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# Through firms' eyes: How SMEs define technological spaces and trajectories in the digital era[1]

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**Abstract:** How do small and medium-sized enterprises (SMEs) set up their technological portfolio, orient their future technological choices, and contribute to shaping the evolution of a specific economic structure? Technology adoption in SMEs has been recognized as a learning path but how this process is characterized in the digital era remains rather unclear. The paper aims to address this research gap by analysing how a population of manufacturing SMEs builds and follows its technological trajectories. By taking advantage of data on a large sample of manufacturing firms, we employ network analysis to map the evolution in the adoption of digital technologies. Findings show a common path of adoption and learning within the population of manufacturing SMEs. However, while some firms are on the edge, riding the learning curve and providing key meaning to the contextual setting of operations and strategies commonly taken under the technological evolution, others lag in their learning process, risking digital devices.

**Keywords:** SMEs; technological trajectory; manufacturing, digital era

**JEL Classification Numbers:** 014; 033

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# 1. Introduction

In the digital era we are experiencing today, a broad range of digital technologies (DT), such as Big Data, Artificial Intelligence (A.I), Internet of Things (IoT), Robots and 3D Printing are contributing to shaping the value creation processes and performances of manufacturing (Cirillo et al., 2023; Mitchell and Brynjolfsson, 2017; OECD 2017; Porter and Heppelmann, 2014; Schwab 2016). Digital technologies are recognised as an opportunity for manufacturing firms and their value chains allowing to increase customization, efficiency, and reduce the harmful impact of economic activities on the physical environment (Bianchini et al., 2023; Bai et al., 2020; Castellani et al., 2022; Ghisetti and Montresor, 2020).

Mapping the firms' technological adoption is today important for understanding the degree of digital transition of economic systems and their future trajectories (European Commission, 2019; Verhoef et al., 2021). However, the technological adoption may be unevenly distributed, and the learning stage may be different for different typologies of firms. Business studies have so far investigated the topic by applying an organizational-centric perspective where maturity models or readiness assessments have been implemented to support companies in the definition of their technological trajectory (De Carolis et al., 2017; Schuh et al. 2017). Here, maturity refers to the company itself, its knowledge bases, its organizations, processes, and personnel capabilities that are considered to be the main drivers of smart manufacturing. Empirically the degree of maturity has been mainly analysed through case studies based on larger manufacturing companies, having often established strategy departments that can utilize the insights gained from maturity models and readiness assessments to plan investments and adjust the long-term digital strategy (Mittal et al., 2018). If those aspects can be somehow analysed in large companies, it remains more difficult to grasp within small and medium-sized enterprises (SMEs), typically lacking strategic resources and a long-term vision of the digital transition.

When referring to the literature in innovation and business studies exploring Industry 4.0 (I4.0) in the environment of SMEs the main focus of researchers has been on the enabling factors and constraints encountered by those types of firms in adopting digital technologies (Garbellano and Da Veiga, 2019; Müller et al., 2018). From this branch of literature, the main lesson learnt is that successful technology adoption requires a strong strategic approach, where investments and changes in the organizational structures of the company combine with an ongoing commitment to employees' training and development (van Dun and Kumar, 2023; Tortorella et al., 2019). Indeed, SMEs are still lagging behind large firms. SMEs' barriers to the adoption of digital technologies and the exploitation of their environmental benefits depend on several factors, both at firm and systemic levels. This

shortcoming is due, for example, to uncertainty regarding the value of digital technology, and the integration of digital tools into the industrial organization. Traditionally, these barriers have been locally reduced through place-specific mechanisms fostering knowledge sharing, collective learning, imitation, and technology spill-over, particularly in those locations where SMEs represent the main population of firms that characterize the industrial structure.

While, on the one hand, understanding these issues is important to provide suggestions on possible favourable conditions for digital innovation, on the other hand monitoring the typology and phases of evolution of the technological spaces of SMEs is useful for understanding which technological trajectory these firms are entering.

So far how SMEs define their technological portfolio and trajectory is still unclear. Several papers focusing on some specific DTs show the existence of heterogenous patterns of technology adoption in relation to specific technologies (Denicolai et al. 2021; Kinkel et al., 2022). Frank et al. (2019) show for example that companies entering a digitalization path can be clustered into progressive stages of adopting the entire array of technologies. Moreover, the authors demonstrate a significant interconnectedness among these technologies, and how Smart Manufacturing technologies complement each other rather than serving as substitutes, particularly as companies advance in their maturity levels (Frank et al., 2019).

By entering the trajectory debate, the aim of the paper is not to investigate the nature and role of different factors supporting or hampering the technological adoption of SMEs, but instead to track how manufacturing SMEs define technological spaces and future technological trajectories in relation to the learning curve they could reach while adopting the digital technologies. This implies monitoring both the evolution of digital technological adoption firms undertake, and the way firms, particularly those on the edge, contribute to shaping the role that those technologies assume in their contextual setting of operations and strategies, so that it could be imitated by others.

To do so, we take advantage of a survey sent out by the Regional Union of Chamber of Commerce (Unioncamere) collecting a representative and randomized sample of 2082 manufacturing firms. Employing network analysis techniques we analysed the recent evolving adoptions of technologies within the so-called adopters, i.e., 1051 firms. Finally, we complement the survey with qualitative information collected through interviews with some of the SMEs technological adopters belonging to the survey list. The interviews conducted with those firms had the purpose of triangulating the main findings of our quantitative analysis and exploiting more in depth the survey arguments and the impact of DTs on firms' development.

The paper is organized as follows: the next section discusses the theoretical framework in which the main industry DTs as well as their diffusion and learning processes in SMEs are presented;

the third section illustrates the sample firms and introduces the methodological part; the section four, through a social networks analysis, presents the recent evolution of the SMEs technological space; section four provides qualitative insights from case studies about the direction of the technological trajectory resulting from recent operations and strategies of firms on the edge. The fifth section discusses the future orientation of the technological trajectory. The last section concludes by adding policy implications and recommendations.

## 2. Theoretical framework

### *2.1 Digital technologies and manufacturing in the digital era*

Manufacturing has undergone a remarkable transformation over the last few decades, largely driven by the relentless advancement of DTs (Kagermann et al., 2013; OECD 2017; Schwab 2016). This evolution, spanning from the early stages of automation to the contemporary Industry 4.0 (I4.0) era, has brought about significant improvements in manufacturing processes, completely reshaping the way organizations produce and redistribute value (Bellandi et al., 2019; Büchi et al., 2020; Lafuente et al., 2022).

The integration of physical components with smart and connectivity components enables manufacturers to monitor equipment performance and collect valuable data for predictive maintenance, reducing downtime and associated costs (Porter and Hepperlmann, 2014). The opportunities resulting from the storage and analysis of vast data sets through Big Data analytics have revealed critical information for optimizing processes, improving product quality, and reducing the impact of economic activities on the environment (Bianchini et al., 2023; Dalenogare et al., 2018; Ghisetti and Montresor, 2020). In this regard, this transformation driven by the twin imperative of efficiency and sustainability starts to be central for scholars, practitioners, and policymakers.

Considering the imperative of this transformation, in the last decades scholars have deeply explored different aspects of DTs adoption and innovation. A seminal paper by Hermann et al. (2015) has identified the main design principles of I4.0 been the cyber-physical systems, Internet of Things, Internet of Services and Smart Factories. Since then, a lot of work has been done to understand innovation trajectories and learning paths at different levels, for example at the level of regions, ecosystems, value chains, and companies (Benitez et al., 2020; De Propris and Bailey, 2020; Teece, 2018). Scholars investigating trajectories posit that I4.0 technologies exhibit and encompass certain attributes commonly associated with general-purpose technologies (GPT) showing a high potential for triggering virtuous innovation paths, a widespread use, and application in different industries (Goldfarb et al., 2023; Martinelli et al., 2021).

Despite literature on innovation studies agree on recognising path dependency in the adoption of I4.0 technologies (De Propris and Bailey, 2020), there is still a lack of studies applying a technology-centric approach in the exploration of SMEs digital technologies adoption considering at the same time the learning curve stage.

### *2.2 Perspectives on digital technologies adoption in manufacturing SMEs*

Considering the vital role SMEs play in all economies, particularly in the manufacturing industry, how SMEs react, and approach technological transitions has often been at the attention of scholars and policymakers (Kergroach, 2021; Meredith, 1987).

Literature exploring specifically the adoption of digital technologies among SMEs, although principally focusing on barriers and drivers, is divided mainly into two research lines: the field focussing on the internal organizational aspects (i.e. organizational-centric perspective), which is englobing recently also a technology-centric perspective, and the field investigating the environmental elements in which what is key are the forces that move the adoption process at a more systemic level.

As for the former, scholars have so far strongly focussed on the different elements characterising the organizational structure of companies (Zamani, 2022; Cirillo et al., 2023). Several papers have investigated for example the role played by the organization size, resources, age, employees, and the cultural approach to innovation (Stock et al, 2002).

The discussion surrounding costs has also spurred research into resource allocation, with financial resources garnering the most attention (Agostini and Nosella, 2020; Frank et al., 2019).

The commitment of top management during early technology adoption and implementation in SMEs and its consistent presence throughout the process has also been identified as a critical factor for technological adoption (van Dun & Kumar, 2023). It derives that SMEs tend to rely on informal, flat organizational structures, and often have limited management, leadership, and strategic capabilities to be able to envision a possible technological pathway for themself (Pati et al., 2018; Radas and Božić, 2009).

In the exploration of internal factors linked to the digital transition of SMEs, both practitioners and scholars have taken advantage of maturity models or readiness assessment to understand and support companies in the definition of their technological trajectory (Schuh et al., 2017; De Carolis et al., 2017). Here, by applying an organizational-centric approach, technology adoption is described as a natural evolution of the organization when some internal capabilities allow to embed new technologies.

In this regard, since SMEs typically lack strategic resources and a strategic vision navigating them through the digital transition, maturity models did not impact as expected in the digital transition of manufacturing (Mittal et al., 2018).

Papers with an organization-centric perspective have so far contributed mainly to enhancing our understanding of how technologies support SMEs in delivering superior products and services to their customers (Dalenogare et al., 2028; Attaran and Woods, 2019; Asadi et al., 2022; Urbano et al., 2023). However, there is a growing literature that applying a more technology-centric perspective is helping to explore technology-specific features influencing the trajectory (e.g. enabling or blocking the diffusion of specific technologies among SMEs) (Justi et al., 2023; Mekhum, 2020). In this other debate, compatibility among technologies and the degree of technological complexity emerge as crucial determinants of technology adoption (Roger, 1983). Some researchers englobing this other perspective seem able to consider better how well a technology and its compatibility and complexity characteristics meet technical requirements and support the organization in fulfilling its mission (Chittipaka et al, 2023; Kinkel et al., 2022). Moreover, in the exploration of complementarities between DTs scholars show how technologies are not adopted in isolation but in bundles (Cho et al., 2023). In this context, complementarity plays an important role in determining a certain technology diffusion pattern.

As for the literature focusing on the external environment, findings underline the importance of considering in the technological adoption competitors' pressure, customers' pressure, and external support factors including governmental and service provider assistance (Lafuente et al., 2017; Larrea and Estensoro, 2021; Lombardi et al., 2022; Maroufkhani et al., 2020). Embracing a more path development perspective some contributions have also specifically considered the role of knowledge exchange and learning opportunities when SMEs have common geographical cultural or institutional contexts (Bettiol et al., 2021; Corò et al., 2021; Nguyen et al., 2015).

Although innovation literature recognises the important role of technology specificities, complementarities, and path dependency of new technologies, there is still a lack of studies applying a combination of approaches in the exploration of SMEs digital technologies adoption able to consider at the same time the technological progress and the learning curve of firms when adopting those technologies which provide a common sense to the undertaken direction.

## 3. Data and Methodology

To explore how manufacturing SMEs takes specific technological adoption trajectories and through their learning provides a sense of direction of the undergone technological development we took advantage of primary data collected in 2020 through one of the regular quarterly surveys sent

out by the Union of Chamber of Commerce (Unioncamere) in the Veneto Region, an Italian region with a population of SMEs still largely employed in manufacturing activities[2].

In the survey sent out on the third quarterly period a special session dedicated to the DTs related to Industry 4.0 has been added. The special session was aimed to map out the level of technological adoption among manufacturing firms in the 13 different subsectors characterizing the traditional manufacturing activities of the regional economy. The questions related to the session have been developed by a multidisciplinary team involving academic research group and other regional stakeholders in a common project. The main questions concerned the adoption and the time of adoption by the firms of 10 different digital technologies defined as key in the main literature: Artificial Intelligence (A.I), Automations and Robotics, Additive Manufacturing, Internet of Things (I.o.T), Virtual & Augmented Reality (V.R), Cloud Services, Cyber Security, Big Data Analytics, Blockchain and Digital twin.[3]

Data refers to a representative and randomized sample of 2082 manufacturing firms. Table 1 shows the overall sample of SMEs broken by size, type of production and sector. Of the total sample 1068 firms (51,3%) have declared to have adopted at least one of the 10 technologies. For most of those firms (1051) where possible to track the type of technology adopted and when the technology has been adopted.

[2] With a population of 4.8 million inhabitants, Veneto region has 425,00 active enterprises, accounting for 8.3% of the national total. The share of manufacturing in the total regional GDP exceeds 40 percent, the highest value among Italian regions (national average of 31 percent) and one of the highest in Europe. The restriction to a specific region allows us to keep control of key common policy contributions, incentives, and regulations shaping the technological trajectory of manufacturing SMEs.

[3] Some scholars have identified a list of disruptive technologies as the key technological pillars of I4.0 able to support the transformation of production and organizational models in manufacturing SMEs (e.g. Brynjolfsson and McAffee, 2014; Büchi, et al. 2020). For example, Yu and Schweisfurth (2020) who investigated SMEs in the German–Danish regional border have focused on 9 different technologies: simulation; autonomous robots; IoT; horizontal and vertical system integration; additive manufacturing; augmented reality; big data and analytics; cybersecurity; and cloud computing. However, despite the different tentative to provide technological classifications, there is still not an exhaustive and universally accepted list of foundational technologies, nor univocal technological methods of aggregations that can be used to define the evolution of firms' technological space (Büchi, et al. 2020).

**Table 1 -** Description of the sample

| **Technological adopters** | | | | |
|---|---|---|---|---|
| No | 1014 | 48.7 | | |
| Yes | 1068 | 51.3 | | |
| | **Total sample** | | **Only adopters** | |
| **Size** | **Freq.** | % | **Freq.** | % |
| Small | 1778 | 85.40 | 857 | 80.24 |
| Medium | 304 | 14.60 | 211 | 19.76 |
| **Type of production** | | | | |
| Capital goods | 353 | 16.95 | 195 | 18.26 |
| Intermediate goods | 1012 | 48.61 | 545 | 51.03 |
| Consumer goods | 717 | 34.44 | 328 | 30.71 |
| **Sector** | | | | |
| 1. Food. drinks and tobacco | 157 | 7.54 | 81 | 7.58 |
| 2. Textile. clothing and footwear | 270 | 12.97 | 109 | 10.21 |
| 3. Wood and furniture | 201 | 9.65 | 88 | 8.24 |
| 4. Paper and print | 90 | 4.32 | 44 | 4.12 |
| 5. Rubber. Plastic | 147 | 7.06 | 91 | 8.52 |
| 6. Marble. glass. ceramic and other minerals | 66 | 3.17 | 30 | 2.81 |
| 7. Production of metals and metal products | 381 | 18.30 | 218 | 20.41 |
| 8. Mechanic machines and apparatus | 205 | 9.85 | 120 | 11.24 |
| 9. Electrical and electronic machines | 106 | 5.09 | 68 | 6.37 |
| 10. Means of transport | 22 | 1.06 | 8 | 0.75 |
| 11. Goldsmith | 16 | 0.77 | 11 | 1.03 |
| 12. Eyewear | 16 | 0.77 | 6 | 0.56 |
| 13. Other manufacturing firms | 405 | 19.45 | 194 | 18.16 |

We applied to our analysis a mixed method approach combining and integrating the collection of quantitative with qualitative data (Creswell et al., 2003). The quantitative data has been then analysed taking advantage of social networks techniques that allowed us to map the recent firms' technological advancement and intensity in the adoption considering the evolution from the adoption stage in 2018 up to the adoption stage in the year 2020[4] counting the number of linkages that each firm has established with all the 10 aforementioned technologies, as well as calculating for each period the total number of technological ties established within the sample firms.

[4] Data about 2020 is partial since it refers to economic performances up to June 2020 which represents an important moment to control if the Covid-19 emergency created some acceleration in the firms' technological adoption. Indeed, in one dedicated question of the survey, around 9% of the sample explicitly declared that the emergency has brought the firm to speed up the process of digitalization and acquisition of digital technologies (e.g., use of video conferencing platforms with customers and suppliers, e-commerce, digital marketing, smart working).

To validate the main results of our quantitative empirical analysis we complemented the survey with qualitative information. To gather information, we conducted interviews with some of the SMEs' technological adopters belonging to the survey list (see Appendix A). The interviews conducted with those firms had the purpose to triangulate the results and exploit more in-depth the survey arguments, the potential impact of digital technologies on SMEs' production and offers, and the SMEs' strategies.

Potential companies to be interviewed have been selected adopting a shared protocol within the project team. Since the team intended to capture adoptions by firms 'on the edge' in the region, we selected only firms' top performing in their respective sub-sectors. After extracting firms standing in the first decile of the positive quarterly turnover, we chose those firms possessing at least a medium technological intensity[5] and already experiencing some positive impacts of those technologies for their business. We selected also those firms showing positive productivity and order variations despite the COVID crisis that has characterized that specific period. After checking further information on the firm's website, we ended up with a short and weighted list of 34 firms covering the main manufacturing subsectors of the region and all the regional counties[6]. Of that short list 10 firms accepted to be interviewed.

The interviews have been semi-structured on a series of thematic around the key technologies adopted: degree of exploitation, type of impact in relation to strategies, business performances and firms' network, related human resources involved as well as related investments and financial issues, position with respect competitors and other companies. All the interviews lasted around one hour. To ensure a correct interpretation of the results all the interviews have been conducted by the same researcher using digital platforms for all the meetings. The researcher has been also in charge of recording and transcribing the information. To ensure validation and triangulation of the findings at least two members of the project team were always participating in the meetings. For further validation, the main results have then been shared and discussed among the project team in the subsequential project meetings. A related webinar with invited interviewers, other regional firms, and stakeholders has been organized on February 5, 2021, where key results have been publicly presented and discussed.

[5] In terms of number of technologies and type of technologies adopted that were not under the overall sample average.
[6] Since we had no representative manufacturing firms in the construction sector, which is quite relevant in the regional economy, we decided to add a company in that sector that was not listed in the survey list but that we controlled that had all the selected characteristics to be considered top performers.

# 4. Results

### *4.1 The recent evolution of SMEs' technological space within the Veneto region*

Employing network analysis techniques, we analysed the evolving adoptions of technologies within the 1051 adopting firms considering the growth from the technological adoption maturity level in 2018 to the maturity level reached in 2020, in terms of established ties with the 10 digital technologies. We clustered then the firms on the K-core algorithm that identifies a measure of network density. Table 2 summarizes the main measures.

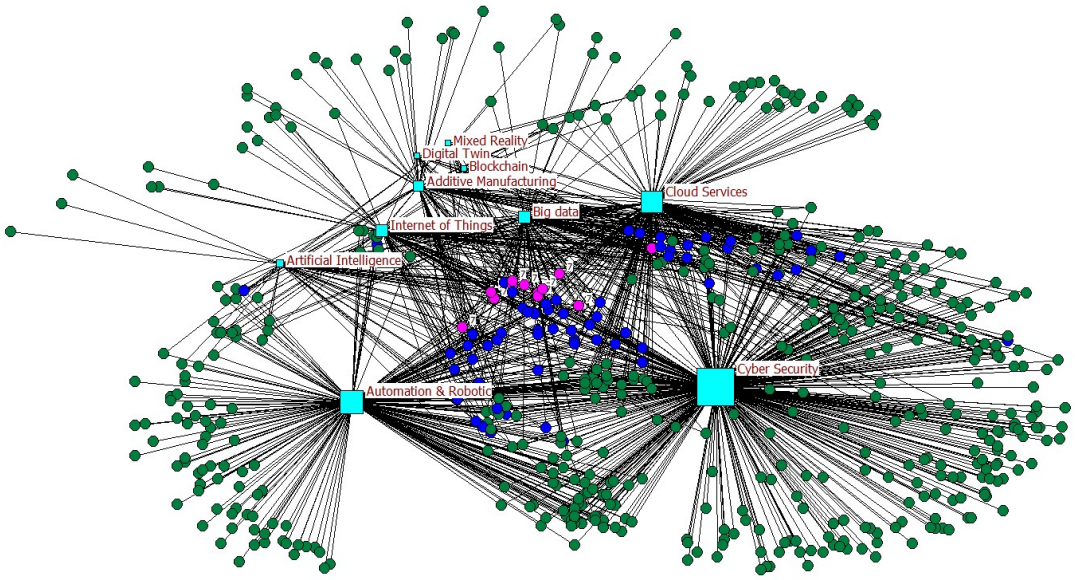
**Table 2 -** The space and trajectory of technological adopters

| **Percentage of firms adopting a technology in the different maturity stages (N: 1051)** | | | | |
|---|---|---|---|---|
| | Up to 2018 | Up to 2019 | Up to 2020* | **Δ of growth** (Base 2018) |
| **Type of adopted technology** | | | | |
| Cyber Security | 47.38% | 60.70% | 69.84% | 22.46% |
| Automation & Robotic | 26.26% | 36.25% | 42.44% | 16.18% |
| Could Services | 23.41% | 33.87% | 41.77% | 18.36% |
| Big Data | 10.75% | 13.70% | 17.60% | 6.85% |
| Internet of Things | 10.37% | 15.22% | 18.65% | 8.28% |
| Additive Manufacturing | 8.18% | 11.51% | 14.37% | 6.19% |
| Artificial Intelligence | 4.28% | 5.80% | 7.23% | 2.95% |
| Blockchain | 2.09% | 2.85% | 3.81% | 1.72% |
| Mixed Reality | 1.90% | 2.76% | 4.66% | 2.76% |
| Digital Twin | 1.62% | 2.09% | 3.24% | 1.62% |
| **Intensity of technological space (K-core)** | | | | |
| 0 ties | 33.59% | 13.13% | | |
| 1 tie | 31.11% | 39.87% | 43.67% | |
| 2 ties | 17.60% | 20.65% | 23.31% | |
| 3 ties | 9.13% | 13.51% | 16.65% | |
| 4 ties | 4.85% | 6.95% | 8.28% | |
| 5 ties | 2.19% | 3.62% | 4.57% | |
| 6 ties | 0.29% | 0.86% | 0.95% | |
| 7 ties | 1.24% | 0.86% | 1.14% | |
| 8 ties | | 0.57% | 0.19% | |
| 9 ties | | | 0.19% | |
| 10 ties | | | 1.05% | |
| **Total technological ties** | 1432 | 1942 | 2350 | |

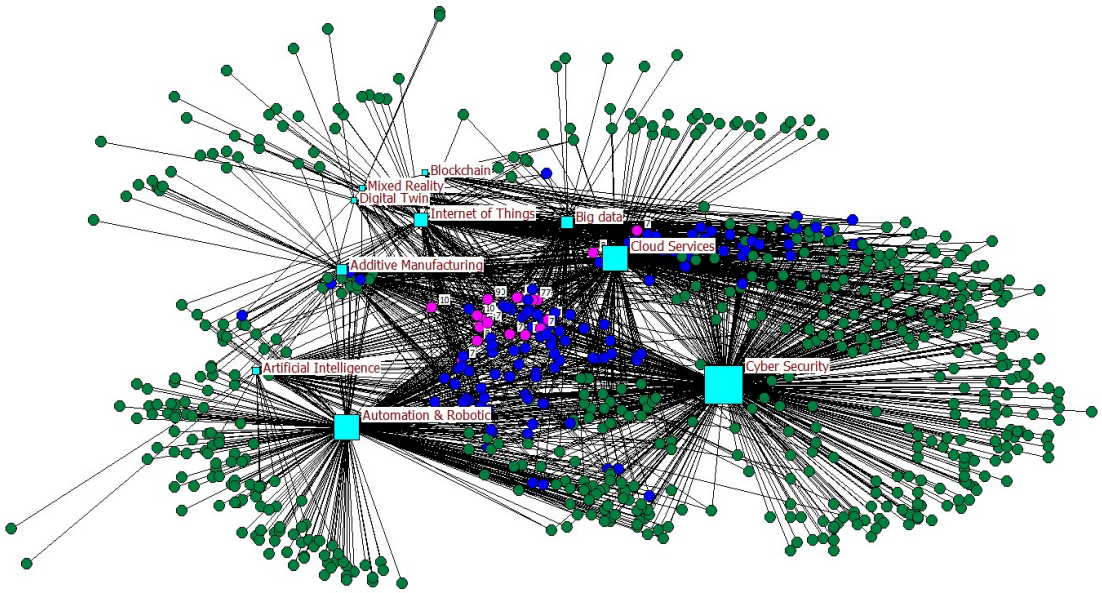
The largest positive variation in the technology's adoption has concerned those digital technologies more commonly exploited by SMEs, such as automation and robotic, cloud services and cybersecurity, which usually serve the more basic technological needs of the manufacturing firms (Corò et al., 2021). We can observe however that from 2018 to 2020 the adoption of digital technologies such as big data, internet of things and additive manufacturing has substantially been growing, contributing to an increase in the technological intensity of the SMEs technological space. Consistently, Fig. 1 below graphically illustrates the evolution in the firms' technological adoption in terms of network structures. The whole representation of the network which is based on the geodesic distance among the nodes allows to understand more concretely how the technological space of SMEs has been recently evolving and in which direction. The different clusters that are depicted represent respectively firms with the same range of co-adopted technologies. To help visualization we represented 3 main clusters: the green cluster composed of firms with 1 up to 3 co-adopted technologies; the blue cluster composed of firms with 4 to 6 co-adopted technologies; and the pink cluster composed of firms with more than 7 co-adopted technologies.

**Fig. 1 -** The evolution of firms' technological space

**Network 1: year 2018**



**Network 2: year 2020**




Source: Our own elaboration of the Unioncamere dataset 2020 using UNICET software (Borgatti Everett & Freeman 2002). Node size corresponds to the number of adopters of that technology in the sample firms. The shape of the node indicates when square a technology when round a firm. A tie between a firm and a technology is formed when a firm adopts that technology. Firms are clustered in different colors on the base of their technology intensity: green = up to 3 ties; blue from 4 to 7 ties; pink if 7 or more ties.

As it is possible to observe when comparing the network related to the year 2018 with that of 2020 there has been an evident increase in the number of SMEs (depicted with round nodes) falling within the blue cluster and to a lesser extent pink cluster. In particular, the enlargement of the blue cluster tells us that with a certain probability a good number of firms have been able already to overcome the technological threshold related to the introduction of the three most popular technologies (i.e., cybersecurity, automation and robotics, and cloud services).

In the analysis of the two networks depicted in Figure 1, it can be noticed also how SMEs have strengthened the trajectory in certain specific directions of co-adoptions. The connections of firms towards technologies are shaping particularly a closer move of big data with cloud services and of additive manufacturing with automation and robotics. In the former case we can see a market oriented technological pattern: indeed, the closer move of big data analytics and cloud services point to an increase within the firms of data strategies shared through the cloud internally and within business networks, reinforcing with the combination of the two technologies the sharing information tools, application and analysis of data in common decision-making processes. In the latter case we

have a more production technology pattern, with a potential use of those combined technologies for producing new niches and develop product experimentation.

### *4.2 Building a common sense of direction*

Building upon the insights resulting from the empirical analysis, the interviews helped to corroborate and clarify key emerging features of the technological trajectories of manufacturing SMEs. Interviewers shared their thoughts and perception not only in relation to their own business, but also in relation to the other local firms and competitors attituded, providing further insights about current challenges and impact in the adoption of new digital technologies. While there is still a large base of manufacturing firms that culturally find difficulties in introducing new digital technologies, from the interviews emerged clearly that manufacturing SMEs adopting technologies share four common elements.

Firstly, SMEs navigating the digital transition share a common idea about investments. Investments in basic technologies such as automation and robotics are necessary to survive the current pressure and instability of markets only if combined with other digital technologies. While in the past the investment in those technologies have been mainly related to support a general firms' efficiency, today when co-adopted with other digital technologies or when used strategically with an appropriate human resources investments, represent a key lever for remodelling production on the base of different contextual uses and for responding to different types of market demands. This is the case for example of firm **F,** in the food sector, that has invested strongly in Industry 4.0 automation and robotics of the productive processes but also to other digital soft technologies, to speed up and enlarge the variety of flours mixes for bread making and the related service activities. All the types of flours are today internally produced and packed specifically to respond to a wide range of clients' needs. The overall investment in digital technologies has helped the firm to manage the higher complexity resulting by customisation of a wide range of products, strengthening its competitive advantage.

Secondly, additive technologies such as 3D printing which have been introduced by some of the interviewed companies already investing in automation and robotics are today adopted not only for producing small lots but to experiment prototypes and speed up R&D processes. They serve therefore to accelerate the creative phase. This is the case for example of firm **A,** in the electro-mechanics sector, which during the pandemic period needed to adapt rapidly some textile machines to new clients' needs, and of firm **D,** in the furniture sector, that to win a prestigious international auction needed to prototype faster an alternative solution for producing theatre collective chairs.

Thirdly, in almost all the interviewed cases there are important investments and restructuring of databases and data management systems for planning new activities, but also for increasing

network collaborations using cloud tools. The management of big data, particularly in the most traditional 'Made in Italy' sectors is mainly aimed to improve sell and post-sell services.

Lastly, the most sophisticated technologies such as AI and virtual reality are instead still in the early phase of adoption in SMEs, and only a pair of the interviewed companies that have already reached a certain level of technological sophistication are trying to exploit their potentiality. This is the case for example of firm **K,** in the construction sector, which recently employed a physician to experiment with new AI algorithms applications.

The general trends that we observed common to firms that somehow, we can consider 'on the edge' is however the application of digital technologies for supporting the more intangible values of production and servitization processes. We report here some of the current strategies interviewed firms have undertaken in this direction. While some of them have been just implemented, once they are consolidated, they can support business model solutions more centred on intangible values.

Firms in traditional sectors such as mechanics and electro-mechanics thanks to the recent investment in I4.0 technologies, have been able to strengthen the value of their business activities towards more service and post-service assistance. An example is firm **B,** selling textile machinery incorporating digital technologies, which from being a machinery supplier is becoming a supplier of service as well. An increase in value for the company comes today from activities of post-maintenance and client assistance that are guaranteed with a fixed annual fee paid by the customers. A similar situation is facing firm **F,** which offers instead solutions for industrial automatization. Thanks to digital investments the firm is now able to provide tailored-made technological revamping solutions for data, processes and technology integration in old automation plants. The service fee for maintenance contracts has reached around the 20% of the total turnover. In the case of firm **H,** which produces metal working machines, and in the case of firm **K**, the investments in digital tools have instead guaranteed the possibility to do remotely the testing of new types of machinery delivered to international clients and see lively how machinery were functioning in remote places. The possibility to experiment with these types of services using virtual tools during the lockdown may increase future investments in long-distance testing and post-maintenance activities without the need to move physically human resources.

We observed that processes of creativity that can arise from the application of new digital technologies and that orient firms towards more intangible aspects are already diffused within the firms we interviewed. Firm **J**, has, for example, launched in 2020 an academy online for training the networks of distributors in relation to the potential application of their products in the activities of decorations. While this is still a free service designed on the base of customers' needs, online training

in the future can become a real value-added activity to expand to the final clients. Some of the firms more related to the 'Made in Italy' culture have then been able to creatively find new ways to use digital technologies to increase the experience provided to the customers and increase the uniqueness of their products. This is the example of firm **D** employing Internet of things technologies, 4.0 data and management systems, and shared cloud tools with a network of collaborators at the international level that has improved its capacity to deliver unique products. Firm D recently have been able to conjugate different types of digital and non-digital competencies to produce high-quality chairs with touch screens incorporated that guarantee sound and visual synchronization during public performances in theatres and the possibility for the audience to buy related gadgets and see them delivered just at the end of the performance. Firm **G** instead developed in the year 2020 an original digital application providing new key utility functions for their distribution channels of flour mix (skip the queue in the shop, count the calories, use new receipts, etc.).

### *4.3 Forecasting future trajectories*

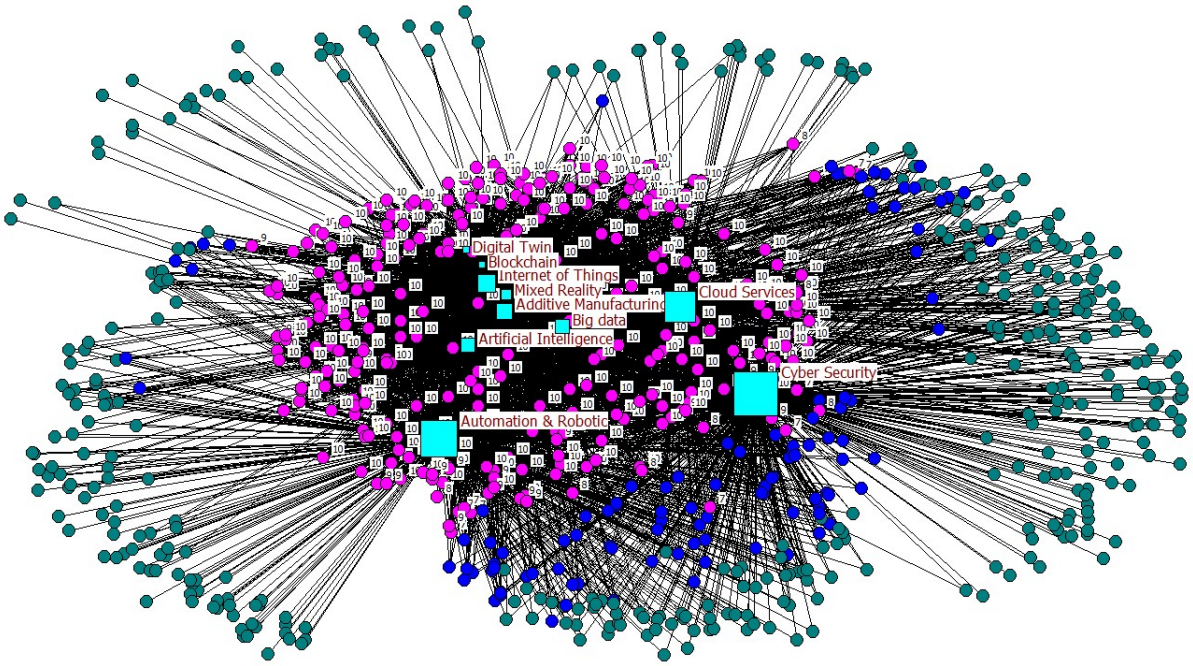
In most of cases emerged the need to keep investing in digital technologies despite the pandemic crisis. We could capture a similar trend through the survey as well. In one of the questions, we asked about the intention of regional adopters to employ other technologies in the future. As it shows in table 3, around 30% of the sample firms are aimed to reach sooner or later the adoption of all the 10 technologies. In particular, the delta of growth forecasted by the SMEs is quite impressive for all the technologies that today are yet not exploited. An increased intention to invest in technologies such as artificial intelligence, blockchain, mixed reality, and digital twin by many firms in the region supports the hypothesis that the virtual sphere will play in the future a more central role in the business activities of the regional manufacturing firms.

**Table 3 -** SMEs forecasted technological adoption

| | **Firms % on total sample adopters (N: 1051)** | |
|---|---|---|
| | *Future forecasting of reached adoption* | **Δ growth** (base 2020) |
| **Type of adopted technology** | | |
| Cyber Security | 77.16% | 7.32% |
| Automation & Robotic | 67.94% | 25.50% |
| Could Services | 61.47% | 19.70% |
| Big Data | 44.43% | 26.83% |
| Internet of Things | 47.95% | 29.30% |
| Additive Manufacturing | 46.15% | 31.78% |
| Artificial Intelligence | 43.58% | 36.35% |
| Blockchain | 36.06% | 32.25% |
| Mixed Reality | 38.63% | 33.97% |
| Digital Twin | 35.11% | 31.87% |
| **Potential Intensity of technological space (K-core)** | | |
| 1 ties | 25.50 | |
| 2 ties | 15.60 | |
| 3 ties | 11.70 | |
| 4 ties | 6.09 | |
| 5 ties | 2.95 | |
| 6 ties | 1.90 | |
| 7 ties | 0.95 | |
| 8 ties | 0.67 | |
| 9 ties | 2.19 | |
| 10 ties | 32.45 | |
| **Total technological ties** | 5239 | |

As it is possible to observe in Figure 4 those mentioned technologies are now more central in the overall network and the distance among each other is substantially reduced, which points to a strength in their co-adoption. However, the network highlights also a certain number of firms that seems will remain at the margin of the technological space. All the firms in the green cluster (which are around one-fourth of the total adopter firms) intend to co-adopt in the future a maximum of 3 technologies. A technological divide seems therefore to arise between firms belonging to the green cluster and those of the pink cluster which are aimed to reach a very high level of internal technological intensity in the adoption of technologies. While in the former case, firms risk remaining with a minimum technological investment not sufficient to support a substantial rerouting, in the latter case firms will have probably the possibility to explore real transformation in the traditional business models.

**Fig. 2.** The forecasted future evolution of firms' technological space




Source: Our own elaboration of the Unioncamere dataset 2020 using UNICET software (Borgatti Everett & Freeman 2002). Node size corresponds to the number of adopters of that technology in the sample firms. The shape of the node indicates when square a technology when round a firm. A tie between a firm and a technology is formed when a firm adopts that technology. Firms are clustered in different colors on the base of their technology intensity: green = up to 3 ties; blue from 4 to 7 ties; pink if 7 or more ties.

## 5 Discussion and Conclusions

Findings show that manufacturing SMEs are strengthening trajectories where the co-adoption of different technologies is in place, taking a common direction of technological development in relation to the wave of digital technologies. Consistently with previous studies, we find that there is typically a lack of strategic resources and vision navigating most of the SMEs through the digital transition (Mittal et al., 2018). However, the investigated manufacturing SMEs shows that there is a sense of direction of technological development in relation to the wave of digital technologies that seems commonly taken. Our findings emphasize, on one hand, the strong path dependency of the digital trajectory where the digital transition is shaped by the SMEs' technological space; on the other hand, how a common sense of the technological trajectory could be drawn by the firms' population while those technologies are adopted. Firms of our sample are building technological adoption trajectories towards downstream innovation and servitization processes. The implementation in the management data systems and the closer move of big data to cloud services points for example to an increase of data access strategies in the targeted SMEs for supporting the

share of information tools, applications, and analysis within the value chain, and with the main aim to implement clients' services and post services activities.

The investigated cases of the firms on the edge show that virtuous firms ride the technological learning curve investing in multiple, complex, and interconnected technologies and exploiting technologies complementarities to change their business model. While the actual technological trajectory is occupied, those are the companies that could orient more manufacturing activities towards profitable and new intangible values. However, while in this we observe a trajectory that can support even traditional manufacturing firms in the servitization processes, on the other hand, we also witness the widening of the digital divide. In 2020, nearly half of the manufacturing companies had not yet invested in technology, and the analysis of the predictive network reveals a certain divide in the ongoing trends. Are we witnessing a 'digital divide' in the technological development trends of manufacturing SMEs?

The implications of this observation are significant. On one side, there is a potential for manufacturing firms to leverage intangible assets and services, aligning with the evolving market demands (De Propris and Bailey, 2020; Lombardi et al., 2022). On the other side, the digital divide among companies could hinder the overall progress and competitiveness of traditional manufacturing. To address this, policymakers and industry leaders must consider strategies that promote learning when technology is still uncertain, and decision-making is not a trivial process. We need policy tools able to support technological trajectories that are commonly defined by the targeted population and embed a common sense of direction. When firms are lagging, it is better to first train them than provide them funding for investing.

To obtain a more robust analysis, further research should focus on a larger sample and different geographical settings. Moreover, a longitudinal analysis based on updated data is particularly interesting considering the dynamic nature of learning processes. Investigating in-depth firms' internal factors that influence a specific learning position of the firms within the technological space is also one of the future directions that this study can take with the disposal of more data at the firm level.

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## **Appendix A –** List of interviewed SMEs

| Code (anonymized firms) | Interview date | Interviewee | Sector | Main Activity | Size |
|---|---|---|---|---|---|
| A | 27-Oct-20 | R&D manager | Electrical and electronic machines | Machines and software for the textile sector | Small |
| B | 28-Oct-20 | Owner | Production of metals and metal products | Laser cutting of laminates, tubes, and beams | Small |
| C | 29-Oct-20 | CEO | Production of metals and metal products | Components for refrigeration in the industrial and air conditioning sector (manifolds, pipes, bends) | Medium |
| D | 04-Nov-20 | CEO | Wood and furniture | Chairs | Medium |
| E | 11-Nov-20 | CEO | Rubber. Plastic | Plastic molding | Small |
| F | 18-Nov-20 | CEO | Other manufacturing firms (automation) | Industrial automation systems | Small |
| G | 20-Nov-20 | IT and production manager | Food. drinks and tobacco | Semi-finished products and flours for bread-making | Small |
| H | 24-Nov-20 | Marketing manager | Mechanic machines and apparatus | Construction of sheet metal working machines | Medium |
| J | 25-Nov-20 | IT manager and quality manager | Other manufacturing firms (chemical) | Paint products, varnishes | Medium |
| K | 02-Dec-20 | CEO; Digital manager; Engineering manager | Construction | Machinery and plants for concrete production | Medium |