SMEs @ Industry 4.0: a comparison between top and average performers

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Abstract

Purpose of the paper: *This study explores the adoption of Industry 4.0 technologies by small- and medium-sized enterprises (SMEs), evaluating if firm's economic and financial performances play a strategic role in the implementation paths.*

Methodology: *Through a quantitative survey that collected 366 questionnaires, the study used a multivariate analysis to assess the similarities and differences between two different groups of Italian manufacturing SMEs with respect to the adoption of Industry 4.0.*

Findings: *Despite some similarities in terms of adoption (technologies most adopted, most important motivations, and barriers of adoption), top performers show a higher adoption rate of robotics and big data/analytics, consistently with their orientation towards international competitiveness and the competitive strategies characterizing small firms (customization and flexibility).*

Research limits: *Despite the explorative purpose of the study, it is worth mentioning that it considers a small sample of manufacturing SMEs operating in different sectors. Future studies could investigate these comparisons, focusing on a larger sample or on fewer sectors.*

Practical implications: *Although the financial resources support and affect the implementation of Industry 4.0, especially in terms of intensity of investment, the digital transformation of SMEs is based on the firm's innovation resources and capabilities that are the result of the firm's overall strategy.*

Originality of the paper: *The research is one of the first studies that explores the effects of economic and financial performance on the implementation paths of Industry 4.0, with a focus on SMEs and with the aim to advance literature about the Industry 4.0 trajectories.*

Key words: Industry 4.0; digital transformation; digital strategy; economic-financial performance; SMEs; comparative multivariate analysis

1. Introduction

In recent years, the industrial landscape has begun undergoing a deep technological transformation concerning the full digitalization of business processes (Frank *et al.*, 2019a). The peculiar feature of this fourth industrial revolution, known also as Industry 4.0, is its higher degree of complexity compared to the previous technological waves. It encompasses the integration of different digital technologies into a knowledge-based production system (Kagermann, 2015) and products (Porter and Heppelmann, 2014, 2015) in order to face the growing complexity of markets and competition. The Industry 4.0 paradigm embraces several enabling technologies. Focusing on the production, operation, and services related to the manufacturing industries, scholars have outlined different enabling technologies as follows: big data and analytics, cloud-computing, Internet of Things (IoT), cybersecurity, simulation, value-chain integration systems, additive manufacturing, augmented reality (AR), and artificial intelligence (AI) (Dalmarco *et al.*, 2019; Lee *et al.*, 2018).

Some of these technologies affect the manufacturing processes and outputs, from the optimization of the overall production process (through an effective use of inputs, less waste, lower production time, higher control, and support over operation phases) to the improvement of prototyping, new product development, and customization processes (Fettermann *et al.*, 2018). Production optimization is related to adopting technologies such as robotics (autonomous and collaborative robots), simulation, and AR (Lu, 2017). The improvements of product development and customization are related to the adoption of additive manufacturing technologies, such as 3D printing, which allows firms to enhance the customers' active role in producing (design and production) personalized products (Rayna and Striukova, 2016). Other technologies, such as AI, big data, and IoT, are mainly used for marketing through an effective customer targeting and offering; they are used on the relationships along the value chain as well as on the strategic approach to markets and supply chain activities (Schrauf and Berttram, 2016; Büchi *et al.*, 2020).

The firm's information technology (IT) maturity, referring to the IT infrastructure and digital skills is considered essential for the implementation of Industry 4.0 (Mittal *et al.*, 2018). However, recent research shows that the main hurdle that firms need to overcome, in approaching Industry 4.0, is the financial constraints (Arnold and Voigt, 2019; Piccarozzi *et al.*, 2018). In particular, this issue is particularly relevant for SMEs, where the amount of financial resources available could represent either the main risks of Industry 4.0 failure (Moeuf *et al.*, 2018) or the driver for a positive adoption (Tortorella and Fettermann, 2018). In this regard, several government initiatives were implemented in Europe to financially support firms in the adoption of new technologies (Sony and Naik, 2019). Among those initiatives, the Italian Government launched the Industry 4.0 National Plan in 2016 to foster the implementation of Industry 4.0 within the manufacturing industries (Agostini and Filippini, 2019) and to give financial support to the manufacturing firms for adopting Industry 4.0 technologies (Bettiol *et al.*, 2020, Lucchese *et al.*, 2016).

The literature on Industry 4.0 focused on the barriers, drivers, and benefits of firms adopting it (Dalenogare *et al.*, 2018). Despite this growing attention, little is known about the role of economic and financial performances on the patterns of adoption and the use of Industry 4.0 technologies in the realm of SMEs. In other words, the literature did not investigate if and how the economic and financial issues influence the probability and intensity of adopting those technologies. In this regard, the study aims at filling this gap by exploring the adoption of Industry

4.0 technologies between the SMEs with higher economic and financial performances (top performers) and the SMEs with average performances (average performers). In so doing, the study assessed-through an online survey that collected 366 questionnaires (166 top and 200 average performers) - the type of technologies adopted by the two different groups of SMEs, the role of firm strategy (motivations and barriers of adoption), firm resources (IT and skills), and of the public financial support, in order to verify differences and similarities between top and average performers that adopted Industry 4.0 technologies.

Following existing literature on the analysis of the technology adoption paths between different groups of firms (Oettmeier and Hofmann, 2017), we adopted a multivariate analysis of variance (chi-square and t-test) method based on data collected through a survey on Italian manufacturing SMEs. The study mainly works to advance literature on the digital transformation of SMEs by showing how economic and financial performances strategically affect the implementation of Industry 4.0 in terms of both drivers and barriers of adoption. In so doing, the study stresses the higher relevance for top performers respect to the average performers of both robotics and big data with the aim to improve efficiency and develop new products to compete in the new international scenario. Moreover, the top performers have invested in the adoption of a higher number of different technologies (sum of the Industry 4.0 technologies adopted), reaching a high level of digital transformation (Mittal *et al.*, 2018). In this case, the higher levels of economic and financial performances may be directly linked to the investment in more different technologies. Another contribution addresses the role of public funds in supporting the diffusion of Industry 4.0 in Italy. Paradoxically, access to the national funds for the adoption of Industry 4.0 technologies has been particularly important for top performers rather than average performers, showing that there is not a direct relationship between the lack of financial resources and the access to public resources.

2. Theoretical background

2.1 Industry 4.0 enabling technologies

The digital transformation of manufacturing industries through Industry 4.0 is driven by the adoption of a large set of technologies (Lu, 2017)-even if scholars and practitioners focused only on those considered the pillars of the Industry 4.0 technological revolution (Agostini and Filippini 2019; Moeuf *et al.* 2019)-that allow firms to improve in different domains, from product development and design to operation and logistic activities, as well as marketing activities (Dalenogare *et al.*, 2018).

Considering Industry 4.0 as a new manufacturing approach that relies on technologies able to gather and analyse data in real time, in order to control and customize the production processes, we have limited the scope of our review to empirical studies concerning the adoption of the following enabling technologies (Agostini and Filippini 2019; Büchi *et al.* 2020; da Silva *et al.* 2019; Mitra *et al.* 2018; Mouef *et al.* 2020; 2018):

- *Advanced and innovative robotics* concern interconnected and modular

production systems (i.e., automatic machinery, autonomous and advanced robotics, collaborative robots, etc.) that use robots and machineries connected with other information technologies, such as sensors, artificial intelligence, machine-learning, IoT, cloud computing, big data, and/or 3D printing. Such types of technologies are used principally in the production processes for their effects on productivity and employment (Daim *et al.*, 2018).
- *Additive manufacturing* refers to the use of 3D printing technology that bases on the additive production which creates products by building up layers of plastic, metal or other material, directly from digital design files. 3D printing enables firms to improve the design, prototyping, and production of complex products as well as the customization of products (Candi and Beltagui, 2019).
- *Systems integration* considers the integration offered in two directions: internal and/or external. The former (horizontal integration) regards the integration of information systems within the internal business areas (Veile *et al.*, 2020). The latter (vertical integration) concerns the integration of information systems between the firm from one side and its suppliers and customers from the other side. Vertical integration systems allow manufacturing improvements as they could reduce production costs and improve productivity and product quality due to more effectiveness of incoming and outgoing supply chain activities (Fiorini *et al.*, 2019).
- *Big data and analytics* are technologies, tools, and techniques used to gather, archive, and analyse huge amounts of data coming from smart products, smart manufacturing systems, and people interconnected and integrated within the firm's environment as well as the environment around it. Such technologies could enable the firm to improve the production processes and product quality and customization due to the possibility of using the knowledge emerged from the analysis of data and affecting the decision-making process, thereby making it more effective (Raguseo, 2018).
- *Cloud computing* technologies are adopted to manage the storage and processing of large amounts of data with high performance in terms of speed, flexibility, and efficiency. Most of the time it is combined with other technologies, such as Enterprise Resource Planning (ERP) and/or big data, allowing the real-time sharing of information across business areas and external networks and ensuring data for different purposes in the production of other business domains (Gupta *et al.*, 2019).
- *Artificial intelligence (*AI) addresses technological solutions developed to act alone without human intervention to solve problems that would typically require it. It is "a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation" (Haenlein and Kaplan, 2019, p. 5). Artificial intelligence affects the firm's decision-making process with positive effects on several applications, from production processes (Lee *et al.*, 2018) supporting productivity and quality, to marketing improving customer services and customization (Davenport *et al.*, 2020).

- *Cybersecurity* technologies include technological measures developed to ensure the security of information and data flows moving in the online environment over interconnected corporate systems. The increasing use of inter-connected technologies makes the smart manufacturing systems vulnerable to cyber risks (Tuptuk, 2018).
- *Augmented reality* (AR) is a series of technologies and devices used to simulate an environment containing real and virtual objects with the aim to improve production processes by enhancing design, prototyping, and product development; reducing set-up costs; processing time-receiving information in real-time, and providing virtual training. In this way, the human performances increase through the ability to reproduce and reuse digital information and knowledge to support the operation activities (Uva *et al.*, 2018). In particular, AR is considered a key technology for the development of smart manufacturing systems as it makes possible the shift from mass production to mass customization (Uva *et al.*, 2018).
- *Internet of Things* (IoT) refers to technologies, devices, and sensors that favour the integration among people, products, and machines. Internet of Things creates a new world in which objects can automatically communicate in real-time, providing valuable feedbacks and information that improve services for the benefit of mankind (Sestino *et al.*, 2020).

Industry 4.0 is characterized by the integration and interoperability of enabling technologies that allow the digitalization of business processes within and beyond the boundaries of the organization (Lu, 2017). However, Industry 4.0 technologies affect the business processes in a different way, allowing firms to implement them in different business functions for different purposes linked to the benefits they expect (Dalenogare *et al.*, 2018). Despite the key role of strategic expectations about the benefits of the use of Industry 4.0 technologies, the implementation depends on other factors that act as constraints of adoption, such as financial resources (Mittal *et al.*, 2018).

2.2 Drivers and barriers of Industry 4.0 implementation

Initially, the digitalization strategy based on Industry 4.0 aimed at automating and optimizing the manufacturing processes with the main purpose of increasing productivity and efficiency (Sanders *et al.* 2016). In this first step, firms aimed principally to automate the production processes through the adoption of advanced and innovative robots (Mittal *et al.*, 2018). In a second step, other types of strategic purposes arose, mainly linked to market benefits (Chiarini *et al.*, 2020). Within this new technological revolution, production and market goals play a joined role as they could enable firms to implement a mass customization and personalization strategy (Wang *et al.*, 2017). This is very important for SMEs' growth because it puts together the marketing-benefits of a single (customized) batch with the cost-benefits of mass production (Fogliatto *et al.*, 2012). The linkage between technologies and new managerial opportunities relates to the effects that the different technologies may have on the different business processes (Liao *et al.*, 2017). Recently, scholars have identified several impacts of this, including the increase of productivity, production efficiency, flexibility, and environmental sustainability from the side of manufacturing domains (de Sousa *et al.*, 2018; Fettermann *et al.*, 2018; Tortorella and Fettermann, 2018). They also recognize the rising of product quality and customization, the reduction of time-to-market response, the new role of consumers and suppliers interactions along the value chain (Bogers *et al.*, 2016; Leeflang *et al.*, 2014), the impact on the business model (Wei *et al.*, 2017), and the increase of servitization (Bortoluzzi *et al.*, 2019). The benefits expected from the use of the new technologies become strategic drivers of adoption (Agrawal *et al.*, 2018).

The adoption of new technologies also depends on some challenges that firms have to face. This is particularly true in the realm of SMEs that have specific features that may undermine the adoption of the concept of technologies (Moeuf *et al.*, 2020). As already shown for the adoption of previous technologies (Haug *et al.*, 2011), SMEs may find it difficult to adopt Industry 4.0 technologies in relation to specific constraints. Recent research highlights some internal and external constraints/barriers for SMEs (Horváth and Szabó, 2019; Masood and Sonntag, 2020; Mittal *et al.*, 2018) that may be summarized as follows:

- lack of financial resources;
- lack of adequate technological assets;
- lack of adequate internal and/or external information systems;
- lack of adequate skills/expertise;
- reluctance towards opportunities, most of the time linked to the long implementation time.

Among the different barriers, researchers have broadly investigated the lack of financial resources (Kiel *et al.*, 2017; Mittal *et al.*, 2018; Müller *et al.*, 2018) in relation to the comparison between SMEs and large firms (Horváth and Szabó, 2019). Such works have suggested that the lack of financial resources is a significant obstacle to implementing Industry 4.0. To overcome this obstacle, several national governments of advanced economies, such as the Italian government, introduced public financial initiatives to support SMEs in the implementation of Industry 4.0 (Capestro and Kinkel, 2020). Those initiatives aim to reduce barriers, to foster digital transformation, and to increase the number of firms that could benefit from new technologies. The public financial support is an exogenous event that could reduce the risk of the SMEs in investing in such technologies and, in doing so, could enlarge the number of firms that use Industry 4.0 technologies to improve their competitiveness. However, the firm's availability of financial resources, as literature points out (Frank *et al.*, 2019a), could be relevant for adopted Industry 4.0 technologies affecting the intensity (number of technologies) and the breadth (variety of technologies) of Industry 4.0 investment (Agostini and Nosella, 2019, Büchi *et al.*, 2020). Hence, our main research question is as follows: *Do SMEs with different levels of economic and financial performances follow different Industry 4.0 implementation paths?*

In addition, SMEs with different financial resources could be driven by different strategic motivations in adopting this paradigm. In particular, they may be driven by different expected benefits that the new technologies will allow them to achieve (Dalenogare *et al.*, 2018). Beyond financial resources, several scholars hypothesized the relevance of specific characteristics of the firm, i.e., Strategy, Research and Development (R&D), and Marketing, in the adoption of technologies (Laforet, 2009), as well as of Industry 4.0 (Dalenogare *et al.*, 2018; Müller *et al.*, 2018). In this vein, it is not the dimension (small or large) of the firm that is relevant but its strategic drivers. Despite this growing interest, there is a lack of empirical evidence on the relevance of firms' strategic drivers. Therefore, the study tries to answer a second research question: *Are there any differences about the strategic drivers of adoption between the SMEs with different economic and financial performances?* In so doing, the paper also aimed at assessing the role of internal skills and if there is a direct relationship between the lack of financial resources and the access to the public financial funds.

3. Methodology

To assess if economic and financial performances may play a role in differentiating the implementation of Industry 4.0 by SMEs, we have taken into consideration two different groups of SMEs with different levels of economic and financial performances. Specifically, the two groups include one group of SMEs with economic and financial performance indicators above the average values of the population (named top performers), and to another group of SMEs with economic and financial performance indicators equal to the average values of the population (named average performers). The two groups of SMEs (top and average performers) and the related performance indicators used to identify them are based on an Italian bank report[1] (respectively for the top performers → Average Turnover 2016-2018: €7.1 million; Average Turnover growth 2016-2018: +15.8%; Average ROE: 2016-2018 = 20.1%; for the average performers → Average Turnover growth 2016-2018: €4.6 million; Average Turnover growth 2016-2018: +4.3%; Average ROE: 2016-2018 = 8.0%). Both groups include SMEs operating in the main manufacturing "Made in Italy" sectors-mechanics, fashion, food, home system, and furniture-as well as in other relevant industries, such as in addition to automotive, chemical, and pharmaceuticals; logistic and transport, and building-related productions and technology. The choice that the different economic and financial indicators use to identify the two SME groups is based on opportunistic methodology. The choice about the use of multi-industry samples is based on recent literature on the topic (Cimini *et al.*, 2021; Pirola *et al.*, 2019). Both choices are suitable for exploratory purposes.

After identifying the two groups of SMEs, a CAWI-based survey[2] was carried out between September 2019 and February 2020. The

[1] Banca IFIS, Market Watch PMI Fattore I, https://www.bancaifis.it/app/uploads/2020/06/MW-PMI-Fattore-I-febbraio-2020.pdf

[2] A CAWI survey, acronym of Computer Assisted Web Interviewing, is a web-based data collection methodology based on a questionnaire provided with a link, in a panel, or a website, to the respondents that autonomously answer the interview by computer, tablet, smartphone, or any other device.

questionnaire was sent to a stratified sample of 1,986 top-performing firms and to a stratified sample of 4,808 average-performing firms, randomly selected and resulting in a total of 366 questionnaires. Specifically, 166 questionnaires (representing about 8% of the sample considered with a response rate of 8.4%) refer to SMEs with higher financial performances and 200 questionnaires (representing about 3% of the sample considered with a response rate of 4.2%) refer to SMEs with average performances. The sample stratification and the random selection of both samples (top and average performers) allowed all sectors to be investigated, enhancing the generalizability of the study as past research has shown (To and Ngai, 2006).

The questionnaire has several sections. First, it outlines the firm's competitive characteristics, such as industry, firm size, percentage of export and R&D expenditure on turnover, the type of market-Business-to-Business (B2B) or Business-to-Consumer (B2C)-the competitive factors (O'Regan *et al.*, 2006), and the Information and Communication Technologies (ICT) firms already use. Then, the survey focused on the assessment of the Industry 4.0 implementation, both in terms of technologies adopted as well as of strategic decisions that drive the adoption. In particular, the adoption of the technologies listed in the Industry 4.0 Italian National Plan (Agostini and Filippini, 2019) were assessed through a binary variable (yes or no) with a multiple-choice option. The investigated technologies are as follows: advanced and innovative robotics (robotics), 3D printing, value chain integration systems (integration systems), big data and analytics (big data), cloud computing (cloud), AI, cyber-security technologies, AR, and IoT.

As far as the assessment of strategic variables related to the digital transformation, the questionnaire assessed both the motivations and the barriers of adoption (Dalenogare *et al.*, 2018; Müller et al, 2018) as well as the link between Industry 4.0 and digital skills through a five-points Likert scale (completely disagree = 1; completely agree = 5) and, finally, the access to the government financial supports through a dichotomous variable (1 = yes; 0 = no). According to the exploratory purpose of the study, we performed a multivariate analysis of variance (chi-square and t-test) for the variables investigated, with the aim at comparing top and average performers. The core analysis has taken into consideration the adoption firms of top- and average-performing groups. For the sample descriptive statistics, the analysis was also performed to explore the differences between adopting and non-adopting firms within the two main groups (top and average performer) of SMEs.

4. Results

4.1 Descriptive results

The first step of analysis focused on the description of the sample and a preliminary evaluation of the two different groups of SMEs (top vs. average performers). Technology, mechanics, constructions, and food are the main sectors composing both groups. The overall sample shows an adoption rate of 49.2% (186 firms adopted at least one of the Industry 4.0 technologies investigated), with significant differences between the two groups (see Table 1). In the top performer group, 60.8% (101 of 166) adopted at least one of the Industry 4.0 technologies investigated. Instead, for the average performer group, the adoption rate was 42.5% (85 of 200). In addition, Table 1 shows that top and average performers are mainly composed of B2B firms with a proprietary brand and the suppliers localized in the company's region and/or in Italy.

Tab. 1: Descriptive statistics

Descriptive	Overall sample			Adopters			Top performers			Average performers		
	Adp vs No-adp		Sig.	Top vs Avg		Sig.	Adp vs No-adp		Sig.	Adp vs No-adp		Sig.
Industry 4.0 adoption	49.2%	50.8%		54.3%	45.7%	***	60.8%	39.2%	***	42.5%	57.5%	***
Employees (avg. 2018)												
Total	29.8	18.8	***	36.2	22.2	*	36.2	20.0	**	22.2	16.3	°
Graduate/ Technical	10.3	5.6	**	13.8	7.7	*	13.8	4.9	**	7.7	4.1	°
Export (% on turnover 2018)	33.6%	21.8%	***	35.0%	23.8%	*	35.0%	31.5%		23.8%	20.3%	
R&D (% of turnover 2018)	7.3%	5.4%		8.0%	7.9%		8.0%	6.1%		7.9%	3.6%	**
Market												
B2B	93.0%	83.3%	**	95.0%	90.6%		95.0%	87.7%	°	90.6%	80.9%	°
Buyer brand	*32.7%*	*29.5%*		*30.2%*	*28.6%*		*30.2%*	*36.8%*		*28.6%*	*30.1%*	
Owner brand	*67.3%*	*70.5%*		*69.8%*	*71.4%*		*69.8%*	*63.2%*		*71.4%*	*69.9%*	
B2C	7.0%	16.7%	**	5.0%	9.4%		5.0%	12.3%	°	9.4%	19.1%	°
Supplier's location												
Company's region	44.4%	52.8%	*	42.2%	47.1%		42.2%	50.5%		47.1%	54.0%	
Italy (other regions)	38.9%	34.6%		40.5%	37.0%		40.5%	33.8%		37.0%	35.2%	
Abroad	16.7%	12.6%	°	17.3%	15.9%		17.3%	15.7%		15.9%	10.8%	
N	166	200		101	85		101	65		85	115	

Notes: Adp = I4.0 adopters, No-adp = I4.0 non-adopters; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ° $p < 0.10$.

Source: Authors' elaboration

Top performers have more skilled resources and a higher international orientation compared to the average performers (Table 1). The same significant differences characterize the adopters respect the non-adopters, with the top performers showing higher values for employees and export rate. Instead, comparing adopters and non-adopters of both top and average performers determined that adopting firms have a significantly higher number of employees and of graduate and/or technical diplomas (total employees: 36.2 vs. 20.0, $p < 0.01$; graduate/technical employees: 13.8 vs. 4.9, $p < 0.01$ for the top performers; total employees: 22.2 vs. 16.3, $p <$

0.10; graduate/technical employees: 7.7 vs. 4.1, $p < 0.10$ for the average performers).

The second preliminary step of analysis focused on the comparison of the competitive factors. For both groups, production flexibility is the most important competitive factor and price is less important (but with statistically significant differences between the two. Respectively, 22.5% vs. 12.5%, $p < 0.05$; values based on high/very-high answers of the five-point Likert scale). This is also true for the adopting firms of both groups of SMEs. Instead, considering the adopters group, the only significant differences between top and average performers refer to the higher importance of *product uniqueness* and *variety* for each (respectively, 63.4% vs. 52.9%, $p < 0.05$; 50.5% vs. 37.6%, $p < 0.10$). Within the non-adopters, no differences arise between top and average performers.

In order to frame the Industry 4.0 investment strategy of firms, an additional analysis refers to the assessment of ICT endowment (see Table 2) that can show a firm's technological trajectory (Bettiol *et al.*, 2019). There are interesting differences emerging among the groups. As one might expect, analyses confirm a difference between top and average performers with the former being more technologically advanced than the latter, especially in relation to the technologies' ability to manage business processes (such as ERP, 58.4% top vs. 45.5% average performers, $p < 0.01$) and customers (CRM, 52.5% top vs. 28.5% average performers, $p < 0.001$).

Tab. 2: ICT

ICT	Overall sample			Adopters			Top performers			Average performers		
	Adp vs No-adp		Sig.	Top vs Avg		Sig.	Adp vs No-adp		Sig.	Adp vs No-adp		Sig.
Website	93.0%	92.2%		94.1%	96.5%		94.1%	89.2%		96.5%	90.4%	
Social Network	57.2%	61.0%		69.3%	62.4%		69.3%	38.5%	***	62.4%	60.0%	
E-commerce	9.0%	6.5%	*	5.9%	12.9%	°	5.9%	13.8%	°	12.9%	19.1%	
Enterprise Resource Plan. (ERP)	58.4%	45.5%	**	67.3%	54.1%	°	67.3%	44.6%	**	54.1%	37.4%	*
Customer Relationship Man. (CRM)	52.5%	28.5%	***	64.4%	40.0%	**	64.4%	33.8%	***	40.0%	20.0%	**
Supply Chain Man. (SCM)	16.9%	9.0%	**	18.8%	12.9%		18.8%	13.8%		12.9%	6.1%	°
ICT intensity												
One ICT	12.7%	15.5%		4.9%	10.6%		4.9%	24.6%	***	10.6%	19.1%	°
Two ICT	27.7%	36.0%	°	23.8%	32.9%		23.8%	33.8%		32.9%	38.3%	
Three ICT	30.1%	32.5%		31.7%	33.9%		31.7%	27.7%		33.9%	30.6%	
Four+ ICT	29.5%	16.0%	**	39.6%	25.9%	*	39.6%	13.9%	***	25.9%	8.7%	**
N	166	200		101	85		101	65		85	115	

Notes: Adp = I4.0 adopters, No-adp = I4.0 non-adopters; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ° $p < 0.10$.

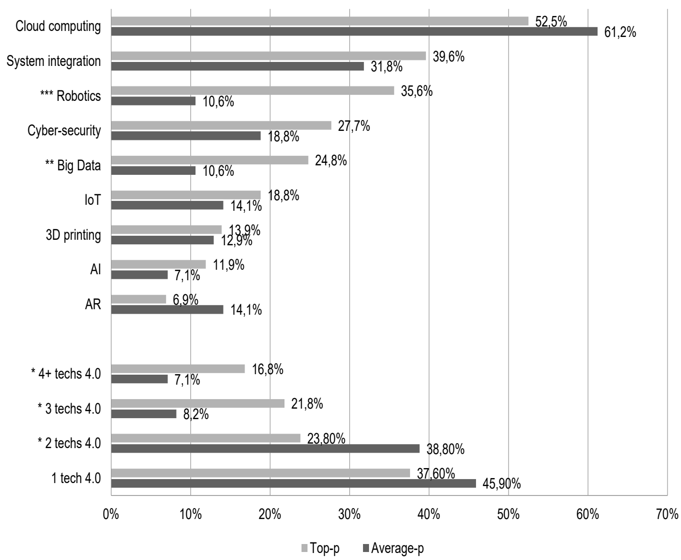
Source: Authors' elaboration

Top performers also show higher ICT intensity consistently with prior studies (Hendricks *et al.*, 2007). Focusing on adopting firms, the comparison between top and average performers shows similar differences, and specifically the higher use of CRM (64.4% vs. 40.0%, $p < 0.01$) and the use of a highest number of ICT (four or more ICT: 39.6% vs. 25.9%, $p < 0.05$) of the top performers. Finally, the most interesting results concern the differences between adopters and non-adopters. Indeed, such differences are similar in both the top and average performers. The adopters of both groups have, in general, higher rates of adoption in relation to the different technologies (especially the more complex ones, i.e., ERP) and a higher ICT endowment compared to non-adopters.

4.2 Industry 4.0 results

The core of our analysis is related to the implementation of Industry 4.0 comparing top and average performers. Firstly, as shown in Figure 1, the analysis aimed to evaluate the differences in the adoption rate of the single enabling technologies of the Italian Industry 4.0 National Plan as well as the intensity (number of different technologies adopted) of Industry 4.0. Cloud is the technology most adopted by both groups. Except for cloud and AR, top performers show higher adoption rates for all the technologies investigated, but the only significant differences refer to the robotics (35.6% top vs. 10.6% average performers, $p < 0.001$) and to big data and analytics (24.8% top vs. 10.6% average performers, $p < 0.01$). Consistent with the evidence on ICT endowment, top performers adopted a higher number of Industry 4.0 technologies (three or more technologies) with respect to the average performers.

Fig. 1: Industry 4.0 adoption

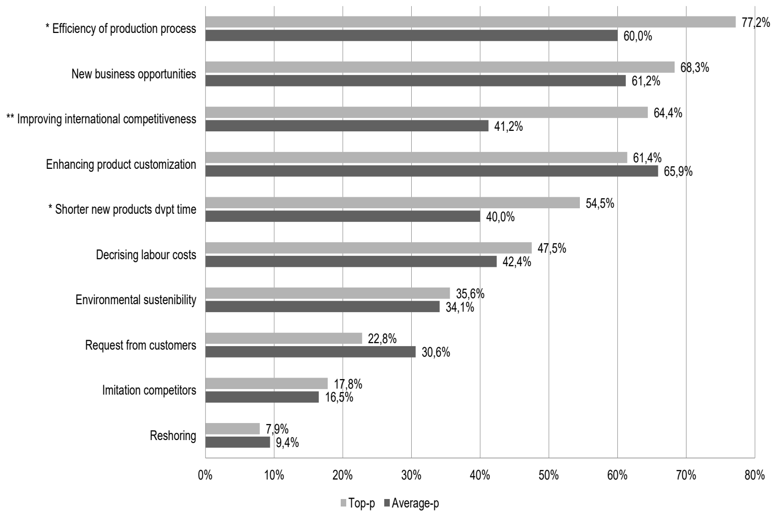


Notes: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; top performers = 101, average performers = 85.

Source: Authors' elaboration

The Industry 4.0 implementation seems to follow a specific technological trajectory that depends on the firm's overall strategy (Agrawal *et al.*, 2018) and this emerges from the motivations of adoption reported in Figure 2.

Fig. 2: Motivations for adopting Industry 4.0 technologies



Notes: ** $p < 0.01$; * $p < 0.05$; top performers = 101, average performers = 85.

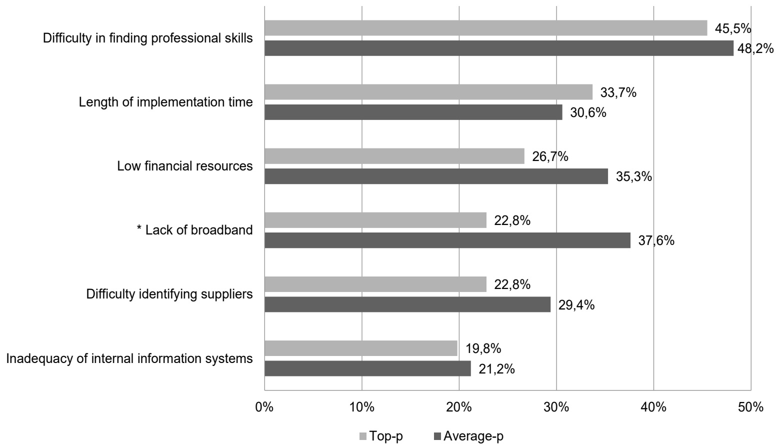
Source: Authors' elaboration.

Top performers' main motivation for adoption is improving the production process efficiency, which is significantly different from the group of average performers (77.2% vs. 60.0%, $p < 0.05$). This correlates with the higher investments in technologies used in the production domain, such as robotics, that characterize the top performer adopting firms. Other significant differences refer to the higher relevance of adoption related to the improvement of international competitiveness and the new product development process for the top performers in respect to the average performers (respectively, 64.4% vs. 41.2%, $p < 0.05$; 54.5% vs. 40.0%, $p < 0.01$). In this case, facing international competitiveness plays a key role for the implementation of Industry 4.0.

The analysis on the barriers of adoption shows that top and average performers are very similar (see Figure 3). For both groups, the main barrier relates to the difficulty in finding professional competences related to Industry 4.0, followed by the length of the implementation process. The only significant difference among the two groups of adopters refers to the higher lack of broadband for average performers when compared to the top performers (respectively, 37.6% vs. 22.8%, $p < 0.05$). Despite the similarities between adopters in the difficulties of finding key competences to manage Industry 4.0 adoption, the comparative analysis between top and average adopting firms highlighted a significantly higher investment of top performers in the recruitment of new competences to manage the

Industry 4.0 technologies (54.7% vs. 45.1%, $p < 0.05$). Instead, both top and average performers stated that the adoption and use of new technologies needed of specific training courses.

Fig. 3: Barriers of Industry 4.0 technologies adoption



Notes: * $p < 0.05$; top performers = 101, average performers = 85.

Source: Authors' elaboration

Finally, as far as access to public financial funds to support Industry 4.0 investments are concerned, in a counterintuitive way, the comparison between the two groups of adopting firms showed that 34.2% of top performers compared to only 21.0% of average performers requested and accessed public funds. This could be interpreted as the top performers' stronger ability to gain access to public incentives for innovation. This interpretation is supported by the fact that top adopting firms show higher willingness in future adoption of the Industry 4.0 technologies (64.3% vs. 40.0%, $p < 0.01$), even without public funds.

5. Discussion

The multivariate analysis performed to compare the Industry 4.0 implementation paths of SMEs with different levels of economic and financial performances highlighted some interesting findings. Despite the differences in the performance profiles, the adopting firms of both groups show similarities that highlight common features at the basis of digital transformation-such as the human resource endowment (Schneider, 2018) and the R&D investments that may be considered as baseline resources that stress the firm's readiness for digital transformation (Mittal *et al.*, 2020). Research and development activities are essential for the successful implementation of Industry 4.0, independent from the firm size or from performance (Szalavetz, 2019). Indeed, top and average performers adopting Industry 4.0 technologies have a similar R&D expenditure percentage. This result suggests that the financial endowment may support the adoption, but the firm's innovation resources and capabilities are the main dimensions that may affect the investment in new digital technologies, consistent with their broader innovative strategies.

Prior to analysing the Industry 4.0 implementation, we performed a comparative analysis aimed at exploring the ICT endowment of two groups of SMEs. The use of previous technologies could be seen as a strategic enabling factor that may affect the adoption of new technologies as well as the type of technologies adopted because of the relevance of dynamic capabilities that SMEs could improve over the years (Lin *et al.*, 2016). The most interesting results of the ICT endowment concern the differences between Industry 4.0 adopters and non-adopters. In this regard, the differences between adopting and non-adopting firms are similar for both the top and average performers groups. The adopting firms of both groups are technologically more advanced as they show a higher percentage of all technology use and of the number of ICT used and have some specific features and maturity that do not depend from the level of performance (Mittal et al 2018). Instead, respect to the differences between the top performing adopters and average performing adopters, the former show to give a higher relevance to the management of relationships with customers. This finding may be relevant in the evaluation and understanding of the Industry 4.0 paths of the two different groups.

In regards to the Industry 4.0, cloud computing is the technology that both groups adopt the most. It could be considered a basic technology that firms need to have to manage the huge amount of data related to Industry 4.0 (Liu and Xu, 2017). Instead, in terms of differences, top performers show a higher adoption rate of robotics (advanced and innovative) and of big data and analytics. While robotics could be industry-specific, the adoption and use of big data and analytics could be related to some specific company's features and, in particular, to the human resources and availability of in-house competencies that higher performance allows them to more easily overcome (Côrte-Real *et al.*, 2017). In addition, the higher adoption rate of big data may be linked to the higher importance of CRM for top performers. The relevance of this technology is consistent with the strategic attention to the development of an offering based on product variety that, in addition to flexibility and product customization, represents a key competitive feature of adopting top performers and adopters more generically. Such results highlight the key role of the differentiation strategy for the top performers, where flexibility and product uniqueness are the main sources of competitiveness, in addition to cost-effectiveness. Moreover, consistent with the evidence on ICT endowment, top performers are adopted in a significantly higher number of technologies than average-performing adopters. This could be related to the differing levels of economic and financial performances.

When it comes to the motivations for adoption, top and average performers put the main emphasis on efficiency, new business opportunities, and product customization. However, for the top performers the production efficiency is much more important than for the average performers and the former group significantly differs from the latter in terms of higher relevance of the international competitiveness and the development of new products. In this sense, the adoption of new technologies may allowing to face the global competition enhancing product quality and production efficiency as well as improving flexibility (Fatorachian and Kazemi, 2018), thereby reducing the competitive distance with the larger multinational companies (Horváth and Szabó, 2019). The analysis of adopted technologies and the motivations of adoption outline some interesting differences between top and average performers. The former adopts more technologies to manage the different business process as well as the data created within the Industry 4.0 paradigm; this is related to the enlarged global competition that they have to face (Agostini and Nosella, 2019).

Finally, in terms of barriers of adoption, despite the similarities in the difficulties of finding key competences to manage Industry 4.0 adoption, the comparative analysis highlighted as top performers have significantly invested in the recruitment of new competences to manage new technologies. This finding could be related to the breadth of Industry 4.0 technologies adopted that may require different skills (Orlandi, 2016), showing also a higher willingness to invest in the future in Industry 4.0 to compete.

6. Conclusions

The study aimed at evaluating the adoption paths of SMEs by exploring the role of economic and financial performances in the implementation of Industry 4.0. Top performers are able to adopt several, and most of time complementary, Industry 4.0 technologies, acting like larger firms (Horváth and Szabó, 2019). Moreover, top performers, when compared to average performers, are more interested in the production domain of being competitive in an international scenario by means of efficiency (Fettermann *et al.*, 2018) and without losing control over processes and markets through a higher adoption of big data and analytics that allow them to improve the product development process (Gupta *et al.*, 2019).

Theoretically, the study advances literature on the adoption of Industry 4.0 by SMEs (Horváth and Szabó, 2019; Masood and Sonntag, 2020; Moeuf *et al.*, 2020), highlighting the relevance of economic and financial performance for reducing the distance from the large and multinational companies, especially in terms of higher level of investment that may guarantee higher level of digitalization (Mittal *et al.*, 2018). Although SMEs with higher economic and financial performances are technologically more advanced, thereby stressing the relevance of financial resources in shaping the digital transformation of SMEs, the study highlights that the adopting firms of both groups show higher technology maturity when compared to the non-adopting groups. This finding could be related to the previous technological investment that could allow SMEs to improve their own digital and technological skills and capabilities, in addition to the improvement of the technological culture (Mittal *et al.*, 2018). The investment in new technologies follows a detailed business strategy as well as a technological trajectory that aims to reach certain business goals. Specifically, higher performance links to higher levels of Industry 4.0 maturity (Mittal *et al.*, 2018) with positive effects on the strategic approach to the market, pursuing contemporary efficiency and differentiation effects and thus mass customization goals (Wang *et al.*, 2017). In so doing, human resources and digital skills and competences play a key role in the implementation stage as well as for the achievement of business benefits related to Industry 4.0. Finally, this paper shows that the financial support that national governments introduced to favour the diffusion of Industry 4.0 is not directly linked to the spread of digital transformation of SMEs. In this sense, and also for receiving public funding, the firms with higher economic and financial resources are more ready than others.

6.1 Practical implications

In terms of managerial implications, our research suggests that firms approaching Industry 4.0 should have a clear technological investment strategy consistent with their overall business strategy. Firstly, prior investments in ICT could become an enabling factor that smooth the adoption of Industry 4.0 technologies, and in terms of competences, develop the digital skills and culture that are needed to approach the new technological revolution. Moreover, it should also be considered the potentialities of adopting a large breadth of technologies (captured in terms of different Industry 4.0 technologies adopted) because of the exploitation of the synergy effects of the different technologies on both processes and product innovation (Lee *et al.*, 2019). For manufacturing SMEs, our evidences highlight the potentialities of enhancing both efficiency and the offering of the firms in terms of product customization, flexibility. Investing in Industry 4.0 technologies could become an effective strategy for small firms to strengthen their international competitiveness by coupling technologies for improving production processes-both for efficiency and customization-as well as customer interaction.

At the same time, due to the higher complexity and the multi-technology adoption, SMEs should pay great attention to the specific skills needed to manage the higher complexity of Industry 4.0, as one of the most important challenges is being ready to manage several areas of (digital) transformation within the firm at the same time (Schneider, 2018). Our research also indicates that human resources are important for the successful implementation of Industry 4.0-especially in terms of breadth of adoption (number of different technologies adopted)-that needs different skilled resources. Indeed, top performers invest in skilled resources and, thus, managers should favour training. Finally, entrepreneurs/managers of average performers should be more ready to apply to public announcements to use public funds.

6.2 Research limitations and future research

The limitations of this study create opportunities for future research. First, considering the explorative feature of the research, our results could be influenced by the use of a multi-industry sample. Therefore, future studies should focus on a specific industry to better analyse how top performers differ from other SMEs with respect to the implementation of Industry 4.0. Another limitation regards the focus on a large set of technologies. It would be useful to focus on some technologies and specifically to link with the industry, especially for the technologies that affect the operation/manufacturing process. From this perspective, a limitation regards the missed analysis of value chain activities where firms used the technologies adopted. Therefore, future research should take into consideration this strategic variable as it could affect the motivations of adoption.

Furthermore, some limitations relate to the methodology and the quantitative method adopted where the use of a single source (questionnaire) could expose the results to the risk of common method variance. However, remedies were adopted to limit these potential biases, such as the use of different measures. Future research will include qualitative analysis through case study development. Finally, future research should also consider the concept of dynamic capability for deeper understanding of whether a superior performance affected the firm's technological asset that enables the development of digital and technological skills and capabilities.

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