The Case of the Mechanical Cluster of Friuli Venezia Giulia

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Abstract: The study investigates the adoption of Industry 4.0 technologies among a sample of firms from the mechanical cluster in the Italian Friuli Venezia Giulia region. Based on qualitative data relative to four SMEs and a Cluster Agency, the analysis reveals that the adoption of some Industry 4.0 technologies can drive the evolution and innovation in the cluster. The adoption of technologies follows two main directions: product innovation and process innovation, in some cases involving the entire business model. The discussion highlights the extent to which the spread of Industry 4.0 can benefit from the existence of an ecosystem supporting innovation.

1. Introduction

After the COVID-19 health crisis, digital transformation is no longer an option: the key question for companies is not «whether» to approach the transformation, but «how» to implement it (Seetharaman, 2020). Studies have highlighted a variety of potential benefits deriving from implementing Industry 4.0 (I4.0) (Ardolino *et al.*, 2018; Rüßmann *et al.*, 2015), but companies must define their own strategy to exploit its potential in their specific competitive context (Kane *et al.*, 2015; Porter, Heppelmann, 2014).

Seminal studies on I4.0 emerged in the fields of engineering and computer science (Liao *et al.*, 2017; Chiarvesio, Romanello, 2018), whereas empirical research analyzing I4.0 adoption among companies from a managerial perspective is rapidly increasing, but remains still limited (Frank *et al.*, 2019). Since 2016, Italy has launched a National program to boost digitalization and I4.0 adoption through the so-called «Piano Calenda». Then, regional administrations have created coherent policies and incentives for all-sized

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companies, following the European directives on digitalization. However, extant research has given limited attention to the adoption of I4.0 technologies by companies located in industrial districts or clusters (Bettiol *et al.*, 2020; Hervas-Oliver *et al.*, 2019; Götz, Jankowska, 2017), an interesting topic particularly in consideration of the role of ecosystems supporting technological advancements (Benitez *et al.*, 2020; Veile *et al.*, 2019).

Clusters are local systems of interconnected small and medium-sized companies (SMEs) characterized by high levels of flexibility and innovation that are mainly based on manufacturing competencies. Local agglomeration in a shared social context allows a specific model of knowledge sharing and a collaborative environment within competitive relations (Becattini, 1979; Becattini *et al.*, 2014; Porter, 1998; Capello, 2020). At first glance, clusters and digital technologies might seem antithetical concepts. In fact, technologies that can allow virtual collaboration can reduce the advantages associated with geographical proximity, by decreasing the effects of physical distance (Alcácer, Cruz-Machado, 2019). At the same time, considering that manufacturing was expected to be dramatically impacted by digitalization (Bauer *et al.*, 2016), especially cluster SMEs could exploit digital technologies to become more effective, increase quality and better interact even with distant partners (Hermann *et al.*, 2015). Despite this, some studies have pointed out that some typical characteristics of clusters can be a resource to facilitate I4.0 technologies' adoption (Götz, Jankowska, 2017, 2018). For instance, Hervas-Oliver *et al.* (2019) highlighted that industrial cluster isomorphism and the typical cooperation-competition dynamics can be elements of strength. Bettiol *et al.* (2020) confirmed that belonging to an industrial cluster affects technological innovation paths related to I4.0. In fact, they identified different adoption strategies of cluster and non-cluster firms, arguing the need for further studies that deepen digital transformation by cluster firms. This article aims to contribute to this debate, by analyzing paths of adoption of I4.0 technologies by cluster firms. More precisely, it aims to explore the relationship between the selection and adoption of I4.0 technologies and the types of innovation (i.e. product innovation, process innovation, business model innovation).

For this purpose, we collected qualitative data related to SMEs belonging to the mechanical cluster of Friuli Venezia Giulia (FVG), a region in North-eastern Italy. We developed a multiple case study by investigating five actors: four manufacturing SMEs and a service company (i.e. the local agency that promotes the development of the cluster). The analysis suggests that cluster companies selected I4.0 technologies in line with their past strategies, by following two main innovative trajectories: product and process innovations that allow firms to increase some of their traditional sources of competitive advantages (e.g. productivity, flexibility, and customization). Also, we observed that, in some cases, the adoption of I4.0 technologies drives an increase in innovation levels, pushing companies to innovate business models towards a servitization strategy. In this sense, our study contributes to the emerging literature on I4.0 adoption in manufacturing contexts (Müller *et al.*, 2018).

Another finding relates to cluster-level initiatives that supported firms in exploring I4.0 potentialities first, and then in adopting the technologies, thus sustaining the technological advancement and competitiveness of cluster firms. Our analysis showed innovative initiatives at the cluster level (e.g. web meetings, Digital Hub), besides the traditional dynamics (e.g. imitation between cluster firms), which were promoted to enhance the evolution of the cluster. Hence, the relevant coordinating role of the Cluster Agency clearly emerged, implementing actions to increase the awareness on I4.0 applications and favored the creation of a network supporting the adoption of technologies among companies. This result is aligned with other studies on this topic in the context of districts (Pagano *et al.*, 2020), contributing to the literature on innovation ecosystems as environments that can stimulate I4.0 (Benitez *et al.*, 2020). This also has implications for policymakers, as innovation ecosystems have been promoted in several national digitalization strategies, such as the US, India and Finland, whereas other countries have not focused on this aspect.

The paper is organized as follows: the next paragraph presents the theoretical background and the following paragraph describes the methodology. Then, results are organized into two different parts: the first one describing the number and types of the I4.0 technologies spread within the cluster; the second part deepening the innovation activities associated with the adoption of I4.0 technologies. Finally, discussion and conclusions are presented.

2. Theoretical background

Industrial clusters as a model of organization of economic activities have strongly evolved over the last few decades, thus challenging the typical competitive advantages of manufacturing companies and forcing companies to innovate (De Marchi, Grandinetti, 2014; De Marchi *et al.*, 2018). An important stream of transformation relates to the effects of globalization on the organization of value chains. More specifically, offshoring and internationalization processes have generally transformed local production systems, questioning their capacity to survive globalization effects. In fact, the survival of many local suppliers has been challenged by the emergence of competitors from low-cost countries as a result of offshoring strategies implemented by leading firms chasing higher efficiency levels while maintaining the core focus on high value-added activities. This has, in turn, reduced the overall number of local SMEs. Also, compared to the past, it has transformed the typical innovation model characterizing clusters, sometimes reducing interactions between customers and suppliers and learning opportunities for suppliers, and lowering the relevance of the social dimension of innovation, which traditionally was at the core of this knowledge creation system (De Marchi, Grandinetti, 2014; Bettiol *et al.*, 2017).

Recent studies have shown that I4.0 technologies can positively modify the competitiveness of manufacturing cluster SMEs (Müller *et al.*, 2018), partly dispelling the idea that manufacturing must be considered as a low value-added activity compared to design, R&D, marketing and, more in general, to the activities in the downstream and upstream parts of the value chain (Mudambi, 2008; Rehnberg, Ponte, 2017).

I4.0 refers to a group of complex technologies that have the potential to lead to strong transformations of organizational structures and business functions, sometimes also with disruptive effects on industry structures and competition (Porter, Heppelmann, 2014). Internet of Things (IoT), cloud platforms, Big Data and Analytics (BDA), additive manufacturing, and advanced simulation software systems are some of the main technologies of I4.0, that can reshape the competitive strategies of manufacturing firms (Porter, Heppelmann, 2014; Vendrell-Herrero *et al.*, 2017; Govindarajan, Immelt, 2019).

Actually, it is challenging to assess the consequences of I4.0 in the context of clusters (Pagano *et al.*, 2020). For instance, technologies such as advanced automation or the interconnection of operations towards the smart factory, to give some examples, are expected to increase the efficiency of plants and production systems, enable shorter time-to-market and development cycles and allow customized production at lower costs (Bals *et al.*, 2015). This could somehow see manufacturing companies increasing their overall productivity. This could, in turn, make cluster companies competitive again compared to low-cost suppliers, benefiting from their high quality, reliability, product knowledge and sector experience. Moreover, recent studies have highlighted that some technologies, such as additive manufacturing, may have deep impacts on the localization of economic activities across regions and countries (Ben-Ner, Siemens, 2017), thus generating consequences that have so far only been partially explored and understood (Fratocchi, Di Stefano, 2020). For instance, these technologies could modify the advantages of co-location of manufacturing and innovation (Pisano, Shih, 2009, 2012; Buciuni, Finotto, 2016). Digital technologies can even reduce the advantages associated with geographical proximity, by reducing the negative impact of physical distance; in this case, the possibility to collaborate at a distance in a virtual environment can even reinforce the substitution effect of local suppliers with international ones. For some companies, offshoring can still be the best strategy to realize advantages, leading these firms to decide to increase the efficiency of offshored productions through the deployment of new technologies. However, in the upcoming years, the emerging technologies that increase productivity could open up new opportunities to backshore, which means relocating business processes, production and services that have formerly moved to an offshore location, back to the country of origin (Chiarvesio, Romanello, 2018; Bettiol *et al.*, 2019). This can represent a concrete opportunity for local cluster firms that have decided to innovate their processes in their main factories.

New technologies, such as additive manufacturing or simulation, can be drivers of new competitive advantages by allowing better and more qualified operations, not just for cost savings. Additive manufacturing, also defined as 3D printing, can complement traditional manufacturing technology by allowing the production at lower costs of small batches of customized products that can better respond to the needs of customers (Rehnberg, Ponte, 2016, 2017). Simulation tools are helpful in product development and after-sales services, as they can be used to validate new products or processes, to test products or machines' performance, to reduce costs and increase product quality (Alcácer, Cruz-Machado, 2019). As a result, companies can upgrade their manufacturing processes by investing in process innovation, to better serve the customer in terms of quality and price. Hence, this can improve the overall offering of the companies thanks to the new services in addition to traditional products. This is the case of simulation, but even IoT opens up new opportunities, such as remote maintenance, until a whole re-definition of the business model within the framework of servitization (Bortoluzzi *et al.*, 2018; Bortoluzzi *et al.*, 2020). Product and process innovation related to IoT can allow a transition from a product-based to a service-centric business model where the I4.0 potential can reshape the market.

All these opportunities to enhance manufacturing activities through I4.0 cross the traditional sources of competitiveness of clusters, making it worth deepening the dynamics underpinning the intersection between these two phenomena. Recent research has, indeed, highlighted the extent to which digital transformation can be a driver of cluster evolution (Bettiol *et al.*, 2020; Götz, Jankowska, 2018; Pagano *et al.*, 2020). Bettiol *et al.* (2020) confirmed that belonging to an industrial cluster could impact the adoption paths related to the I4.0 technologies. The authors identified different adoption strategies implemented respectively by cluster and non-cluster firms, showing that I4.0 technologies were adopted to achieve objectives that are consistent with the typical competitive advantages of cluster firms (e.g. customization and flexibility). Other studies have shown that some characteristics of clusters, such as mutual trust and close cooperation, or shared norms, can facilitate the adoption of I4.0 technologies and the related risk (Götz, Jankowska, 2017, 2018). This may be particularly valid in the case of I4.0 that includes a group of technologies, which can be applied in different functions and value chain activities, leading to different outcomes (Chiarvesio, Romanello, 2018). A collective identity and understanding that drives isomorphism in order to gain legitimacy, together with cooperation-competition dynamics can facilitate and push the adoption of I4.0 technologies (Hervas-Oliver *et al.*, 2019). For instance, the adoption of a technology by a pioneer cluster firm can be quickly imitated by other firms. Moreover, local actors operating in clusters may act as facilitators in the diffusion of knowledge and tools among companies or operate as gatekeepers introducing innovation into the cluster (Hervas-Oliver *et al.*, 2019). Apropos studies have highlighted that companies during the I4.0 adoption and implementation processes benefit from being embedded in ecosystems supporting innovation and I4.0 (Veile *et al.*, 2019; Benitez *et al.*, 2020). Despite this, the adoption of I4.0 technologies by companies located in clusters is still underexplored. This paper aims to contribute to reduce this gap by adding a further understanding of the strategies that drive the adoption of I4.0 technologies by cluster firms. Specifically, this research aims to explore the relationship between the selection and adoption of one or more I4.0 technologies (i.e. IoT, augmented reality, BDA, additive manufacturing, horizontal and vertical integration, cloud, simulation, robotics, and cybersecurity) and the types of innovation (i.e. product innovation, process innovation, business model innovation).

3. Methodology

3.1. The method: multiple-case study

The study was focused on the mechanical cluster of Friuli Venezia Giulia (FVG), a region in Northeastern Italy. The FVG region is characterized by a significant manufacturing tradition, in which some industrial clusters emerge (e.g., the mechanical cluster, the wood and furniture cluster). The mechanical cluster stands out for including 3.700 companies and involving 40.000 employees, but also for the economic impact on connected industries, such as the plastic industry (Bortoluzzi *et al.*, 2018; Bortoluzzi *et al.*, 2020).

Over the last two decades, the dynamics of the cluster have considerably changed due to a variety of factors including globalization and technological advances. The 2008 financial crisis has represented a critical event in this transformation. It is interesting to see how companies reacted to this crisis (Bortoluzzi, Tracogna, 2013; Iammarino *et al.*, 2021). Some firms confirmed their past strategies, paying for their inability to change with a performance reduction and, in some cases, with business failure; other companies showed a greater ability to change, mainly thanks to a strong orientation towards innovation (Bortoluzzi *et al.*, 2018). The most innovative companies were able to redefine their competitive strategies, by focusing on specific competitive factors, related to higher product quality, wider product portfolios, stronger brands and value-added services (Bortoluzzi *et al.*, 2018).

This is a particularly interesting empirical setting for two reasons. Firstly, it has a long historical tradition as a cluster; secondly, the industry in which the cluster is specialized is receptive to technological advances in general and has traditionally been open to information and communication technologies over the decades (Chiarvesio *et al.*, 2004).

Table 1: The profile of the manufacturing firms interviewed

Company	Product	Age	Turnover 2019 (M €)	FSTS (%)	Industry diversification
Circle	Saws	40	18	80	Low
Mill	Precision mechanics	38	9	60	High
Cup	Coffee machines	90	21	50	Low
Drinks	Beverage machines and plants	32	12	40	Medium-low

Source: Authors' elaboration.

The unit of analysis is not the cluster *per se*, but cluster firms (Perren, Ram, 2004). The aim of the research is to analyze the process of adoption of I4.0 technologies among SMEs belonging to the cluster. We developed inductive qualitative research (Eisenhardt, 1989) to investigate the reasons why companies chose one or more I4.0 technologies, the expected impacts, and the role of other cluster firms/actors in the process. For this purpose, from June 2018 to December 2019, we adopted a multiple case study approach to investigate five actors: four manufacturing SMEs (Circle, Mill, Cup, Drinks) and a local service company that promotes the development of the cluster, the Cluster Agency. To select the companies, we adopted a purposive sampling technique (Campbell *et al.*, 2020). The four manufacturing companies were identified as early adopters of I4.0 in the cluster. The Cluster Agency, instead, was selected as a key leading and coordinating actor providing services to cluster firms. This allowed us to access data from different, and also contrasting, perspectives both on the adoption of I4.0 by the companies and on the I4.0-related services offered by the Agency. Table 1 describes the main activities of the sampled firms.

The four manufacturing companies are specialized in core activities of the mechanical cluster and early considered the adoption of I4.0 technologies relevant to their competitive advantage. Each company has adopted at least one of the I4.0 technologies described by Rüßmann *et al.* (2015), namely IoT, augmented reality, BDA, 3D printing, horizontal and vertical integration, cloud, simulation, robotics, and cybersecurity.

The Cluster Agency is an institutional actor that promotes innovation of cluster firms by sharing and spreading knowledge about new opportunities and technologies and involving companies in specific projects. The Cluster Agency influences the cluster dynamics as its purpose is to offer services to cluster firms in order to promote the competitiveness of the cluster. The involvement of this actor provided the opportunity to access privileged information on the cluster dynamics over the years, showing the extent to which it is also the result of the actions (and interactions) among manufacturing firms and other cluster stakeholders, such as the Cluster Agency.

Data were collected through face-to-face in-depth interviews with entrepreneurs and CEOs, which lasted between 90 and 120 minutes each and were recorded and literally transcribed. We visited the factories to see the applications of I4.0 technologies. We also analyzed press and archival data. We then interviewed the managing director of the Cluster Agency and developed focus groups with the managing director, the president and some managers to investigate the Agency approach to I4.0 initiatives. Information was collected also from archival data and data related to projects promoted within the cluster. All the interviews were collected as part of a wider project defined as «Observatory on the Mechanical Cluster», which was promoted by the cluster to monitor the evolution of the cluster over the last decade (Bortoluzzi *et al.*, 2018). Different data sources were used for triangulation purposes (Eisenhardt, 1989).

3.2. An overview of the adoption of I4.0 technologies within the cluster

According to a recent study on the mechanical cluster, local companies consider innovation as an important source of their competitive advantage (Bortoluzzi *et al.*, 2018)[1]. Some data confirm this strong orientation towards innovation: a formalized Research and Development unit is present in more than 40% of companies, and almost one-quarter of the companies have filed at least one patent in the last 5 years. An open innovation orientation is generally diffused, where companies interact with suppliers, research centers, universities, technological parks.

In the mechanical sector, innovation is traditionally linked to strong investments in innovative technologies and recently in I4.0. At the national level, about 64% of metalworking companies have adopted at least one I4.0 technology and about 70% of mechanical companies have adopted between 2 and 6 technologies (Federmeccanica, 2017). As highlighted in the above mentioned study (Federmeccanica, 2017), data related to the awareness and adoption of I4.0 technologies by mechanical companies at the national level are aligned with the ones of firms in the mechanical cluster in FVG (Bortoluzzi *et al.*, 2018): the percentages shown in Table 2 suggest that FVG companies declare a good level of knowledge of I4.0, even if the degree changes according to each I4.0 technology (Table 2). Indeed, technologies such as connected machines in production, additive manufacturing/3D printing, collaborative robotics are well known by the majority of respondents, whereas other technologies (e.g., intelligent materials, augmented reality) are less known (and spread).

[1] The «Observatory on the Mechanical Cluster» promoted a survey on the adoption of I.40 technologies by cluster firms. The final sample consisted of 210 valid questionnaires that were collected from April to June 2018 (Bortoluzzi *et al.*, 2018).

Table 2: I4.0 technologies: level of knowledge and level of adoption

	Technologies: KNOWN		Technologies: ADOPTED	
	Absolute value	%	Absolute value	%
Advanced robotics	193	84.6	85	37.3
Additive manufacturing	193	84.0	32	14.0
Interconnection of production tools	188	82.5	97	42.5
Advanced simulation	163	71.5	84	36.8
IoT	156	68.4	66	28.9
Big data	140	61.4	39	17.1
Cloud computing	140	61.4	39	17.1
Collaborative robotics	124	54.4	12	5.3
Augmented reality	78	34.2	16	7.0

Source: Authors' elaboration based on survey data (Bortoluzzi *et al.*, 2018).

As a whole, 78% of companies adopted at least one technology. Company size impacts on the level of adoption: small companies were interested in I4.0 (67% of adoption in firms with less than 2 million euros of turnover), even if with a higher selective approach. Indeed, among the adopters, 53% of companies with a turnover higher than 10 million euros have more than two technologies; while the percentage is 44% for smaller companies (35% in companies with a turnover lower than 2 million euros). Each I4.0 technology shows different levels of adoption (Bortoluzzi *et al.*, 2018). Some technologies (e.g.. advanced simulation, robotics and the IoT) are adopted by a significant number of sampled firms, whereas other technologies are well known, but not adopted yet. The case of additive manufacturing is emblematic: everyone knows it, but just a few companies have adopted it so far.

In this dynamic scenario, the present study aims to understand whether (and to what extent) the adoption of I4.0 technologies is associated with the introduction of innovations, and eventually the *types* of innovation.

4. The case studies[2]

4.1. Circle: simulation, product innovation and new service offering

Circle was founded in 1978 and has a turnover of about 18 million Euro nowadays, with an export share of 80% distributed around the world. It operates in a niche sector with less than 10 competitors worldwide: it pro-

[2] Names of analyzed cases are invented.

duces specific steel components (i.e., saws) for national and international machinery and equipment manufacturers. Some of these Italian customers are located in the mechanical cluster. Ten years ago, the strong international competition from emerging countries led the company to redefine its competitive strategy: in a market that was still dominated by the price logic, the company made investments aimed at implementing and reinforcing a new strategy characterized by a strong customer orientation. Two main drivers of this change were the strong collaboration with several strategic clients on the one hand, and major investments in innovative technologies, on the other hand. In fact, the company started to collaborate with some of the larger final users of its component (i.e., machine manufacturers) to improve the efficiency of the entire machine. At the same time, the company invested in innovative technologies: over the last fifteen years, it has introduced more than 20 autonomous robots; it has implemented systems of vertical integration within the organization by connecting all the machines and robots in production with the other activities of the company (i.e., from orders and production planning, to the after-sales phase), thus innovating its production process to increase the productivity of plants and the operational efficiency of the factory. All these decisions have contributed to strengthening the firm's competitive advantage. Specific investments in R&D and strong customer orientation have led the company to introduce not only process but also product innovation. For instance, the firm has developed and started to use its own simulation software during the designing phase, to simulate how its component works. Circle simulates the use of its component in different conditions and applied to different machines, thus identifying the potential weaknesses of its product. After using simulation internally, Circle began offering this service to final clients (i.e., the machinery manufacturers) thus enriching Circle's products with an added-value service, improving the customers' satisfaction on the one hand, and the quality of products on the other hand. The simulation service has allowed the company to obtain a new competitive advantage compared to its competitors and to reinforce the relationships with its clients. To sum up, the company adopted many I4.0 technologies with a process innovation orientation to increase the operational efficiency of its factory. However, the use of simulation for internal purposes has shown the possible positive implications of offering this complimentary service to customers, particularly in terms of increased international competitiveness and customer satisfaction. As the main effect, this strong interaction with customers due to this technology has eventually led to product quality increases and an increasing importance of the service as an add-on to the physical product.

4.2. Mill: towards a small but smart factory

Founded in 1979, Mill is a family firm with a turnover of about 9 million euros. The second generation is now managing the company. It works as a turning and milling working center for a variety of products intended for a wide range of industries (e.g. automotive, electro-mechanics, textile-mechanics and medical equipment). Exports represent about 60% of the turnover. Its clients are mainly large MNEs. In line with a past strong orientation towards technological innovation that is common to other cluster firms, over the last few years, Mill has strongly invested in I4.0 technologies: the firm has introduced automated inventories and supply machines, robotic centers and islands for serial production, and a machinery fleet which are all vertically connected with the rest of the firm's operations. The interconnection between machines has allowed the company to monitor, control and manage the production, even remotely. Reduction of wastes and increase of plant efficiency and productivity are some of the main advantages of these investments. The company is willing to allow its clients to real-time monitor the advancement of Mill's production: an important step towards a small fully integrated and interconnected smart factory.

Strong investments in I4.0 technologies have allowed the company to confirm (and enhance) its traditional strong orientation towards customers, and to remain competitive compared to manufacturers located in low-cost countries while maintaining the manufacturing base in Italy, inside the cluster.

4.3. Cup: smart products for the coffee industry

Cup is a coffee machine manufacturer (crank, automatic and with pods), which also produces coffee grinders. Product quality, high customization and Made in Italy production are some of the main valuable attributes of this brand. Founded in 1920, since 1970 it has belonged to a large, renowned group of the sector.

Cup is a small firm with a turnover of 21 million euros and 100 employees. Its customers (e.g., mainly roasters and distributors) are equally distributed in domestic and international markets (Cup exports 50% of its turnover).

Some years ago, the firm started to produce smart products offering a series of advanced services that are available to users both on-site and remotely. For example, the bartender can use an application to remotely define some settings (e.g., water temperature, length of doses, or volume of coffee dispensed) of the coffee machine and then, he/she can directly control the machine's consumption. Moreover, the bartender can potentially use a remote assistance service. Cup also produces some smart coffee grinders that, thanks to some sensors, can automatically dose the amount of coffee to be ground, in relation to the number of active spouts in the filter holder.

The company is evaluating the potential of I4.0 technologies not only for product but also for process innovation. For instance, the company is considering starting a digitalization process to manage the assembly and testing phases. It also uses plastic 3D printing to obtain small batches of customized components, but it outsources to a supplier located in the cluster.

4.4. Drinks: digitalization for the business model innovation

Established in 1978, Drinks is an established machine manufacturing company with a turnover of about 10 million Euro. It belongs to the mechanical cluster and it produces and sells beverage machines and plants. Over the years, it has expanded its product portfolio to also offer turnkey plants to beer manufacturers. Over the last few years, the firm has started a path towards servitization. Indeed, already several years ago, the company started to offer higher and higher levels of service, by granting users post-sales assistance and other additional services. For instance, the firm has started to offer ad-hoc real-time monitoring and managing services to customers of turnkey plants that are vertically and horizontally integrated (e.g., smart machines are interconnected with each other, connected to the customer's cloud and the manufacturer itself). At this stage, the company is implementing an innovative servitization strategy. In fact, it has started to not sell its machines but to give machines on a gratuitous loan and charging a fee to use them. Moreover, in some cases, Drinks maintains the ownership of the plant and remotely manages it from its headquartes, while the customer just has the right to use it while paying the usage fee. I4.0 technologies have a big role in this change towards servitization. For instance, the company has introduced autonomous robots in production; it is investing to improve its competences related to data collection and data analysis. Drinks considers IoT and BDA crucial variables of its future strategy. Drinks' entrepreneur is evaluating the possibility of outsourcing production to other cluster firms and of focusing on developing internally new functions related to big data analytics and service. Since Drinks' localization in the mechanical cluster, the entrepreneur is evaluating the possibility of outsourcing the production locally to cluster suppliers, while maintaining internally the assembly phase to focus the company's resources on developing critical skills and capabilities related to the new core aspects: the product's technological evolution, big data analytics and service.

4.5. Case Five – The Cluster Agency

The Cluster Agency is an agency whose aim is to promote the industrial development of the mechanical cluster. It is a corporate structure made up of private entities: trade associations, science parks and companies located in Friuli Venezia Giulia operating in the engineering sector. Although the ownership of the Agency is not public, a regional law has identified the cluster agencies as institutional actors in charge of promoting the industrial development and international competitiveness of cluster firms.

After the promotion of the national law on I4.0, the Cluster Agency has actively engaged in the promotion of a number of initiatives to increase the awareness and adoption of I4.0 technologies among cluster firms over the years. Firstly, it has organized a «club» where meetings and webinars about I4.0 technologies with cluster firms are organized to raise awareness on the potential applications and outcomes. At these meetings, leading companies in I4.0 adoption operating in other regions were invited to present their business cases and experiences related to I4.0 implementations. Then, a consultant or an advisor discussed with the entrepreneur or manager some technical or strategic aspects that could be of particular interest also for cluster companies. Cluster companies found this initiative particularly useful to learn about the possible applications of I4.0 technologies and to understand which one was more suited to their business model, product or process types.

Secondly, the Cluster Agency has promoted an initiative concerning additive manufacturing. The additive project aims at supporting companies in adopting advanced production technologies (i.e., additive technologies) and stimulating change in business models, improving skills and promoting investments for new start-ups. The project was born from the collaboration between public and private actors: besides the Cluster Agency, other local actors like a technological park, a University and a technical high school also participated. The activities of the project are organized around a shared space where companies can collaborate to develop skills in the field of additive technologies: it is a cutting-edge center in which companies can learn about and experiment with additive technologies in a concrete and market-oriented way. More specifically, the joint effort of institutions and some funding companies allowed investment in some technologies which could be exclusively used by the participating companies to test additive manufacturing in the metal industry. The project was particularly appreciated as the 3D metal printing was new to the market, which made companies particularly reluctant to make a considerable wholly-owned investment in this technology – without guarantees concerning its effectiveness. This approach will be probably extended to involve more companies and even different materials.

The Cluster Agency is also an active member of a Digital Innovation Hub, an actor identified by the national government to support companies during their digital transformation. The Digital Hub is a platform composed of four nodes, each with an area of expertise, namely: advanced manufacturing solutions; data analytics & artificial intelligence; data optimization & simulation; IoT. For each area of expertise, training, workshops and demos are organized in order to involve companies and increase their technological awareness. As most cluster companies are SMEs, this initiative was considered particularly by small and micro-companies endowed with limited financial resources which – however – had an interest in these technologies. Several SMEs had received suggestions from their clients and suppliers inviting them to adopt some technologies, but did not possess the digital competences to approach them. This project, in addition to the other initiatives mentioned above, allowed even micro-companies to increase their awareness and identify potential partners both within the cluster and outside its borders, e.g. technological partners and consultants.

Another group of initiatives relates to a busy schedule of training activities aimed at fostering and promoting the creation of technical and critical skills for the competitive advantage of companies, thanks to the involvement of specialists at the national level and leading technology suppliers. Companies have particularly appreciated this approach, as the courses were short, practitioner-oriented and also affordable, covering a wide range of arguments, from technical English to big data analytics.

5. Discussion

The analysis shows that the adoption of I4.0 technologies follows two main trajectories: product and process innovation (Table 3). In fact, we could see that companies tend to select specific technologies aimed at improving the product on the one hand, or at achieving the process upgrading. Instead, one company (Drinks) has adopted a complex bunch of interrelated I4.0 technologies, which is turning into an innovation of the whole business model. However, the prevalent model of I4.0 adoption allowed cluster firms to maintain their typical competitive factors: flexibility and customization.

Inside the mechanical cluster, production flexibility and product customization were two of the main traditional differentiating factors, which explains why cluster companies invested in product and process innovation to sustain these competitive assets. Recently, investments in I4.0 technologies allowed the most innovative firms to continue on this path. The effects can be appreciated in different aspects. Investment in process innovation through, e.g., advanced robotics allowed the firms to increase productivity in home countries, thus remaining (or becoming again) competitive also with competitors located in low-cost countries (as, for instance, in the cases of Circle and Mill).

At the same time, product upgrading opened up to a new generation of products, which in most of the cases include also a potential offering of new services. In fact, product innovation in this sector often entails the creation of smart products through IoT technologies; this, in turn, opens up new possibilities in terms of customer services related to, e.g., remote and predictive maintenance, or even to a full servitization strategy where the manufacturing firm starts selling services, instead of products. For instance, Cup and Drinks have developed products, which include sensors that may

Table 3: I4.0 technologies adopted and main innovations

Company	Product	I4.0 technologies adopted	Types of innovations
Circle	Saws	Simulation, vertical integration, robotics, BDA	Mainly process innovation Product innovation (service as add-on to physical product)
Mill	Precision mechanics	Robotics, horizontal and vertical integration, BDA	Mainly process innovation
Cup	Coffee machines	IoT, 3D printing	Mainly product innovation Evaluation of process innovation
Drinks	Beverage machines and plants	IoT, simulation, horizontal and vertical integration, cloud, BDA, robotics	Product innovation Process innovation Business model innovation

Source: Authors' elaboration.

collect (simple or complex) data and are connected with other devices or the cloud, in order to offer different degrees and types of additional services. Hence, evidence highlights that the adoption of I4.0 technologies allows companies not only to confirm past competitive strategies, but also to explore new business models.

Actually, the service has traditionally been a differentiation factor for cluster companies. Customization services were used to strengthen and retain a long-term relationship with customers, particularly in business-to-business relationships (Bortoluzzi *et al.*, 2006; Grandinetti, Tabacco, 2015). However, thanks to the adoption of digital technologies, the service offering can be enhanced and even lead to new forms of competition (Porter, Heppelmann, 2015; Cusumano *et al.*, 2015; Chiarvesio, Romanello, 2018). Actually, in the analyzed cases, it is possible to find multiple servitization experiences within an ideal «product-service continuum» (Baines *et al.*, 2009; Oliva, Kallenberg, 2003; Vandermerwe, Rada, 1988; Baines *et al.*, 2017; Bustinza *et al.*, 2017): some companies offer services as an add-on to their products, thus confirming the centrality of the physical product, whereas another company offers services as the main part of its value creation process thus experimenting innovations of the business model (Bortoluzzi *et al.*, 2018). In the perspective of the cluster, however, we should underline that companies maintain a strong control on the product and the manufacturing process: conceiving services as a new way to deliver the product value does not substitute the product features as a component of the value proposition, where manufacturing competencies are crucial both to guarantee quality and innovation (Pisano, Shih, 2012).

In the analyzed cluster, the introduction of innovations associated with the adoption of I4.0 technologies is favored by several factors that are context-specific. Indeed, local actors operating in clusters (local institutions such as the local agency here presented) are acting as facilitators to enhance knowledge and adoption innovations (Hervas-Oliver *et al.*, 2019) (Table 4). This

Table 4: The role of Cluster Agency in supporting I4.0 technologies' adoption

Company	Initiatives	Description	Outcomes
Cluster Agency	Club	Meetings and webinars about I4.0 technologies with cluster firms to raise awareness on the potential applications and outcomes.	Wide participation from cluster companies, which attended the meetings to understand potentialities of I4.0 technologies, challenges encountered during the implementation, benefits, and information about the technological partners' reliability and competencies.
	Additive manufacturing	The additive project aims at supporting companies in adopting advanced production technologies (i.e., additive technologies) through the adoption of a metal 3D printing that was used exclusively by the financing companies for some months, and offered as a free service to the other cluster firms.	The financing companies could try the 3D printing, benefiting from the experience of leading companies in the use of this technology. The exclusive use of this technology allowed these companies to understand its potential applications and benefits in the supply chain. Other (non-financing) companies could test it for free and benefit from the other companies' experiences. This approach raised awareness on this technology used with a relatively new material, metal.
	Digital Innovation Hub	A Digital Hub that aims to support companies during their digital transformation.	An assessment tool has been defined to evaluate the technological needs of companies that implement specific projects; and obtain information about financial support.
	Training activities	Training activities (i.e., short courses) developed in collaboration with technology suppliers, consulting companies, academics and sector experts.	Entrepreneurs and managers attended the courses to develop the technical and critical skills necessary to adopt and implement I4.0 technologies, but also to develop the competitive advantage of companies. It was often also an opportunity to find a technology partner or to develop collaborations with other cluster companies.

Source: Authors' elaboration.

result is particularly interesting in consideration of the rising literature on innovation ecosystems related to I4.0 (Benitez *et al.*, 2020), especially when looking at policy implications. Several governments have favored the creation of industrial ecosystems to promote digitalization, while some of them have supported the creation of thematic ecosystems, such as the advanced computing ecosystem in the US or the IoT ecosystem in India. The actions of the Cluster Agency underline the importance of creating ecosystems supporting innovation among companies and this becomes more critical in the case of I4.0 which includes complex and resource-demanding technologies that have, in turn, the potential to dramatically improve the competitiveness of cluster firms in the international marketplace.

Cluster actors are well aware of dynamics that characterize cluster context and of the opportunities offered by new ways of interacting. Companies are aware that the adoption of a technology by a pioneer cluster firm can be quickly imitated by other firms, thus fueling a virtuous process of «collective adoption». Workshops among companies are a good way to share experiences. Collective projects, to share investments and experiment with new deployments of more general tools, such as additive manufacturing in metallurgy, seem quite promising and enable working together with both large and small companies.

6. Conclusions and implications

Italy is lagging behind the digital innovation but it is catching up: the most innovative firms started this transformation some years ago, while other companies have accelerated their digitalization during the COVID-19 crisis (Anitec-Assinform, Confindustria digitale, 2020). Among the digital technologies, I4.0-related ones present multiple potentialities and application contexts (Chiarvesio, Romanello, 2018; Müller *et al.*, 2018), but they have been relatively under-explored and unexploited from a managerial perspective.

This paper aims to give some insights about the adoption of I4.0 technologies in the context of clusters, by looking at the FVG mechanical cluster in Northeast Italy.

Our analysis suggests that companies adopt selectively different technologies consistent with their specific needs; and they mostly follow product or process innovation, pursuing productivity, flexibility, and customization increases. In both cases, the service component of the offering increases, with the overall value offered to the customer. In some cases, this can lead to a full servitization strategy, radically innovating the companies' value proposition, but without diminishing the importance of manufacturing, which remains the core of the competitive advantage of clusters. Hence I4.0 can boost the traditional cluster competitive factors, and open up to new innovative strategies for the most dynamic firms, even smaller ones.

The combination of higher value and higher productivity can make cluster companies more competitive and a viable alternative to foreign suppliers; this upgrade process thanks to I4.0 technologies is thus consistent and can take the opportunity raised by the trend of reshoring that is involving many multinationals that used to offshore in the last twenty years.

In terms of managerial implications, the literature and the above analysis suggest that, despite the opportunities, companies can find some difficulties in identifying the best application of each technology consistently with their own strategy. Moreover, the adoption of I4.0 technologies can be associated with the introduction of different types of innovations: not only product and process innovation, but also business model innovation. Single firms should increase their awareness about the multiple potentialities of I4.0 technologies, by exploring the broad spectrum of potential innovations that may be associated with them. In this sense, the existence of institutional actors in an innovation ecosystem contributes to spreading the awareness and adoption of I4.0 as their purpose is to increase the competitiveness of all cluster firms. Particularly in the case of I4.0, this is relevant as technologies are complex and resource-demanding. This has implications for policymakers as well. Local institutional actors typically operating within clusters are better aware of typical industrial cluster dynamics, such as cooperation-competition or imitation, and can find the best ways to leverage them in order to stimulate the sharing of experiences and the interest in learning, explore new solutions and imitate pioneering firms. Moreover, they can promote collaboration among firms, among customers and suppliers, favoring the creation of a dynamic ecosystem where different actors with different roles contribute to increasing the overall competitiveness. In fact, some technologies can provide opportunities that have not been fully deployed or understood yet, which need research and exploration, which are costly and risky. Since cluster companies have similar specializations, it must be reasonable to implement some common actions that allow exploring by spreading the costs. Further, new technologies can pose problematic issues concerning the lack of human resources or internal competencies and the general difficulty to train ICT skilled employees (Sommer, 2015); even in this case, local actors can have an important role in identifying needs and in designing training programs or interacting with training institutions. In this perspective, a Cluster Agency may play a key role, by creating events and projects where companies can explore the potential of I4.0 technologies both on their own and by interacting with other cluster companies and potential partners.

Further research should analyze how I4.0 will be deployed in clusters over the years and how they will interact with the dynamics that have threatened the cluster competitiveness in recent years. The COVID-19 outbreak is the new challenge. On one hand, it is producing an important wave of economic crises; on the other hand, it is making companies and governments rethink global value chains, where the local regions assume a new critical centrality. In this context, digital technologies can have a crucial and decisive role for clusters and cluster firms.

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