by the population of firms that adopted 4.0 technologies (N. 94) are process automation (71,28%), process control (59,57%), increased production speed (55,32%) and cost reduction (43,62%). These results shows that firms increase the internal efficiency focusing majorly on the production process.

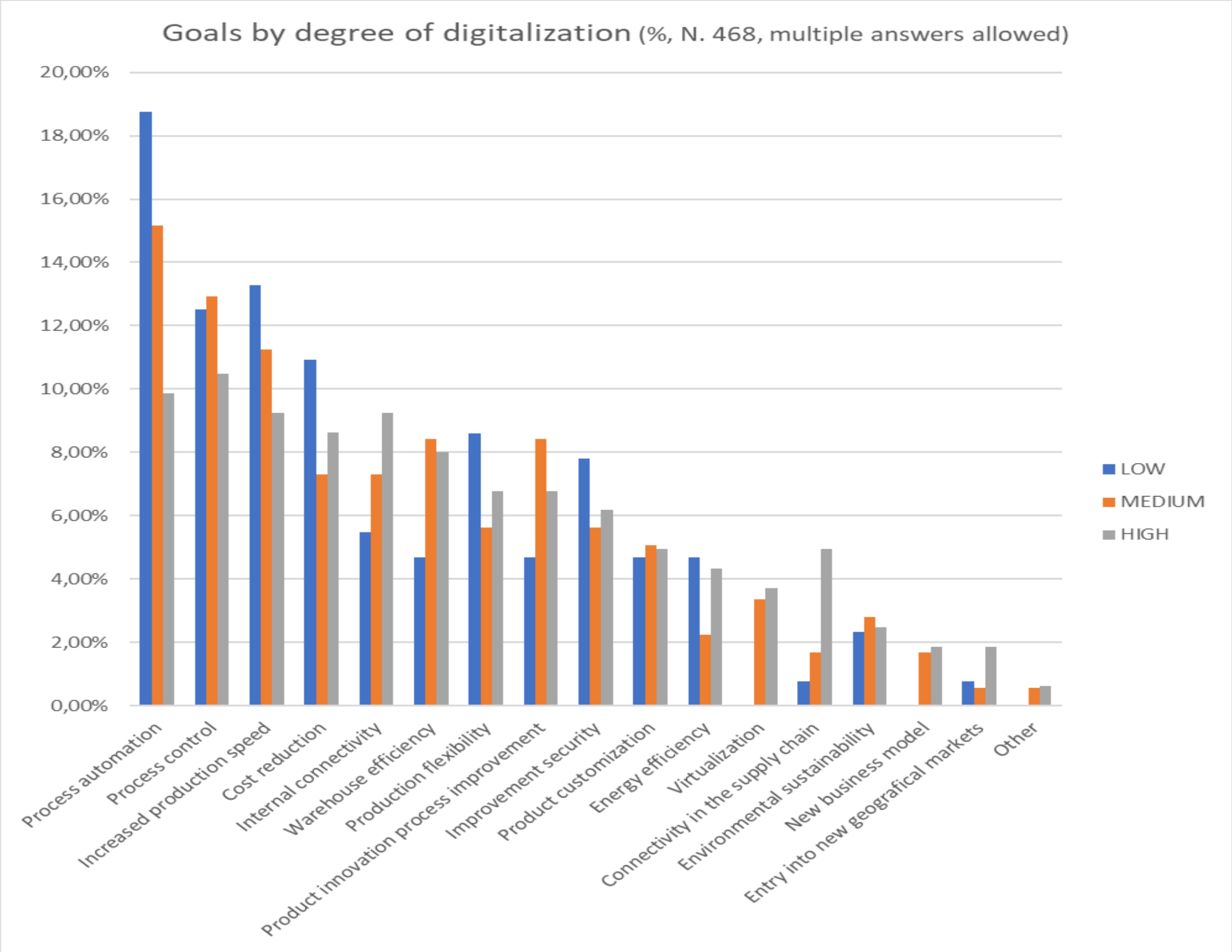
Figure 23. Goals achieved by firms 4.0.



Source: Personal elaboration.

The relationship between the degree of digitalization and goals achieved highlight interesting differences as shown in figure 24. In fact, firms at low level of digital maturity focused on the internal efficiency achieving primarily goal as process automation, process control, increased production speed, and cost reduction, followed by product flexibility and improvement of security. Firms at medium level of digital maturity improve majorly process automation, process control, and increased production speed and secondly, the warehouse efficiency and the improvement of product innovation process, leading to higher diversity of goals. Finally, firms at high level of digital maturity achieved a high variety of goals leading to a great diversification of benefits rather than focusing on a small set compared to the low and medium level of digital maturity.

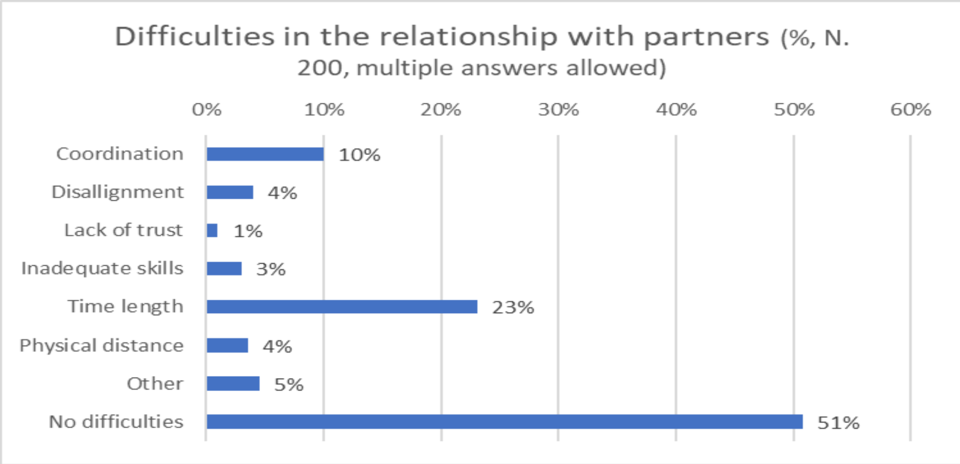
Figure 24. Goals achieved by degree of digitalization.



Source: Personal elaboration.

The relationship with partners allows firms to improve the competitiveness through the acquisition and creation of new knowledge which enhance the possibilities to release the full potential of the adoption of 4.0 technologies achieving several objectives, even if, difficulties within the relationship can arise as shown in figure 25. Firms can encounter more than a single difficulty within the relationship leading to a total of 200 multiple answers collected. Firms, in the majority of cases (51%), don't have any kind of difficulties through the relationships with partners, while the remaining 49% of firms present at least one difficulty arisen within the relationship. The main difficulties identified are the time length (23%) and coordination (10%) for firms that encounter at least one difficulty (49%).

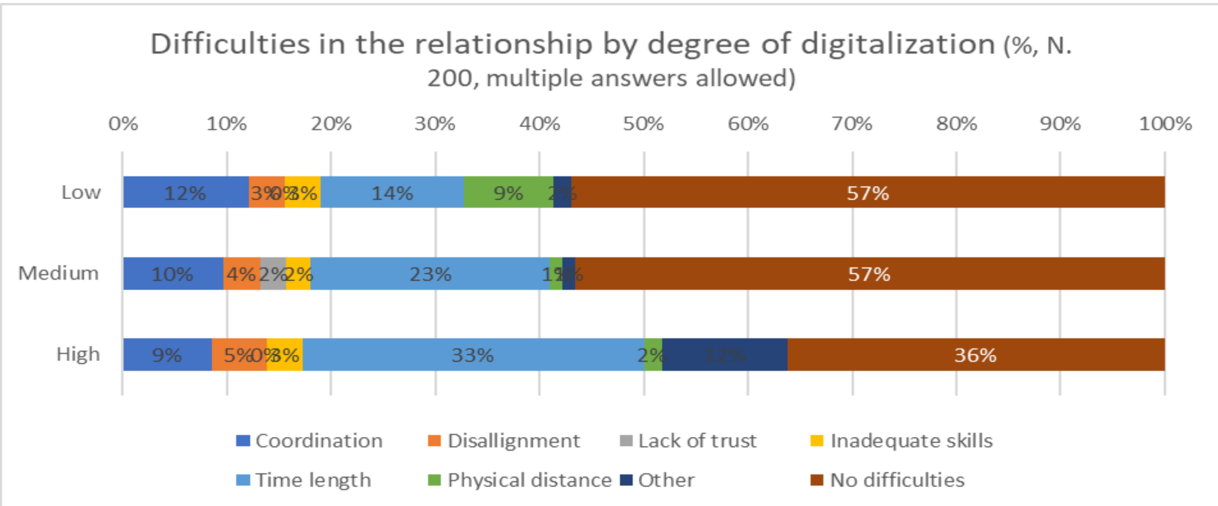
Figure 25. Difficulties with partners.



Source: Personal elaboration.

The analysis of difficulties based on the degree of digitalization highlights interesting peculiarities as shown in figure 26. In fact, firms at low level of digital maturity don't present any arisen issues in the majority of cases (57%). The main difficulties encountered by low level of digitalization are the time length (14%), coordination (12%) and other (9%). Firms at medium level of digital maturity don't present any arisen issues in the majority of cases (57%), as well as the low-level firms. The main difficulties encountered by low level of digitalization are the time length (23%) and coordination (10%). Finally, firms at high level of digital maturity encounters more difficulties with respect to the low and medium level in which only the 36% of them don't present any issue within the relationship while the remaining 64% present at least one. The main difficulties encountered by firm of high level of digitalization are the time length (33%), coordination (9%) and other (12%).

Figure 26. Difficulties with partners by degree of digitalization.



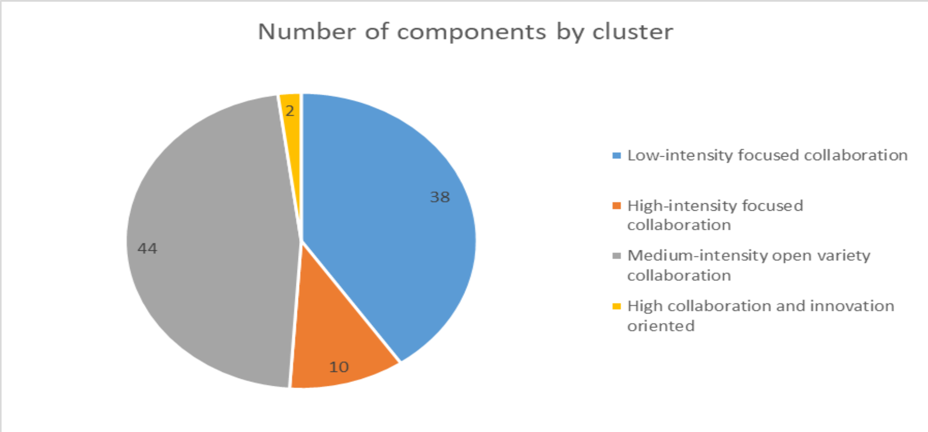
Source: Personal elaboration.

5.2 DETERMINATION AND DESCRIPTION OF CLUSTERS.

Firms that respond to the survey shows interesting insights on the technological, geographical, and social dimensions. These insights are further analysed through the methodology of determination of clusters, based on the hierarchical cluster technique, specifying the complete linkage among clusters. The process for the determination of these clusters passes through the creation of a new database containing the subset of observations referring to industry 4.0 adopters and including several variables for the determination of the technology profile. The variables used for the determination of clusters involve 108 variables which refer to the partners of relationships with firms (12 variables), the content of the relationship (technology, training services, consulting services, innovative projects and financial access) distinguished for each partner (72 variables in total), the knowledge management strategies (knowledge transfer from the partner to the firm or knowledge cocreation) adopted by firms within the relationship distinguished for each partner (12 variables), and the frequency (occasional or continuous) characterizing the relationship distinguished for each partner (12 variables). The data analysis based on this new databased was done using the RStudio[28] statistical software for the application of the cluster technique. The results of the application of the cluster technique based on the technology profile for 4.0 firms (N. 94) lead to the identification of four clusters as shown in figure 27. The results show that the composition of clusters is unbalance in which two clusters have the majority of firms while the remaining two have the minority. In fact, the low-intensity focused collaboration is the cluster composed by the highest number of firms that are 44 (47% of 4.0 firms), followed by medium-intensity open variety collaboration including 38 firms (40% of 4.0 firms), while high-intensity focused collaboration is composed by 10 firms (11%) and, finally, high collaboration and innovation oriented is composed by only 2 firms (2%).

[28] https://posit.co/

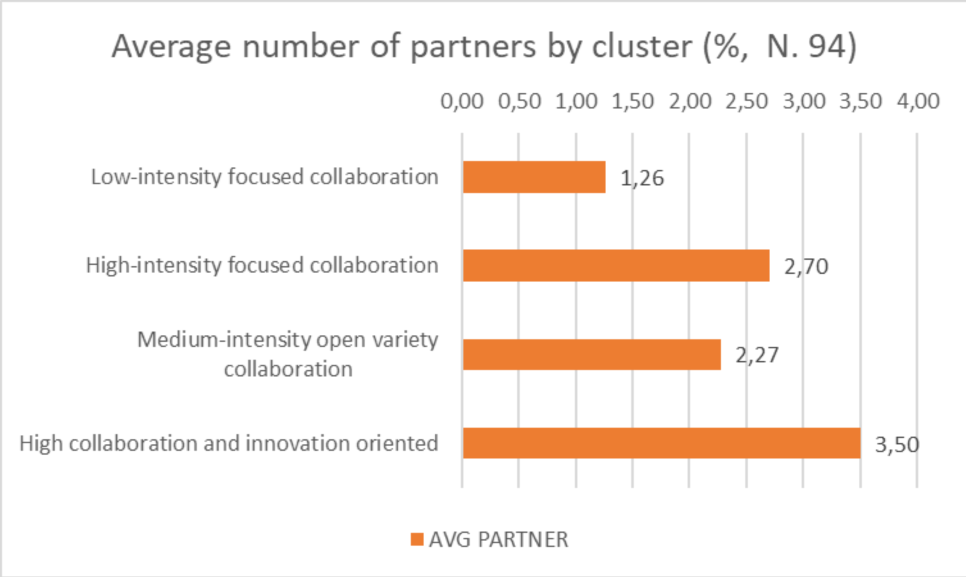
Figure 27. Number of components by cluster.



Source: Personal elaboration.

The collaboration strategy adopted is different among clusters. The number of partners and their identification allow to understand the degree of the collaboration openness and intensity characterising each cluster. In fact, low-intensity focused collaboration is the most populous cluster (44 firms), even if, the number of partners with which firms collaborate is 48, leading to the lowest average of 1,26 partners per firm as shown in figure 28. The low-intensity focused collaboration is the only cluster with the average number of partners below the whole population of 4.0 firms (1,96), while high-intensity focused collaboration, medium-intensity open variety collaboration, and high collaboration and innovation oriented are above it. Medium-intensity open variety collaboration is the second most populous cluster composed by 38 firms in which it is characterized by the collaboration with 100 partners leading to the average of 2,27 partners per firm. High-intensity focused collaboration is composed by 10 firms, and it is characterized by the collaboration with 27 partners leading to the average of 2,70 partners per firm. Finally, high collaboration and innovation oriented is composed by only 2 firms but it is the most collaborative cluster with 7 number of partners determining the average of 3,5 partners per firm.

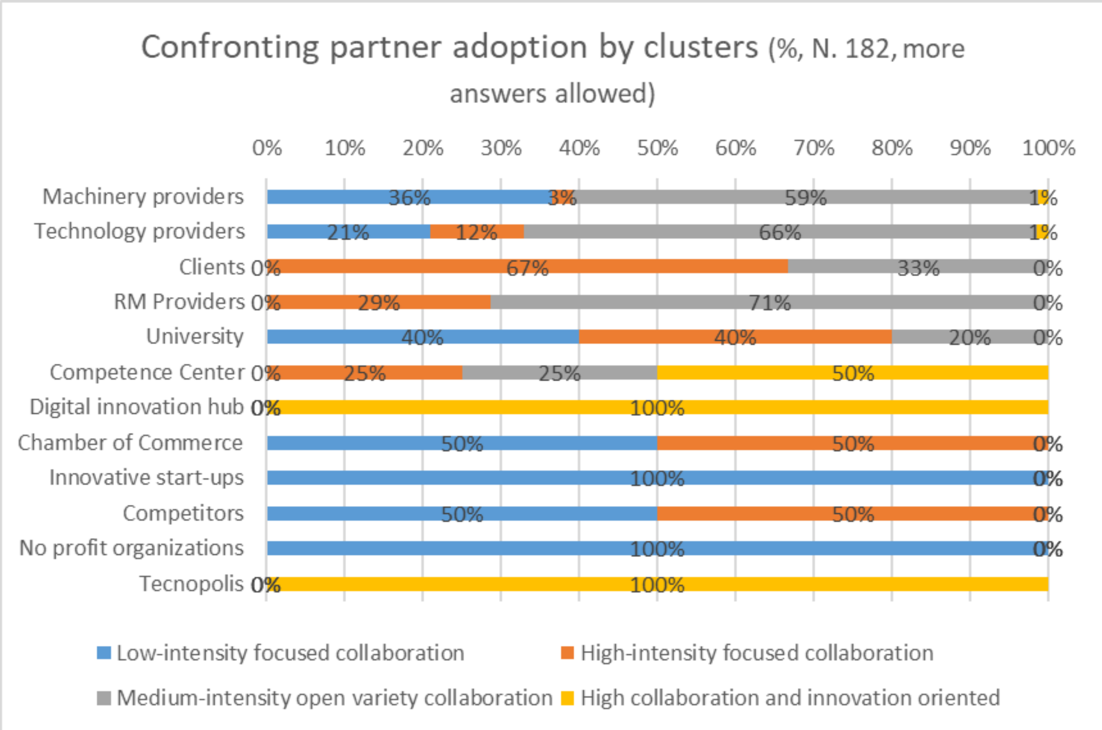
Figure 28. Average number of partners by cluster.



Source: Personal elaboration.

The identification of partners in the set of collaborations for each cluster leads to the identification of interesting characteristics as shown in figure 29. The collaboration set of low-intensity focused collaboration cluster is narrowed and focused on few partners that are primarily machinery providers and secondly, technology providers. High-intensity focused collaboration is mainly focused on the collaboration with clients and technology providers, followed by raw materials providers and universities. Medium-intensity open variety collaboration shows a high degree of collaboration with the major partners that are mainly machinery providers and technology providers, followed by raw materials providers, clients, universities, and competence centres. Finally, high collaboration and innovation oriented is the most collaborative cluster with an average of 3,5 partners per firm, collaborate mostly with competence centers, digital innovation hubs, machinery providers, technology providers and tecnopolis. The set of partners enhance the comprehension of the role of played by the supply chain and ecosystem in the collaboration strategy. Low-intensity focused collaboration and high-intensity focused collaboration are focused on the collaboration mainly with supply chain's actors that are respectively machinery provider and clients. Medium-intensity open variety collaboration shows the highest degree of openness to collaboration identifying mostly supply chain's actors, even if, there is the presence of key ecosystem's actors as universities and competence centers. Finally, high collaboration and innovation oriented is the most collaborative cluster in which the collaboration is structured mostly with ecosystem's actors.

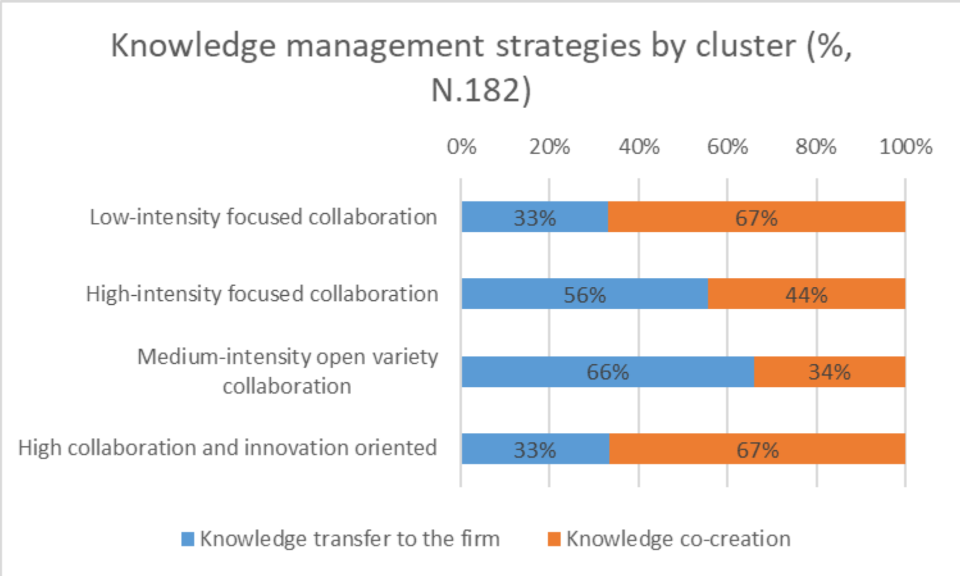
Figure 29. Confronting partner by cluster.



Source: Personal elaboration.

The knowledge management strategy applied by clusters is fundamental to understand the differences of collaboration patterns. Low-intensity focused collaboration and medium-intensity open variety collaboration clusters are characterized by similar application of knowledge management strategies in which dominates the knowledge transfer from the partner to the firm, respectively 69% and 66%, compared to knowledge cocreation strategy that is respectively 31% and 33% as shown in figure 30. High-intensity focused collaboration shows a more balanced choice of strategies compared to the other clusters, in which the knowledge transfer to the firm is 56% and the knowledge cocreation is 44%. Finally, high collaboration and innovation oriented is characterized by the dominance of the knowledge cocreation strategy (71%) with respect to knowledge transfer to the firm (29%),

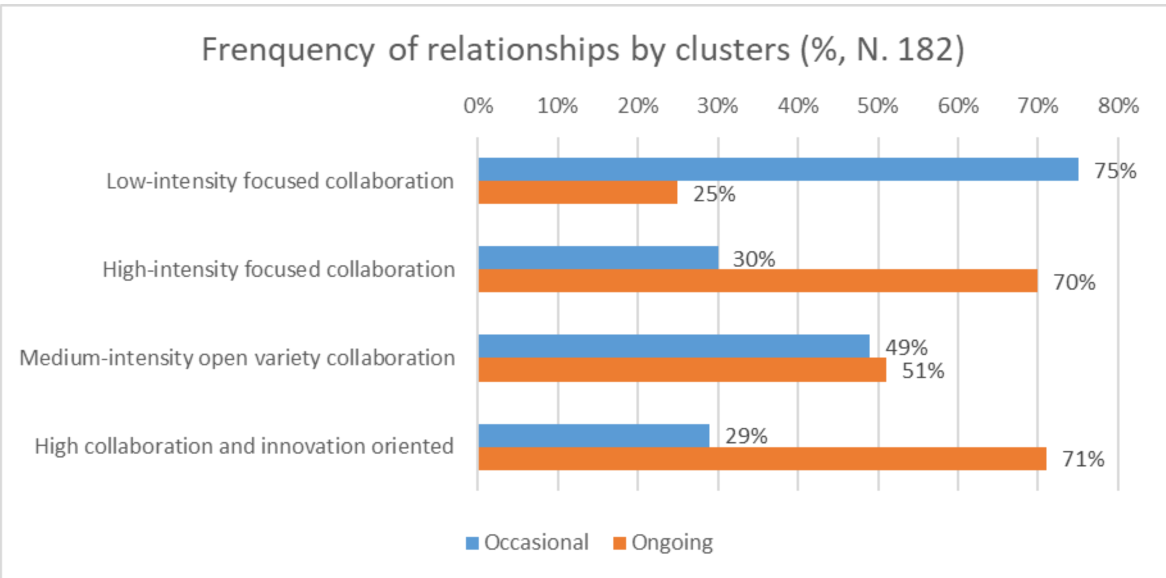
Figure 30. Knowledge management strategies by clusters.



Source: Personal elaboration.

The frequency of interactions is fundamental to understand the complexity and the strength of relationships for each cluster as shown in figure 31. In fact, the 75% of relationships within the low-intensity focused collaboration are characterized by occasional frequency, while only the 25% are continuous. Medium-intensity open variety collaboration presents a more balanced profile with respect to the other clusters, in which the frequency is almost fairly divided into occasional and ongoing. Instead, high-intensity focused collaboration and high collaboration and innovation oriented present the dominance of continuous frequency (70% and 71%) compared to the occasional (30% and 29%).

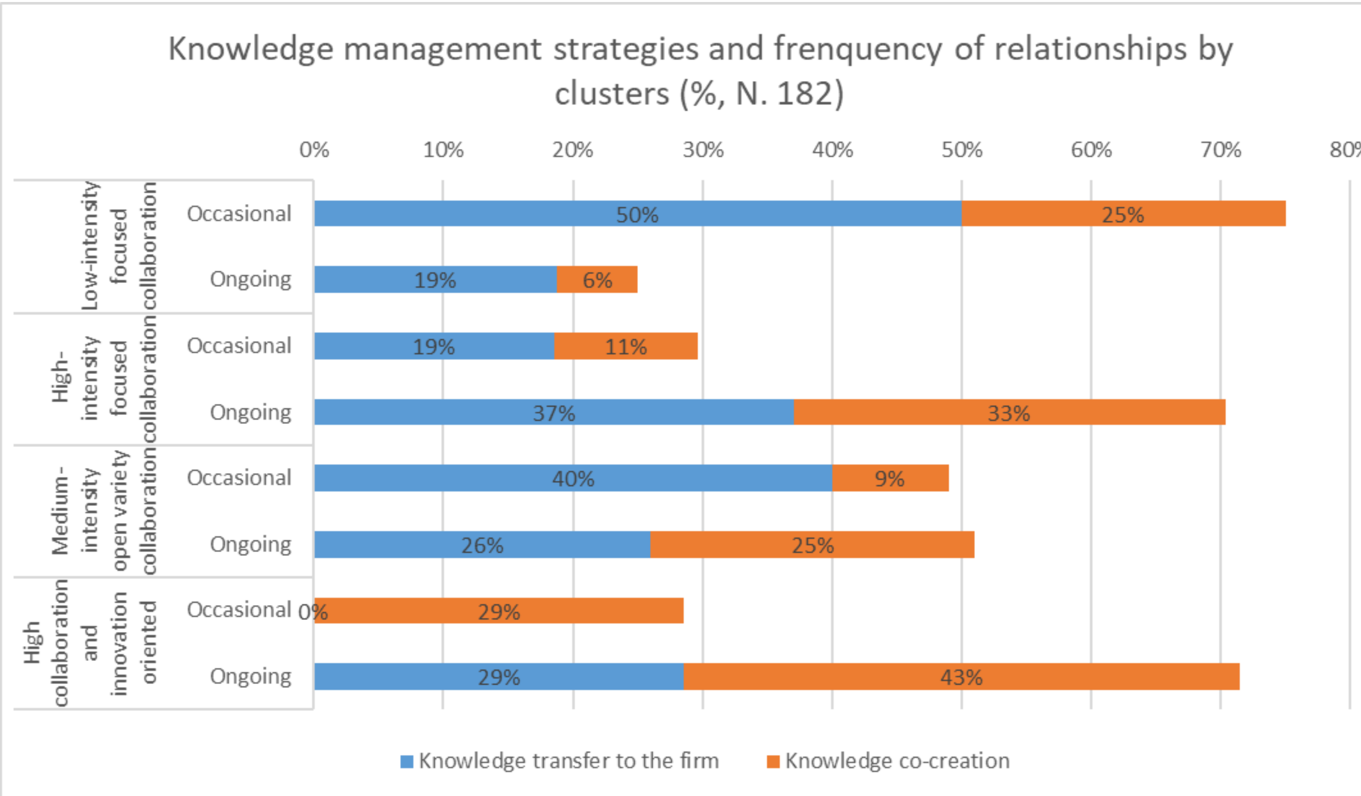
Figure 31. Frequency of relationship by clusters.



Source: Personal elaboration.

The cross analysis between the knowledge management strategy and the frequency of relationships differentiated among clusters is shown in figure 32. Low-intensity focused collaboration is strongly focused on the knowledge transfer strategy in all relationships where it prevails over the knowledge cocreation on both frequency type, occasional (50%) and ongoing (19%). High-intensity focused collaboration present a well-balanced knowledge management strategy adoption for both frequency type. Medium-intensity open variety collaboration is interesting due to the prevails of knowledge transfer strategy in relation to occasional frequency (40%), while the two knowledge management strategies are balanced in relation to ongoing frequency, leading to major adoption of knowledge cocreation in ongoing rather than occasional relationships. Finally, high collaboration and innovation oriented is strongly characterised by the adoption of knowledge cocreation strategy over the majority of relationships, in which occasional frequency relationships are entirely covered by the cocreation strategy while the knowledge transfer is dedicated only 29% of the ongoing relationships.

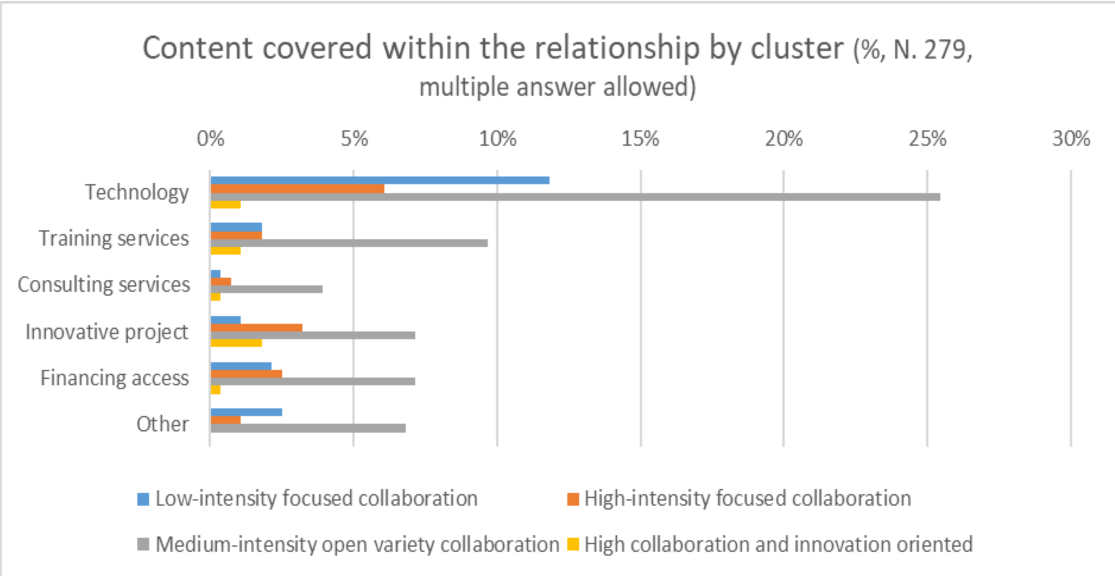
Figure 32. Knowledge management strategies and frequency of relationship by clusters.



Source: Personal elaboration.

The analysis of the content of the relationship is necessary for the comprehension of differences among clusters as shown in figure 33. Firms can have more contents covered within their set of partnerships leading to the identification of the total number of contents up to 279. The results show that low-intensity focused collaboration is strongly focused over the technological content (12%) within the partnerships, while medium-intensity open variety collaboration presents the highest coverage of contents in all categories leading to the identification of the strong diversification strategy. The content of relationships of high-intensity focused collaboration is primarily focused on the technology and secondly followed by innovative projects and financial access. Finally, high collaboration and innovation oriented is focused on the innovative projects, training services, and consulting services, determining a strong differentiation toward the other clusters.

Figure 33. Content covered within the relationship by clusters.



Source: Personal elaboration.

The process of cluster's determination is based on the technological profile leading to the identification of four clusters. These clusters present differences on social and geographical dimension requiring further analysis to enhance the comprehension of their specific characteristics.

The size of firms composing each cluster is shown in table 1. The results show that low-intensity focused collaboration is primarily composed by small sized firms (n. 20) counting for 53% of the entire cluster, followed by medium and large firms (n. 14) counting for 37%. The composition of high-intensity focused collaboration is relatively balanced with a prevalence of medium and large firms (n. 5) determining the 50% of its population. Medium-intensity open variety collaboration is almost evenly divided between small and medium-large firms counting for 52% and 45% of its population. Finally, high collaboration and innovation oriented is composed by two firms, one micro and one medium-large firm. The highest concentration of micro firms is present in low-intensity focused collaboration (n. 4) determining the allocation of 50% of them, while the distribution of medium-large firms is primarily in medium-intensity open variety collaboration and low-intensity focused collaboration counting for 40% and 28% respectively.

Table 1. Size of firms by clusters.

Size	Low-intensity focused collaboration	High-intensity focused collaboration	Medium-intensity open variety collaboration	High collaboration and innovation oriented
Micro	4	2	1	1
Small	20	3	23	0
Medium-large	14	5	20	1
Total	**38**	**10**	**44**	**2**

Source: Personal elaboration.

The distribution of the digital maturity of firms composing clusters is shown in table 2. Low-intensity focused collaboration is primarily composed by low digitalized firms (n. 20) that weight for the 53% of cluster's composition, and medium degree of digitalization (n. 13) counting for 34%. High-intensity focused collaboration is composed prevalently by medium digitalized firms (n. 6) which represents the 60% of cluster's population. Medium-intensity open variety collaboration is composed primarily of medium digitalized firms (n. 20) counting for 45% of its population and, secondly, it is composed by high degree of digitalization (n. 14) which weight 32%. The composition of high collaboration and innovation oriented is evenly distributed between the medium and high degree of digitalization. Interestingly, the low digitalized firms are majorly present in low-intensity focused collaboration (63%) and, secondly, in medium-intensity open variety collaboration (31%). The distribution of medium digitalized firms is prevalent in medium-intensity open variety collaboration (50%), secondly, in low-intensity focused collaboration (33%) and with a discrete presence in high-intensity focused collaboration (15%). Finally, firms that present high degree of digitalization are concentrated in medium-intensity open variety collaboration counting for 64% of them.

Table 2. Degree of digitalization of firms by clusters.

Degree Of Digitalization	Low-intensity focused collaboration	High-intensity focused collaboration	Medium-intensity open variety collaboration	High collaboration and innovation oriented	**TOT**
Low	20	2	10	0	32
Medium	13	6	20	1	40
High	5	2	14	1	22

Source: Personal elaboration.

The relationship between the degree of digitalization and size of firms composing each cluster is analyzed capturing key aspects. Low-intensity focused collaboration is majorly composed by low digitalized firms (n. 20) which are prevalently small firms (n. 11) counting for 55%, followed by medium-large firms (n. 6) that represents the 30% of them, and, similarly, the medium level of digitalization (n. 13) is majorly composed by small firms (n. 7) weighting for 54% and secondly by medium-large firms (n. 5) counting for 38% of them. High-intensity focused collaboration is primarily composed by medium digitalized firms (n. 6) which are represented by small firms (n. 3) and medium-large (n. 2) counting for 50% and 33% respectively. Medium-intensity open variety collaboration is majorly composed by medium digitalized firms (n. 20) which are prevalently small firms (n. 12) counting for 60%, followed by medium-large firms (n. 8) that represents the 40% of them, and, similarly, the high level of digitalization (n. 14) is majorly composed by medium-large firms (n. 9) weighting for 64% and secondly by small firms (n. 5) counting for 36% of them. Finally, high collaboration and innovation oriented is composed by a medium-large firm that present the medium level of digitalization and a micro firm for the high level of digitalization.

The geographical location of partners for each cluster is shown in table 3. The partner's locations of low-intensity focused collaboration are almost evenly divided into the regional dimension (n. 22) and the extra regional dimension (n. 24) counting for 46% and 50% respectively. The geographical location of partners related to high-intensity focused collaboration cluster is mainly within the regional dimension (n. 14) weighting for the 52%, followed by the foreign dimension (n. 7) counting for the 26% and lastly the extra regional dimension (n. 6) which is the 22%. Medium-intensity open variety collaboration's partners are majorly located within the extra regional dimension (n. 56) representing the 56%, followed by the regional dimension (n. 35) counting for 35%. Finally, the locations of partners related to high collaboration and innovation-oriented cluster are distributed within the regional dimension (n. 4) and extra regional dimension (n. 4) representing the 43% and 57% respectively. The regional partners are concentrated in medium-intensity open variety collaboration (47%), followed by low-intensity focused collaboration (30%) and high-intensity focused collaboration (19%), while the extra regional partners are present mainly in medium-intensity open variety collaboration (62%) and secondary in low-intensity focused collaboration (27%). Finally, the foreign partners collaborate primarily with low-intensity focused collaboration's firms (50%) and high-intensity focused collaboration's firms (39%).

Table 3. Geographical location of partners by clusters.

Geographical location of partners	Low-intensity focused collaboration	High-intensity focused collaboration	Medium-intensity open variety collaboration	High collaboration and innovation oriented	TOT
Regional	22	14	35	3	74
Extra regional	24	6	56	4	90
Foreign	2	7	9	0	18

Source: Personal elaboration.

The relationship between the degree of digitalization of firms composing each cluster and the geographical location of partners is further analysed capturing key aspects. In low-intensity focused collaboration, most partners collaborating with low digitalized firms (n. 23) are located within the regional dimension (n. 9) and extra regional dimension (n. 12), representing the 39% and 52% respectively, while partners that collaborate with medium digitalized firms (n. 20) are evenly distributed between the regional and extra regional dimensions. In high-intensity focused collaboration, most partners that collaborate with medium digitalized firms (n. 14) are located primarily within the regional dimension (n. 7) representing 50% of them, and the concentration of partners that collaborates with high digitalized firms (n. 7) is prevalent in the regional dimension (n. 5) counting for 71% of them. In medium-intensity open variety collaboration, the distribution of partner's geographical location for each level of digitalization is prevalently extra regional counting for 62% of low level, 54% of medium level and 55% of high level.

The following analyses is related to objectives achieved by each cluster. Firms in low-intensity focused collaboration achieved a total of 128 objectives determining an average number per firm (n. 38) of 3,37. Low-intensity focused collaboration's firms focused on the improvement of the production process, in terms of process automation (n. 24, 19%), process control (n. 16, 13%), increased production speed (n. 17, 13%) and cost reduction (n. 16, 13%)

that represent the 57% of achieved cluster's goals. Firms in high-intensity focused collaboration achieved a total of 61 objectives determining an average number per firm (n. 10) of 6,10. High-intensity focused collaboration's firms achieved a high variety of goals focusing on the process automation (n. 7, 11%), cost reduction (n. 6, 10%), product customization (n. 6, 10%) and the improvement of the product innovation process (n. 7, 11%) that represent the 42% of achieved cluster's goals. Firms in medium-intensity open variety collaboration achieved a total of 268 objectives determining an average number per firm (n. 44) of 6,09. Medium-intensity open variety collaboration's firms achieved the highest distribution and highest frequency of goals covering all categories. Firms concentrated on the improvement of process automation (n. 34, 13%), process control (n. 33, 12%), increased production speed (n. 31, 12%), internal connectivity (n. 24, 9%) and warehouse efficiency (n. 22, 8%) that represent the 54% of achieved cluster's goals. Firms in high collaboration and innovation oriented achieved a total of 11 objectives determining an average number per firm (n. 2) of 5,50. High collaboration and innovation oriented's firms concentrated on the improvement of process automation (n. 2, 18%) and process control (n. 2, 18%).

The difficulties encountered within the relationships with partners by each cluster is further analyzed capturing key aspects. Firms can face several difficulties within the relationship with partners, in which the collected observations count for a total of 200 answers that are distributed into 101 observations referring to not facing any difficulties and the remaining 99 to the arise of at least one difficulty. The number of difficulties faced by firms in low-intensity focused collaboration sum up to 28 observations weighting for 52% of total observations (n. 54). The prevalent difficulty encountered is referred to the time length (n. 11, 20%), followed by coordination (n. 11, 13%) and misalignment (n. 5, 9%) problems. The total number of difficulties faced by firms in high-intensity focused collaboration are 19 observations weighting for 59% of the total (n. 32). The prevalent difficulty encountered is referred to the other category (n. 6), followed by coordination (n. 4) and physical distance (n. 4) that represent the 19%, 13% and 13% respectively. The total number of difficulties faced by firms in medium-intensity open variety collaboration are 45 observations weighting for 42% of the total (n. 106) determining that is the only cluster in which the majority of firms face no difficulties (58%). The prevalent difficulty encountered is referred to the time length (n. 29) and secondly by coordination (n. 7) that represent the 27% and 7% respectively. The total number of difficulties faced by firms in high collaboration and innovation oriented are 7 observations weighting for 87% of the total (n. 8). The prevalent difficulty encountered is referred to the time length (n. 3) and secondly by coordination (n. 2) that represent the 38%

and 25% respectively. The two major issues faced by firms are time length (n. 46) and coordination (n. 20), in which time length is faced mostly by firms belonging to medium-intensity open variety collaboration (63%) and low-intensity focused collaboration (24%), while the coordination problem is faced by all clusters. Finally, the lack of trust is suffered only by firms belonging to low-intensity focused collaboration and the lack of adequate skills is faced majorly by firms in medium-intensity open variety collaboration.

The summary of characteristics for each cluster is shown in table 6. The technology profile allows us to better understand the differences between clusters in terms of relationship's intensity and complexity, the degree of openness and the nature of involved partner. The set of collaboration characterizing low-intensity focused collaboration is focused on supply chain's actors, mainly machinery providers, in which the set of partners per firm is very low compared to the other clusters and the whole population of 4.0 firms. It is characterised by the lowest intensity within the relationship with partners due to the main adoption of the knowledge transfer strategy based on low frequency of interactions and focusing only on the technology content within the partnership. The set of collaboration characterizing high-intensity focused collaboration is centred on supply chain's actors, mainly clients, in which the set of partners per firm is the second highest compared to the other clusters and it is above of the mean of the whole 4.0 firms. It is characterised by the high intensity of relationship with partners due to the adoption of balanced knowledge management strategy based on continuous frequency of interactions and focusing only on narrow set of content within the partnership that are technology and innovative projects. Medium-intensity open variety collaboration is characterized by a set of collaboration with mixed nature of actors involving both supply chain and ecosystem determining the high degree of openness to partner. It is characterised by the medium intensity within the relationship with partners due to the main adoption of the knowledge transfer strategy based on balanced frequency of interactions allowing to cover the highest variety of content within the partnership among all clusters, determining an open and complex system of relationships. Finally, the set of collaboration characterizing high collaboration and innovation oriented is focused on ecosystem's actors, mainly competence centers and digital innovation hubs, in which the set of partners per firm is the highest compared to the other clusters. It is characterised by the high intensity and innovativeness within the relationship with partners due to the main adoption of the knowledge cocreation strategy based on continuous frequency of interactions and focusing on innovative projects and training services within the partnership.

The findings related to the differences on the social and geographical dimensions of clusters resulting from the determination of technological profile are summarized in the second part of table 4. Low-intensity focused collaboration is primarily composed by small firms, which present majorly a low degree of digitalization. The performance of low-intensity focused collaboration's firms is quite low compared to the other clusters in terms of achieved goals per firm counting for an average of 3,37. The achieved goals are focused on the improvement of production process and cost reduction. The geographical location of partners is balanced within the regional and extra regional dimensions. Finally, the majority of firms faced difficulties within the relationship with partners, especially due to time length and coordination problems. High-intensity focused collaboration is primarily composed by medium-large firms, which present majorly a medium degree of digitalization. The performance of high-intensity focused collaboration's firms is the highest compared to the other clusters in terms of achieved goals per firm counting for an average of 6,1. The achieved goals are narrowed on the improvement of production automation, product customization, improvement of innovation process and cost reduction. The geographical location of partners is primarily within the regional dimension. Finally, the majority of firms faced difficulties within the relationship with partners, especially due to physical distance and coordination problems. The composition of medium-intensity open variety collaboration is balanced between small and medium-large firms, that present medium and high degree of digitalization. The performance of medium-intensity open variety collaboration's firms is the second highest compared to the other clusters in terms of achieved goals per firm counting for an average of 6,09 due to the high number of firms composing the cluster, even if, its performance is the highest in all categories in absolute value. The achieved goals present a high degree of diversification and variety covering all goals' categories with a slight concentration on the process automation, process control and increased production speed. The geographical location of partners is primarily within the extra regional dimension. Finally, firms within this cluster majorly didn't encounter problems within the relationship with partners, even if, for firms that faced problems were related to time length and coordination problems. The composition of high collaboration and innovation oriented is balanced between small and medium-large firms, that present medium and high degree of digitalization. The performance of high collaboration and innovation-oriented cluster's firms in terms of achieved goals per firm count for an average of 5,5. The achieved goals are narrowed with a slight concentration on the improvement of process automation and process control. The geographical location of partners is primarily within the extra regional dimension. Finally, firms within this cluster majorly encounter problems within the relationship with partners, especially due to time length and coordination problems.

Table 4. Summary of characteristics by clusters.

Summary of characteristics	Low-intensity focused collaboration	High-intensity focused collaboration	Medium-intensity open variety collaboration	High collaboration and innovation oriented
Average number of partner	Low: 1,26	Medium-high: 2,70	Medium: 2,27	High: 3,5
Partner	Supply chain	Supply chain	Supply chain and ecosystem	Ecosystem
Degree of openness to partners	Focused	Focused	Diversified	Diversified
Knowledge management strategies	Knowledge transfer from partner to firm	Balanced	Knowledge transfer from partner to firm	Knowledge cocreation
Frequency	Occasional	Ongoing	Balanced	Ongoing
Content of relationships	Focused: Technology	Narrow: technology, innovative projects	Diversified	Narrow: innovative projects, training services
Size of firms	Small	Medium-large	Balanced: Small/medium-large	Balanced: Micro/medium-large
Degree Of Digitalization	Low	Medium	Medium/High	Medium/High
Geographical location of partners	Balanced: Regional/Extra-regional	Regional	Extra-regional	Extra-regional
Number of objectives achieved	128	61	268	11
Average number of goals achieved	3,37	6,10	6,09	5,50
Variety of goals achieved	Focused	Narrowed	Diversified	Narrowed
Firms facing difficulties	52%	59%	42%	88%
Major difficulties	Time length, coordination	Other, physical distance, coordination	Time length, coordination	Time length, coordination

Source: Personal elaboration.

The digitalization process that firms are going through is characterized by high level of complexity, diversification, and dynamicity. The empirical analysis allows the deep understanding of factors affecting firms and their strategic decisions. The results show that the fourth industrial revolution enhance the potential benefits for firms through the adoption of digital technologies. Firms to increase their competitive advantage have to leverage on the creation and development of relationships with external actors based on their strategy leading to the involvement of partners related to the supply chain and ecosystem. The key result related to the management of partner's strategy is the development of a network characterized by relevant partners that are diversified in order to get access to crucial resources. The relationship between firm and partners have to adapt toward the firm's strategy shaping the knowledge management strategy and frequency of them. Finally, partnerships increase the potential benefits that can be captured by firms, even if, firms need to prepare themselves to face and overcome difficulties that can arise within the relationship.

6 Conclusions.

The purpose of this thesis was deepening the comprehension of the complex process of digital transformation, enhancing the understanding on firm's aspects, on the collaborative and geographical dimension, focusing on the role played by key partners. The empirical analysis focused on the Italian firms located in the north-east due to the intrinsic peculiarities related to the promotion of social relationships, application of new technologies and geographical concentration.

The research focused firstly on the digital transformation process at the firm's level, secondly, the analysis of the digitalization's impacts on the set of relationship between the firm and other actors, and, finally, the study of different types of key partners and their contributions to digitalization process. In particular, the digitalization process is not only related to the application of technologies by firms, but it also involves the deep comprehension of the digital technologies leveraging on the culture and human capital of entrepreneur, managers, and employees. The nine technological pillars of the fourth industrial revolution led to the creation of beneficial opportunities for firms to be captured. Hence, it determines the development of new business strategies to capture these benefits, through the identification, application, and integration of key digital technologies suitable for the firm, and, finally, overcoming the difficulties in this process. Firms along the digitalization process face several challenges related to the financial, knowledge and technology constraints. In this process, small size firms face higher degree of difficulties compared to large companies, especially due to lack of financial resources, human resources declined in terms of digital skills and capabilities, and risks related to the technology investments, even if, the potential benefits for SMEs are greater compared to large companies.

The second main topic discussed is related to the firm's collaboration in the industry 4.0 era. Firms, especially SMEs, encounter several difficulties and challenges within the digitalization process requiring support from external actors. These actors play a crucial role for the focal firm enhancing the internal capabilities, improving the technological adoption and the competitiveness. The geographical dimension of the partnerships is necessary to understand the evolution of collaboration, in which firms initially focus their relationships within the supply chain and, subsequently, expand their set of relationships to other partners leveraging on the geographical proximity. The physical closeness of actors and intense relationships among them lead to the arise of peculiar forms of network collaborations leading to the ecosystem approach. The exchange and creation of knowledge is supported by strong relationships among actors characterized primarily by trust, long-term horizon and alignment of interests determining the foundations for the development of social capital within the territory. The fourth industrial revolution encompass the territorial and social dimensions of relationships determining positive impacts on actor's ecosystems and territories, enhancing the competitiveness of industrial districts leading to beneficial results at the overall country level.

Finally, the third topic discussed is related to the partners involved in the relationships with firms, their characteristics, and contributions. The theoretical analysis encompasses the positive contribution of partners focusing on Knowledge intensive business services (KIBS) firms, competence centers and Digital Innovation Hubs (DIHs). The industry 4.0 era enhance the relevancy of these actors leading to their involvement in the set of relationships of firms determining their inclusion into the more complex and articulated actor's ecosystems. The potential benefits deriving from digital technologies can be captured by firms with the support of partners determining new forms of business strategies as the servitization strategy that focus on the collection of data and information, their elaboration, and the creation of services that are useful for customers. This revolution began within the technological domain, expanded to the business domain determining great benefits for the territory and ecosystem determining the enhancement of the competitiveness of the whole region leading to the territorial servitization.

The initial theoretical phase is completed with the empirical analysis performing a qualitative analysis of survey. The survey was carried out by a working group of the Intesa Sanpaolo Studies and Research Department in collaboration with the researchers of the Universities of the Northeast who constitute the SMACT 4.0 Observatory. The selection of companies for the survey is based on active behaviour in the market, on the potential adoption of industry 4.0 technologies, the location within the Northeast area of Italy, specifically in the Italian regions of Veneto, Friuli-Venezia Giulia, and Trentino-Alto Adige, belonging to agri-food, furniture and mechanical sectors. The sample size was reduced to 169 observations to assure the consistency of data. The survey was conducted from September 2021 to November 2021.

The descriptive analysis of the collected data shows that the majority of firms are characterized by mainly, medium size and, secondly, by low degree of digitalization. The high digitized firms are more collaborative with respect to the others with a higher number and variety of partners within their set of collaboration with respect to medium and low digitalized firms that have a narrowed set of relationships. The partners characterized by the highest adoption rate are machinery and technology providers and the technology is the main content covered within the relationships with partners. The geographical location of partners shows that the main location is within an Italian region different from the firm's region. This result is confirmed by the differentiation of firm's degree of digitalization. The frequency of relationship presents differences by the degree of digitalization of firm, in which, low digitalized firms tend to build relationship with low frequency of interactions, the medium level of digitalization tends to balance between the continuous and occasional frequency, while the high level of digitalization tends to build relationships characterized by continuous frequency. The knowledge strategy mainly choose by firms is related to the knowledge transfer from the partner to the firm, in which, at the high level of digitalization the knowledge cocreation strategy is still dominated by the first strategy, even if, it shows a higher adoption rate. Generally, the knowledge transfer from partner to firm strategy prevails for supply chain's actors, while the knowledge cocreation strategy prevails for ecosystem's actors. The adoption of knowledge transfer from the partner to the firms is mainly supported by relationships characterized by low frequency of interactions, while the knowledge cocreation strategy is supported by relationship with high intensity interactions. The main goals achieved by firms are related to the improvement of production process, in which, low and medium digitalized firms focused on process automation, control and increase production speed, while high digitalized firms show a higher variety. Finally, the most faced problems within the relationships are time length and coordination problems.

The data collected was deepening analysed using the hierarchical cluster methodology specifying the complete linkage between clusters. The determination of clusters was based on the technology profile. including 108 variables, determining four clusters. Each cluster presents different characteristics that allows to better understand the role of industry 4.0 technologies, the geographical dimension of partners and the role of partners. The geographical proximity is a crucial driver for the creation of strong relationships, facilitating the creation of network of actors, and the exchange of knowledge, boosting the creation of strong social capital within the territory. The empirical results show that the first two clusters, low-intensity focused collaboration and high-intensity focused collaboration, are characterized by the set of collaborations with close located partners that are primarily supply's chain partners in which the degree of openness to the variety of partners is limited. These results confirm the scientific literature in terms of the relevance of the strategic choice for suppliers and customers, along the supply's chain, to be closely located to the firm in order to gain several competitive advantages. The second two clusters, medium-intensity open variety collaboration and high collaboration and innovation oriented, are characterized by high level of collaboration with ecosystem's actors, showing high degree of openness to diversified partners which determine impacts on the geographical dimension leading to the choice of partners involving the extra regional dimension. These results show that the choice of partners is based on the contribution to the firm's strategy, in terms of content of the relationship and the access to knowledge, rather than the geographical proximity, determining that the benefits arising from the collaborations are greater than the difficulties and costs related to the geographical distance. These results confirm the scientific literature describing the benefits of collaboration with partners that are technologically advanced, highlighting their contributions and the strong frequency of collaboration in order to satisfy complex and advanced needs of digital mature firms.

It is acknowledged that the analysis of survey has some limitations, despite the empirical research methodology applied. In fact, the generalization of results of the qualitative analysis suffers of the limitations related to the collected sample of firms located in specific Italian regions. For these reasons, future investigations and analysis can better address the analysis of this complex phenomenon by enhancing the sample size, involving several regions and expanding the time horizon that could lead to new opportunities for reflections and debates in the scientific community.

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