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Technical change and digital transformation. Firms' performance and behavior in an innovation ecosystem

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Digital Transformation and firms' dynamic capabilities: a literature review

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ABSTRACT

The aim of this literature review is describing how the mechanisms underlying firms' value creation processes in a Digital Transformation environment can be better investigated and understood from the dynamic capabilities' perspective. It has been proved that digital technologies such as IoT, Big Data and Artificial Intelligence, albeit their numerous benefits, are able to provide just a little contribution to the firms' value creation if not supported by a diversified set of managerial and organizational skills. In line with this, our review tries to go beyond the technology-centric perspective of Digital Transformation, emphasizing actor-driven organizational transformation of capabilities, processes and business model components both from a supply-side (digital solution providers) and a demand-side perspective (SMEs). In this respect, the dynamic capabilities' approach provides new interesting insights on how Digital Transformation players improve their innovation performance and competitiveness.

Keywords: dynamic capabilities, Digital Transformation, innovation performance, organizational innovation, firms' performance, new digital technologies

1. Introduction

Recently, Digital Transformation has emerged as a crucial phenomenon regarded as "the most pervasive managerial challenge for incumbent firms" over the past and future decades (Nadkarni and Prügl, 2020). It has radically changed the mechanisms through which firms create and capture value, nurture business model innovation and develop long-lasting relationships with customers, providers, and other stakeholders (Bresciani, Ferraris, and Del Giudice, 2018; Scuotto, Arrigo, Candelo, and Nicotra, 2019).

The topic of Digital Transformation has gained increasing importance particularly in the strategic information system research (Cha, Hwang, and Gregor, 2015 ; Bharadwaj et al., 2013; Piccinini et al., 2015a) business organization and strategic management literature (Morakanyane, Grace, and O'Reilly, 2017; Rachinger et al., 2018; Galindo-Martín, Castano-Martínez, and Mendez-Picazo, 2019; Warner and Wager, 2019), as well as among practitioners (Fitzgerald et al., 2014; Westerman et al., 2011), leading to a significant increase in the number of papers addressing its different technological and organizational aspects.

In the context of Digital Transformation (e.g., Morakanyane et al., 2017; Piccinini et al., 2015b), part of literature has examined the transformational process of value creation through which companies take advantage of new digital technologies to redefine their business model (Osterwalder and Pigneur, 2010).

Most companies started to invest their resources on the application of cross-boundary digital technologies (Li et al., 2018), such as IoT-driven sensors (Ng and Wakenshaw 2017), 3D printing (Rayna and Striukova 2016), and Big data analytics (Dremel et al. 2017) to improve the way to create

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and exchange value with their customers (Yadav and Pavlou, 2014).

In particular, digital technologies enable firms to boost communication with extant and potential customers by providing firms with a better comprehension of their clients' preferences. Moreover, they offer to companies the possibility to create customized offerings and new products to effectively meet ever more specific customers' needs (Barnes et al., 2012) and gain a competitive advantage.

Therefore, Digital Transformation can be considered the way through which "a firm employs digital technologies to develop a new digital business model that helps to create and appropriate more value for the firm" (Verhoef et al., 2019, p.1) and its deep impact on business processes, operational routines, and organizational skills has been widely underlined (Li, Su, Zhang, and Mao, 2018).

Matt et al. (2015) have introduced the concept of Digital Transformation Strategy to analyze "the transformation of products, processes and organizational aspects owing to new technologies". The authors affirm that Digital Transformation Strategy "supports companies in governing the transformations coming from the integration of digital technologies, as well as in their operations after a transformation.". In addition, they argue that structural changes, defined as "variations in a firm's organizational setup", should be carefully taken into account to exploit digital technologies for improving the benefit of the firm in compliance with financial constraints. In line with this concept, Hess et al. (2016) investigated the Digital Transformation of three media companies in Germany and discovered that the companies' financial constraints had a strong impact on firms' capability to implement digital technologies.

In his Digital Transformation review, Vial (2019) has underlined how the use of digital technologies can affect a firm's value creation process by transforming value propositions (Huang et al., 2017) and networks, as well as digital channels. Barrett et al. (2015) affirm that digital technologies foster the development of new value propositions largely based upon the provision of services. Organizations leverage digital technologies to improve profits and sales from their physical products by offering services as an integral part of firms' value proposition in order to provide customers with innovative solutions able to satisfy their needs (Porter and Heppelmann, 2014; Wulf et al., 2017). A case in point is represented by Netflix, with an original business model based on the rental of movies stored on physical media. Over the years, Netflix has developed a new value proposition through the use of digital technologies becoming a leader in the video streaming market worldwide. Moreover, Netflix has analyzed data gathered on the use of its streaming service to improve the comprehension of their customers' preferences in order to suggest more tailored contents (Günther et al., 2017).

Digital technologies have also been described as potential drivers of new value networks (Delmond et al., 2017; Tan et al., 2015a). According to Andal-Ancion et al. (2003), a company can leverage digital technologies to implement three mediation strategies and effectively rise customer engagement's levels. In a "disintermediation strategy" digital technologies promote direct exchanges among the value network's members (Hansen and Sia, 2015), while in a "remediation strategy" digital technologies foster collaboration and coordination among participants in order to strengthen the members' linkages, for example by the use of a platform to coordinate exchanges within a supply chain (Klötzer and Pflaum, 2017). Finally, in a "network-based mediation strategy", complex relations among different stakeholders, potentially rivals in their interests, are strongly encouraged (Tan et al., 2015a) and digital technologies give customers the possibility to become value co-creators (prosumers) (Lucas Jr. et al., 2013).

Moreover, it has been demonstrated that the use of digital technologies enable disrupted changes to firms' distribution and sales channels. For instance, in the manufacturing industry, IoT-driven sensors have dramatically improved the efficiency of the supply change (Klötzer and Pflaum, 2017), while the emergence of AI-driven algorithms to incentivize the decision-making process (Günther et al., 2017; Newell and Marabelli, 2015) has given firms a priceless opportunity to effectively coordinate activities across organizations through their software applications.

In addition, extensive literature have shown how digital technologies increase firms' ability to effectively face the changes (Fitzgerald, 2016b; Günther et al., 2017; Hong and Lee, 2017; Huang et al., 2017; Kohli and Johnson, 2011) by encouraging firms "to detect opportunities for innovation and seize those competitive market opportunities by assembling requisite assets, knowledge, and relationships with speed and surprise" (Sambamurthy et al., 2003).

However, albeit their numerous benefits, digital technologies alone provide a little contribution to the firms' value creation process (Kane, 2014). Recent research has shown that it is the context where technology is used that gives firms the possibility to come up with new strategies to create value and maintain their competitive advantage in a data-driven world. The capability to ideate and implement new strategies (Bharadwaj et al., 2013; Matt et al., 2015), as well as promote organizational changes in structure (Selander and Jarvenpaa, 2016), processes (Carlo et al., 2012), and culture (Karimi and Walter, 2015) is necessary to generate new paths for value creation (Svahn et al., 2017a).

In line with this perspective, our review tries to go beyond the technology-centric perspective of digital transformation, supported by literature on technological disruption (e.g. Tushman and Anderson 1986; Anderson and Tushman 1990). Instead, we focus on the description of actor-driven organizational transformation of capabilities, processes and business model components from a supply-side (digital solution providers), as well as a demand-side perspective (small-medium firms).

The remainder of the paper is structured as follows. Section 2 introduces the dynamic capabilities' theoretical framework. Section 3 and 4 explain how this framework has been used by past literature to investigate the key role played by solution service providers and small and medium-sized firms (SMEs), respectively, in the Digital Transformation context. Section 5 presents the concluding remarks.

2. How dynamic capabilities contribute to explain Digital Transformation

Over the recent years, the topic of dynamic capabilities has emerged as a crucial concept in management and innovation literature (Di Stefano, Peteraf and Verona, 2010; Di Stefano, Peteraf Verona, 2014; Easterby-Smith, Lyles and Peteraf, 2009) and extant literature has shown an interesting link between dynamic capabilities' framework as a theoretical foundation and the nature of Digital Transformation as an economic and social phenomenon (Vial, 2019).

According to the dynamic capabilities' perspective, companies need "to continuously build, integrate and reconfigure their skills and abilities to adapt to their environment and sustain competitive advantage" (Ferreira et al., 2020; Eisenhardt and Martin, 2000). Teece et al. (1997) have probably provided the first contribution to this concept: they argue that " it is not only the bundle of resources that matter, but the mechanisms by which firms learn and accumulate new skills and capabilities, and the forces that limit the rate and direction of this process". In this respect, dynamic capabilities' approach tries to extend the resource-based view of firms by underlining firms' abilities to redefine their resource base in order to increase their level of adaptability with a changing environment, with the aim to maintain a competitive advantage (Jiang et al., 2015; Schilke et al., 2018). According to Teece (2014), firms are able to leverage both ordinary and dynamic capabilities. Ordinary capabilities refer to "the performance of administrative, operational, and governance-related functions that are necessary to accomplish tasks", while dynamic capabilities "involve higher-level activities that can enable an enterprise to direct its ordinary activities toward high-payoff endeavors". Therefore, the dynamic capabilities' approach has turned out to be more useful to examine competitive and changing environments in comparison with ordinary capabilities' framework which was not able to demonstrate how firms build and maintain competitive advantage (Teece, 2014).

Moreover, Teece in his research (2007) explains how dynamic capabilities foster firms' innovation and adaptability to changes through three main mechanisms: the "identification, development, co-development, and assessment of technological opportunities in relationship to customer needs" (sensing); the "mobilization of resources to address needs and opportunities, and to capture value from doing so" (seizing); and the "continued renewal" of firms (transforming) which reconfigure their resources to strategically seize opportunities and effectively implement strategies under threats. In light with this, Vial (2019) has elaborated a new conceptual inductive framework based on dynamic capabilities to study these mechanisms. He has emphasized the nature of Digital Transformation as a process where digital technologies support firms' abilities to sense disruptions, seize them by the implementation of strategic responses, and redefine elements of their business model accordingly.

In the recent years, other significant empirical and theoretical research on dynamic capabilities have offered valuable contribution to detect, develop, demonstrate, investigate and assess these resources in several settings. Moreover, it has been drawn up guidelines for firms to create dynamic capabilities and explore their usage in different industrial sectors, providing the evidence of their successful implementations through case studies. In this respect, various industries' aspects have been considered, including high-tech (Helfat and Peteraf, 2003), organizational learning, knowledge management (Zollo and Winter, 2002; Marsh and Stock, 2006; Ho and Tsai, 2006) and strategic management (Teece, Pisano and Shuen, 1997; Eisenhardt and Martin, 2000; Helfat and Peteraf, 2003; Zhou and Li, 2009).

Dynamic capabilities were originally identified as firms' abilities to integrate, develop and redefine internal and external competences to effectively survive in changing environments (Teece, 1997). However, Eisenhardt and Martin (2000) proposed a broader definition describing dynamic capabilities as a set of specific processes such as product development, strategic decision making, and alliancing. Following the entrepreneurship point of view, Zahra et al. (2006) pointed out that dynamic capabilities enable firms to reconfigure their resources and traditional procedures according to their main decision makers' perspective. Consistent with Teece et al. (1997) approach, Wang and Ahmed (2007) defined dynamic capabilities as "a firm's behavioral orientation constantly to integrate, reconfigure, renew and recreate its resources and capabilities and, most importantly, upgrade and reconstruct its core capabilities in response to the changing environment to attain and sustain competitive advantage". Although the seminal contributions of Teece et al. (1997) and Eisenhardt and Martin (2000), have enabled dynamic capabilities to acquire an increasingly importance in innovation and strategic management research, the fragmentation of the literature in this field still represents a relevant shortcoming (Arend and Bromiley, 2009) and it can be observed in the amount of different dynamic capabilities' definitions and conceptualizations (Ambrosini and Bowman, 2009).

Although left unexplored in the relevant literature, a particular type of dynamic capabilities, has gained increasingly attention over the recent years: integrative capabilities. Helfat and Raubitschek (2018) have described integrative capabilities as abilities which can be developed both inside and outside the firm and are able to "provide the capacity for reliable, repeatable communication and coordination activity directed toward the introduction and modification of: products; resources and capabilities; business models."

In the Digital transformation environment, external integrative capabilities are regarded as fundamental resources, since the firms' value networks to create and capture value have become increasingly broad and complex over the past years (Vial, 2019). Indeed, firms were forced to interact with a plethora of different stakeholders (Tan et al., 2015a), such as complementors[2] (Ghazawneh and Henfridsson, 2013), or customers (Li et al., 2017). In this respect, the integration of digital technologies has acquired a key strategic relevance for firms' value creation and capture, revolutionizing the traditional business process outsourcing.

Most works on Digital Transformation have underlined the need for companies to engage with other actors to create digital innovation (e.g., Hansen and Sia, 2015; Nehme et al., 2015). Therefore, sensing the extent of the changes implemented by a firm to reconfigure its processes becomes a crucial issue not only for the firms facing Digital Transformation's challenges, but also for the digital solution providers. Although research in strategic management and industrial organization has started to turn toward digital solution providers (Brusoni and Prencipe, 2011), the investigations on the impacts of these digital transformation actors on firms' abilities to adapt to disruptive changes, is still scant and superficial.

3. The role of service solution providers' capabilities in the Digital Transformation

Over the past decade, the advent of new disruptive technologies has generated new challenges for firms enjoying Digital Transformation, replacing the traditional business process outsourcing with a digital transformation one. In the attempt to effectively engage with their customer base and implement new digital technologies (Reis, Amorim, Melao, and Matos, 2018; Zinder and Yunatova, 2016) to sustain their competitive advantage (Verhoef et al., 2021), firms started to reconfigure their original value creation processes (Gulati and Kletter, 2005; Tanriverdi and Lim, 2017) relying on the expertise of digital solution service providers. Consequently, as value creation activities progressively shifted from client-firms to service providers, and as digital applications have become increasingly

[2] Complementors are business actors that directly provide products or services which complement a firm's offering by adding value to mutual customers.

pervasive in the business context, the digital transformational outsourcing started to emerge as a key phenomenon in the new data-driven environment (Mazumder and Garg, 2021).

Extensive literature has independently investigated business process outsourcing and Digital Transformation (Bharadwaj, El Sawy, Pavlou, and Venkatraman, 2013; Lacity, Solomon, Yan, and Willcocks, 2016; Vial, 2019) and undoubtedly, service providers' capabilities are found to play an important role in providing crucial outsourcing outcomes (et al., 2016, Bharadwaj and Saxena, 2010; Feeny, Lacity, and Willcocks, 2005; Lacity, Solomon, Yan, and Willcocks, 2011; Levina and Ross, 2003).
However, the adoption of a solution service providers' view in research is still scant (Jun, Qiuzhen, and Qingguo, 2011; Liang et al., 2016; Taylor, 2007) and little is known on their capabilities, as well as on the mechanisms influencing their performance in the new digitally-transformed outsourcing context.
Many researchers have been demonstrated that providers showing higher levels of human resource management, as well as methodological and technical skills, come up with better outcomes for their customers and themselves, compared with those showing lower levels of the above-mentioned capabilities (e.g., Bharadwaj and Saxena, 2010; Jarvenpaa and Mao, 2008). Lacity et al. (2016) in their business process outsourcing review, reported fifty studies and twenty-one providers' resources and capabilities. However, albeit the role of service providers' resources and capabilities has been recognized as a relevant factor in business process outsourcing decisions and outcomes (Lacity et al., 2016; Pinnington and Woolcock, 1997), the capabilities detected have not been associated with the digital transformation context (Mikalef and Pateli, 2017).

Before the advent of Digital Transformation, the main goal of service providers focused on cost reduction for client firms (Altinkemer, Chaturvedi, and Gulati, 1994). They used to offer the most effective solutions to meet their specific clients' needs. However, as client firms started to concentrate on business core activities (Prahalad and Hamel, 1990), non-core business segments ended up to be transferred to service providers and the "second-generation outsourcing" phase came to play. (Brown and Wilson, 2007; Kedia and Lahiri, 2007; Loh and Venkatraman, 1992). As a result, a critical transition from cost reduction to value enhancement has emerged, along with a reinforcement of firms client-service providers relation (Kedia and Lahiri, 2007).

Finally, in the new data-driven scenario, service providers' activities started to focus on the improvement of firms clients' value creation processes and the alignment of clients' business processes with their strategic goals (Mazzawi, 2002). In this respect, clients started to regard service providers as key allies and partners to gain and maintain their competitive advantage. Therefore, their linkage strengthened further and service providers started to be considered crucial in the reconfiguration of traditional clients' businesses and performance improvement (Brown and Wilson, 2007; Kedia and Lahiri, 2007; Linder, 2004).

In light with the new digital transformation outsourcing context, service providers are thus required to build dynamic capabilities in order to improve the understanding of customers' needs and reconfigure the client's business (Linder, 2004; Mazzawi, 2002), as well as increase their own digital service solutions portfolio (Westerman and Bonnet, 2015).

Firstly, according to Mazumder and Garg (2021), service providers operating in the Digital

Transformation context should to be equipped with specific consulting capabilities to "sense" their customers' needs and expectations, in order to propose more innovative solutions and explore new paths for value creation and capture. (Davies, 2004; Fischer, Gebauer, Gregory, Ren, and Fleisch, 2010).

Secondly, to provide innovative digital solutions, service providers should also consider to gain the ability to manage simultaneously their own digital and non-digital assets, as well as the resources of their network partners (Hfs Research, 2018). In this respect, service providers need to develop coordinating skills (Mikalef and Pateli, 2017), regarded as "seizing" abilities (Teece, 2007) "for harmonising and coordinating across digital and non-digital processes, systems, and subsystems" (Mazumder and Garg, 2021), especially if data are collected from different sources (Zhang, Pan, Yu, and Liu, 2019).

The third crucial skill for service providers to gain, refers to the ability to decrease costs while rise efficiency and flexibility, through standardization of their clients' business processes (Mikalef et al., 2020). This "reconfiguration" capability (Teece, 2007) is useful to enhance value through process automation, supporting closer relationships between end-users and other stakeholders (Weyer, Schmitt, Ohmer, and Gorecky, 2015).

Moreover, service providers require to encourage digital interconnections (Koch and Windsperger, 2017) and networking (Verhoef et al., 2021) by fostering collaborative innovation (Agarwal and Selen, 2009; Mikalef and Pateli, 2017), co-designing, and co-producing (den Hertog et al., 2010). This kind of ability helps them to develop and manage different types of interconnected networks and it can be compared to the alliance management capability analyzed in the alliance literature (Schilke and Goerzen, 2010; Schilke, 2014).

Finally, it is demonstrated that in an innovation ecosystem, the value is mainly created by exploiting insights from large volume of data generated through data-driven and automated business processes (Bozic and Dimovski, 2019; Warner and Wäger, 2019). In this respect, a crucial dynamic capability identified by Mazumder and Garg (2021) focused on the creation and sharing of actionable data. In particular, the ability to exploit Artificial Intelligence algorithms resulting in prescriptive and predictive outcomes, provide firms the possibility to develop effective response strategies and take real-time operational change decisions.

4. The impact of dynamic managerial capabilities on SMEs' Digital Transformation

As we seen, the importance of dynamic capabilities of digital-solution service providers have been recently recognized by innovation and management literature to better investigate the Digital Transformation environment. Moreover, the dynamic managerial capabilities' framework has been found to represent a valuable theoretical approach also to explore the effects of Digital Transformation process from the demand-side point of view, specifically in the context of SMEs' value creation and capture.

However, albeit relevant literature has traditionally investigated the implementation of new digital technologies in large companies (Cenamor, Parida, and Wincent, 2019) and high-tech corporation

(Ghezzi and Cavallo, 2020), it has overlooked, almost in part, the digital transformation mechanisms put in place inside SMEs which turned out to be more robust than large and multi-national companies, thanks to their flexibility, entrepreneurial spirit, and innovation propensity, as demonstrated by the previous financial and economic crisis (Matt 2007; Matt et al. 2016). Therefore, a growing number of authors have recently explored the topic of Digital Transformation for SMEs in their works (Matt et al. 2016; Bär et al. 2018; Türkeș et al. 2019).

It is widely demonstrated how SMEs contribute to innovation and economic growth in many countries. The relationship between SMEs' innovation performance and Information and Communication Technologies (ICTs) has been largely explored in the past research (Scuotto, Santoro, Bresciani, and Del Giudice, 2017), as well as the adoption of ICTs in the context of SMEs (Lucchetti and Sterlacchini, 2002). Moreover, it is affirmed that SMEs have proved to be resilient and innovative not only from a production point of view, but also in terms of their manufacturing procedures (Matt and Rauch, 2020). Indeed, by recognizing the constant competitive pressure, SMEs are able to operate in an increasingly proactive way to enhance the effectiveness of their business operations (Boughton and Arokiam 2000), which is a first crucial step to effectively adopt new digital technologies.

New digital applications are proved to be key competitive tools and success drivers for SMEs, as they enable firms to improve their value creation and customer engagement process more effectively. For instance, customer analytics relying on Big Data are regarded as one of the most crucial assets for fostering the SMEs' competitiveness and innovation (O'Connor and Kelly, 2017). Indeed, Big Data have revolutionized the entire value creation process, for example through dynamic pricing based on evolving customer demand. Big Data have also disrupted the original promotion activities with the exploitation of geospatial data to address the customer base with customized advertising (Erevelles, Fukawa, and Swayne, 2016; Yadav and Pavlou, 2014).
However, the adoption and implementation of new digital technologies is not a trivial issue, and literature has found that SMEs are most of time in trouble in the implementation of new technologies, due to the lack of key resources, skills, commitment, and full awareness of digital opportunities (Giotopoulos, Kontolaimou, Korra, and Tsakanikas, 2017).
In order to overcome these difficulties, SMEs requires a change management and vision based on the acquisition of new organizational and managerial capabilities which can enable them to improve their value creation process. In this respect, the ability to "sense" and "size" new digital opportunities to redefine customers' interactions and reconfigure their business model to create value, have acquired increasingly importance in the Digital Transformation context.

As Besson and Rowe (2012) pointed out, Digital Transformation is more about managerial assets than technical resources. Successful digital transformation mainly relies on facing managerial issues (Doherty and King, 2005) such as redefining business processes and training (Markus, 2004) and investing in organizational skills and dynamic managerial capabilities (Cha et al., 2015), defined as "the capabilities with which managers build, integrate, and reconfigure organizational resources and competences" (Adner and Helfat, 2003, p. 1012). Therefore, the dynamic managerial capabilities' approach has been found to fit particularly well to explain SMEs' Digital Transformation, since in small and medium companies the managers are often in charge of value creation processes. As a result, their capabilities represent a strategic asset to their firms' success.

Past researchers has affirmed that dynamic managerial capabilities rely on three fundamental pilasters: managerial cognition, managerial social capital, and managerial human capital (Helfat and Martin, 2015). Managerial cognition is associated with "managers personal beliefs and mental models for decision-making" (Li et al. 2017; Adner and Helfat, 2003) and with managers' knowledge and opinions of current and future events which affect their decision-making (March and Simon, 1958). It represents also the framework which drive managers' acquisition of new information and knowledge (Cook and Brown, 1999). Therefore, managerial cognition influences how managers sense market changes and their level of adaptability.

Managerial social capital refers to "formal and informal relationships that managers have with others" (Helfat and Martin, 2015, p. 1286) supporting managers to gain and redefine different organizational resources and information (Tsai and Ghoshal, 1998). Moreover, it enables managers to sense market opportunities and challenges more easily (Adler and Kwon, 2002; Burt, 1992), facilitating digital transformation. Finally, managerial human capital is based on skills, knowledge and educational background (Helfat and Martin, 2015) of individual managers, as well as teams of managers (Martin, 2011). A team of managers with a set of diversified knowledge, experience, and capabilities is found to be more likely to succeed in recognizing the right opportunities, and reconfiguring resources (Helfat and Martin, 2015). Therefore, higher levels of dynamic managerial capabilities are proved to increase the likelihood to implement successful strategic changes in a digital transformations context, enhancing firms' business performance (Helfat and Martin, 2015).

In line with the dynamic managerial capabilities' approach, several authors provided significant contributions. Li et. al (2017) highlighted how SMEs can support digital transformation by fostering their executives' dynamic managerial capabilities. According to their analysis, top managers showing high level of managerial cognition, as well as high levels of social and human capital, are more inclined to sense and seize market opportunities and believe in the new technologies' potential value which is crucial to Digital Transformation (Chatterjee et al., 2002). Garbellano and Da Veiga (2019) in their SMEs' investigation, affirmed that entrepreneurs are willing to invest in new digital technologies more relying on "their intuition than on detailed cost-benefit analysis" and that dynamic capabilities can be mainly found in people having the responsibility to "orchestrate" (Teece, 2014), manage, and redefine resources to create value. Some capabilities such as sensing, searching, and selecting the proper digital knowledge sources can be found solely in the entrepreneur or among his/her closest and youngest assistants. However, other capabilities, such as integrating and orchestrating tangible and digital resources, inside or outside the firm, are particularly vested in the executive team. In this respect, a diversified team of managers having complementary knowledge and abilities, represents a key requirement for a SME to sense and seize new opportunities (Kickul and Gundry, 2001; Wright, Coff, and Moliterno, 2014) and orchestrate organizational assets, capabilities and processes (Helfat and Martin, 2015), uncovering new digital transformation paths more easily.

5. Conclusions

Recent research in the Digital transformation field has explored the firm's abilities to appropriately respond to disruptive changes and has identified Digital Transformation as a crucial driver of firms' innovation and performance in a competitive landscape.

As intangible assets gain comparatively more importance than physical resources, as new digital applications become more relevant to meet customers' needs, and as value networks become wider

and intertwined, companies experience higher uncertainty' levels (Vial, 2019). Although the advantages coming from the adoption of digital technologies have been widely demonstrated, it is shown that new digital technologies provide a little contribution to firms' value creation process (Kane, 2014) if not associated with crucial organizational and managerial skills.
In line with this, the aim of our review is to go beyond the technology-centric perspective of Digital Transformation (e.g. Tushman and Anderson 1986; Anderson and Tushman 1990) emphasizing actor-driven organizational transformation of capabilities, processes and business model components both from a supply-side (digital solution providers) and a demand-side (SMEs) point of view.
As recent research has pointed out, it is the context where technology is implemented that really matters (Vial, 2019) and it is the proper use of digital technologies that enables firms to effectively sense and adapt to rapid innovative changes. Therefore, in order to succeed in a data-driven hypercompetitive environment (Svahn et al., 2017a), firms must prove to be able to ideate and adopt new strategic plans (Bharadwaj et al., 2013; Matt et al., 2015), as well as support innovative changes in their organizational structure (Selander and Jarvenpaa, 2016), processes (Carlo et al., 2012), and culture (Karimi and Walter, 2015) through creativity and entrepreneurial spirit.
As a result, the dynamic capabilities' approach provides new interesting insights on how Digital Transformation's players improve their customers' and their own innovation performance and competitiveness to generate new paths for value creation.

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The 3D-printing adoption behavior of Italian manufacturing firms

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ABSTRACT

The aim of this research is to provide a preliminary investigation of the role played by 3D-printing in an innovative Italian manufacturing environment, through the development of an original cross-sectional dataset composed by more than 100 manufacturing firms operating with conventional non-digital procedures. In particular, logit models have been carried on to assess the impact of two 3D-printing advantages (complexity advantage and small-lot size advantage) on the Italian firms' 3D-printing adoption behavior. The complexity advantage shows a significant and positive effect on the adoption of 3D-printing by manufacturing firms. Finally, this paper tries to investigate the level of firms' awareness about their own innovation level through the development of a multiple-case study and the use of Rogers' adoption categories (Rogers 2003).

Key-words: *3D printing, mould, conventional manufacturing, adoption behavior, additive manufacturing*

1. Introduction

In 2013 the United States' President Obama outlined 3D-printing as having "the potential to revolutionize the way we make almost everything" (Barack Obama, 2013). More recently, the global magazine Forbes (McCue, 2020) affirmed that the 3D-printing worldwide market showed a growth of 21,2%, reaching 11.867 billion dollars in the previous year, according to the Wohler Reports 2020. The current literature considers 3D-printing one of the most disruptive processes of the current digital transformation period (Reeves et. al, 2011; Sealy, 2011; Petrick and Simpson, 2013). The advantages associated with 3D-printing additive and mould-free characteristics have resulted in an increasing number of manufacturing firms reconfiguring their traditional production procedures. In this respect, the impact of the benefits provided by the 3D-printing adoption on firms' competitive advantage and innovation performance, started to gain increasingly attention among scholars and researchers (Baumers et al., 2016; Candi and Beltagui, 2018; Yeh and Chen, 2018).

The most recent Eurostat data on the state of adoption and application of digital disruptive technologies in the industrial sector, reveal that Italy maintains a strong position at an international level. Indeed, Italy is ranked as the third most important European country (after Germany and United Kingdom) in terms of the number of high-tech manufacturing companies (5.530). Despite these results, the levels of 3D-printing adoption in Italian manufacturing firms (10%), compared to other digital technologies (e.g. Cloud computing: 59%; IoT: 24%), remain too low to enable firms to

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achieve effective innovative performance (Eurostat 2020). As a result, further investigations on the main drivers associated with firms' 3D-printing adoption behavior would add value.

Moreover, pertinent literature has explored this type of innovation almost exclusively from a technical and engineering perspective (Lee, 2004; Dimitrov, 2006; Boros et. al., 2019). Thus, empirical analyses of 3D-printing from an innovation management and behavioral economics' point of view could provide new interesting insights in this field (Shnederjan, 2017).

In light with these considerations, this research tries to provide a preliminary investigation of the role played by 3D-printing in Italian manufacturing firms operating with non-digital conventional production procedures.

A regional web-survey has been designed to address more than 100 manufacturing firms, almost exclusively micro (23%) and small-medium (74%) ones. Thereafter, the firms interviewed have been grouped into three categories according to their self-declared adoption status: firms adopting 3D-printing (3DP adopters); firms willing to adopt 3D-printing in the future (3DP potential adopters) and firms not inclined to adopt 3D-printing during the following years (3DP non-potential adopters).

Firstly, an econometric analysis is developed to investigate the impact of the two most fundamental 3D-printing relative advantages (complexity and small lot-size's advantages) on the innovation adoption behavior of traditional manufacturing firms. In particular, it is investigated how the firms' perception about complexity advantage and small lot-size advantage impacts on the likelihood for them to be labelled as 3DP adopters or 3DP non-potential adopters.

The main findings from the econometric analysis can be summarized as follows:

- 3DP adopters: our results highlight that the likelihood of manufacturing firms to be categorised as 3DP adopters is positively associated with the fact that they perceive the complexity advantage as one of the most important benefits linked to the use of 3D-printing. However, small size companies, as well as firms operating in the metal sector, are less likely to be classified as 3DP adopters.
- 3DP non-potential adopters: in line with the above-mentioned results, the perception of 3D-printing complexity advantage is negatively associated with the likelihood of manufacturing firms to refuse 3D-printing adoption in the future. Moreover, small companies and companies with more experience (over 30 years of activity) seem to be more likely to use only mould-based conventional technologies in their future production process, compared to younger firms.

Secondly, this study tries to explore the awareness of manufacturing companies about their real innovation level and about the importance of 3D-printing in their value creation process (Linder et al., 2003). To this end, the level of firms' awareness about their own innovation level is investigated through the development of a multiple-case study to explore how firms inclined to adopt 3D-printing in the future (3DP potential adopters) perceive their innovation level, and if this level corresponds with the real one identified through the use of Rogers' adoption categories (Rogers, 2003).

The main results from the multiple-case study show the presence of a misalignment between the level of firms' self-perceived innovation and their real innovation level, proxied by their propensity to adopt 3D-printing. In particular, almost the totality of firms interviewed (4 out of 5) overrate their innovation level. In the light of these findings, possible solutions to face this issue are provided.

The rest of this article is organized as follows: in the next section, the relevant theoretical background is presented. Section 3 summarises the methodology and results of the econometric analysis employed. Section 4 describes the methodology and the results of the multiple-case study. Finally, Sections 5 closes the paper discussing theoretical and managerial implications, as well as limitations and directions for future research.

2. Theoretical background

2.1 3D-printing versus conventional production methods in the Digital Transformation

Many researches from different fields (e.g. business management, industrial economics and engineering) have investigated the advantages and drawbacks behind both traditional methods in established manufacturing areas (Achillas et al. 2015, Pereira et al. 2018) and additive mould-free technologies, with a special focus on 3D-printing (Boros et al. 2019; Kaynak and Varsavas 2019).

3D-printing is regarded as the most famous digital additive and mould-free technique, able to create solid products from 3D model data, avoiding waste of material and providing high level of design freedom. In more detail, it builds up a component in layers by depositing material, as opposed to traditional subtractive and shaping methodologies whereby material is either removed through machining, drilling or grinding procedures or casted into moulds (ISO/ASTM International, 2015; Holmström and Partanen, 2014; Petrovic et al., 2011).

Therefore, after the advent of 3D-printing in manufacturing, firms which operated with traditional procedures started to think about the possibility to integrate the new digital technology in their conventional methods to enhance their innovation performance.

However, it is not without technical limits (including cleaning of cooling channels, printing of large moulds, precision and surface finishing) which demand for high skilled workers (European Commission 2016). In this respect, several analyses have been developed to study the advantages and drawbacks, especially in terms of lead time, quality and production cost, coming from a combined use of conventional and innovative manufacturing methods.

For instance, Boros et al. (2019) have demonstrated the effectiveness of a new combination technique resulting from the connection between injection moulded and 3D-printed parts. Moreover, 3D-printing is found to be able to reduce the maintenance and tooling costs of traditional moulds, providing important advantages to some industries in terms of social, economic and environmental impact (Chan et al. 2018).

It is also widely demonstrated that the implementation of 3D-printing technologies in manufacturing firms can be directly associated with important firms' value-adding processes, such as new product development and ordered fulfillment processes (Fontana et al., 2018). In particular, several scholars have identified and described two fundamental properties of additive-manufacturing techniques as strategic for improving the value creation in the above-mentioned processes (Gibson et al., 2010;

Klahn et al., 2014; Yadroitsev et al., 2007; Vayre et al., 2012). They are not just considered the main sources of advantages provided by 3D-printing compared to traditional methods, but also the main drivers for its adoption and implementation: complexity advantage and small lot-size advantage (Holmström et al., 2010; Petrovic et al., 2011; Berman, 2012; Mellor et al, 2014).

In literature, the so called "complexity advantage" is also defined as "complexity for free" (Gibson et al, 2010; Eisenhut and Langefeld, 2013; Weller et al., 2015), since it is widely demonstrated how 3D-printing is able to provide high levels of freedom to reproduce complex geometric shapes, avoiding additional costs (Gao et al., 2015). Thanks to the 3D-printing complexity advantage, firms can be able to provide customers with more efficient, lightweight and functional customized products (Ahuja et al., 2015). In this respect, 3D-printing can enable firms to strongly increase their levels of flexibility and customizability. Indeed, it offers the chance to virtually create any kind of shape with complex cellular structures, optimizing the distribution and integration of the employed material (Sealy, 2011). In addition, 3D-printing can manipulate the internal shape of products in ways extremely difficult to be reproduced by other manufacturing processes (Campbell and Ivanova, 2013).

Taking into account these facts, the first baseline hypothesis is established:

Hypothesis 1. The perception of 3D-printing "complexity advantage" has a significant and positive impact on 3D-printing adoption in manufacturing firms operating with traditional technologies.

In addition to the ability of reproducing complicated structures without the aid of moulds or machining, another benefit associated with 3D-printing refers to a higher cost efficiency provided for small lot sizes, even in high variety, compared to traditional procedures (Fontana, Klahn and Meboldt, 2018). Indeed, although subtractive and shaping techniques, like injection moulding, are considered the most effective solution for mass production procedures thanks to lower material cost and high quality of production (Kaynaz and Varsavas 2019), they show several limitations in the small batch sizes. These drawbacks are due mainly to the high initial cost of tooling, moulding equipment and design.

In this respect, 3D-printing is considered the most effective choice for low-volume series, up to lot-size 1 (Tuck et al., 2008) [4]. Fontana et al. (2018) have determined that the implementation of 3D-printing in the case of low-volume production and high-variety manufacturing could substantially lead to a reduction of per-item cost, and to an improvement in delivery lead times.

Moreover, Franchetti and Kress (2017) in their break-even cost structure analysis, have determined the threshold of batch sizes under which 3D-printing is expected to be more cost-effective relative to injection moulding.

Taking into consideration the literature addressed, the second hypothesis of this paper would read as follows:

Hypothesis 2. The perception of 3D-printing "small lot-size" relative advantage has a significant and positive impact on 3D-printing adoption in manufacturing firms operating with traditional technologies.

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[4] For a different opinion see Achillas et al. (2015) who considered the additive techniques a strategic option also for conventional mass production systems, thanks to the enhancement of injection moulds' productivity.

3. Econometric analysis

3.1 Data description

Our empirical study is based on a cross-section composed of 101 manufacturing firms adopting conventional technologies located in Marche Region (Central Italy). At the end of 2019, after a period of three weeks, 1000 managers from different industries were solicited and a sample of 500 Italian manufacturing firms was reached out through an original web-based survey.

The sample was recruited in the AIDA bureau Van Dijk database (containing information on 365 million Italian companies).
A response rate (including only usable responses) of 20% equated to 101 companies was obtained and the participation of companies involved in the survey was completely free from monetary benefits. A purposeful sampling was considered in order to avoid the introduction of biases, based on incentives for survey participation (Schnederjan 2017).
The genuine interest in the subject was considered an essential driver of participation and an indicator of the importance of this subject in the manufacturing environment. Despite the lack of a payment, the response rate was considered acceptable thanks, almost in part, to a preliminary engaging strategy based on phone calls. Most of respondents have previously accepted by phone the chance to take the web survey, and have been told they would have received the final survey report as an incentive to participate. Two criteria were imposed to ensure that respondents were actually qualified to provide the information about their firm's innovation adoption strategy: working as top-managers with a role in the firms' decisions on new technologies adoption, and being knowledgeable about the conventional procedures of their firms. Without these requirements, respondents would have not been considered suitable candidates to provide the needed information.

Before reaching the identified sample, a preliminary test was performed by interviewing the manager of a regional company who provided reviews and comments on the survey. His responses turned out to be extremely useful to ensure the survey was comprehensive and reliable.

According to our regional survey figures (see Table 1), most of the companies interviewed operate in the footwear (33 firms) and metals (29 firms) sectors. These represent the two most important industries for the manufacturing firms located in this area, according to the latest data provided by Infocamere[5]. The other sectors considered in our sample refer to industries classified according to the following NACE codes: C26, C27, C28, C30, C31 and C32. Almost the totality of respondents are SMEs (99 out of 101) with maximum 50 employees and 10 million of annual turnover: small-size firms account for 65% of the sample, while micro firms for 23%. 3DP adopters and 3DP non-potential adopters account for about 20% and 35% respectively.
Although not fully representative in a statistically rigorous sense, we believe that this study provides a good representation of manufacturing firms operating with traditional procedures in a national innovative environment. According to our elaboration of the Infocamere dataset, Marche (along with Veneto) represents the third most important Italian region in terms of concentration of innovative

[5] Considering only the manufacturing sector and detailing the divisions of economic activity, footwear and leather goods companies are the most widespread in the Marche Region (19%), followed by metallurgical and metal production companies (14%).

manufacturing SMEs, following Lombardia and Emilia Romagna, as shown in the Table 2 below.

Table 1

Sector	micro	small	medium	large	Total
	Size				
Plastics	4	13	2	1	20
	20.00	65.00	10.00	5.00	100.00
	17.39	19.70	22.22	33.33	19.80
Metals	6	20	3	0	29
	20.69	68.97	10.34	0.00	100.00
	26.09	30.30	33.33	0.00	28.71
Footwear	10	19	2	2	33
	30.30	57.58	6.06	6.06	100.00
	43.48	28.79	22.22	66.67	32.67
Others	3	14	2	0	19
	15.79	73.68	10.53	0.00	100.00
	13.04	21.21	22.22	0.00	18.81
Total	23	66	9	3	101
	22.77	65.35	8.91	2.97	100.00
	100.00	100.00	100.00	100.00	100.00

Table 2

Italian Regions	Innovative manufacturing SMEs by Region (%)
ABRUZZO	3%
BASILICATA	0%
CALABRIA	2%
CAMPANIA	8%
EMILIA-ROMAGNA	13%
FRIULI-VENEZIA GIULIA	3%
LAZIO	3%
LIGURIA	2%
LOMBARDIA	24%
MARCHE	**9%**
MOLISE	0%
PIEMONTE	7%
PUGLIA	6%
SARDEGNA	0%
SICILIA	3%
TOSCANA	4%
TRENTINO-ALTO ADIGE	3%
UMBRIA	1%
VALLE D'AOSTA	0%
VENETO	9%

The 3D printing adoption status by size and sector is described by Table 3 and Table 4.

Table 3

3DP adoption status	**Size** micro	small	medium	large	Total
non-pot adopt	5	28	2	0	35
	14.29	80.00	5.71	0.00	100.00
	21.74	42.42	22.22	0.00	34.65
pot adopter	13	28	5	0	46
	28.26	60.87	10.87	0.00	100.00
	56.52	42.42	55.56	0.00	45.54
adopter	5	10	2	3	20
	25.00	50.00	10.00	15.00	100.00
	21.74	15.15	22.22	100.00	19.80
Total	23	66	9	3	101
	22.77	65.35	8.91	2.97	100.00
	100.00	100.00	100.00	100.00	100.00

Table 4

3DP adoption status	Plastics	Metals	Footwear	Others	Total
3DP non-potential adopters	6	10	12	7	35
	17.14	28.57	34.29	20.00	100.00
	30.00	34.48	36.36	36.84	34.65
3DP potential adopters	9	16	15	6	46
	19.57	34.78	32.61	13.04	100.00
	45.00	55.17	45.45	31.58	45.54
3DP adopters	5	3	6	6	20
	25.00	15.00	30.00	30.00	100.00
	25.00	10.34	18.18	31.58	19.80
Total	20	29	33	19	101
	19.80	28.71	32.67	18.81	100.00
	100.00	100.00	100.00	100.00	100.00

According to the academic and managerial literature review described above, specific items are created to gather more detailed information about firms' perception on 3D-printing advantages, compared to traditional procedures' benefits, in terms of flexibility and customization, as well as effectiveness in low batch size. Moreover, companies were distinguished according to their 3D-printing adoption status in the following three categories:

1) 3DP adopters: firms adopting 3D-printing along with conventional procedures in their production processes;
2) 3DP non-potential adopters: firms which adopt only conventional procedures in their production processes and are not inclined to adopt 3D-printing in the future;
3) 3DP potential adopters: firms which adopt only conventional procedures in their production processes but are willing to adopt 3D-printing in the future.

We have carried on an econometric analysis through the use of two logit models to test the impact of the two most important perceived advantages linked to the use of 3D-printing (complexity advantage and small lot-size advantage) on the likelihood of manufacturing firms using traditional technologies to be labelled as 3DP adopters or 3DP non-potential adopters.

3.2 Variables and model specification

In order to explore the likelihood of firms to be labelled as 3DP adopters or 3DP non-potential adopters, two dummy variables were developed. The dependent variables are described as follows:

3DP_Adopters
(Please indicate if your company can rely on a 3D-printing technology integrated with conventional methods).

The *3DP_Adopters* dummy assumes the value 1 if the firm is a 3DP adopter and the value 0 otherwise.

3DP_Non-potAdopters
(Please indicate if your company cannot rely on a 3D-printing technology but it is inclined to integrate 3D-printing with its conventional methods in the following years)

The *3DP_Non-potAdopters* dummy assumes the value 1 if the company is not inclined to adopt 3D-printing in the future and the value 0 otherwise.

Complexity relative advantage
(Please indicate if according to your opinion 3D-printing can (could) enable your firm to create more complex products, compared to the existent conventional methods)

This is a dummy variable indicating the perception of a complexity relative advantage associated with the use of 3D-printing, compared to traditional technologies. It assumes the value 1 if the firm declares to perceive this kind of advantage, and the value 0 otherwise.

Small lot-size relative advantage
(Please indicate if according to your opinion 3D-printing can (could) be considered a more effective solution for low-volume production, compared to existent conventional methods)

This is a dummy variable indicating the existence of a small lot-size relative advantage associated with the use of 3D-printing, compared to traditional technologies. It assumes the value 1 if the firm declares to perceive this kind of advantage, and the value 0 otherwise.
We also controlled for firm and environment-specific characteristics related to firms' size (*Size*), sector (*Sector*) and age (*Age*). With regards to firms' age, an ordered 3-category variable is constructed: firms with under 30 years of experience (=1), from 31 to 40 years (=2), and over 40 years (=3).

In accordance with European Commission Recommendation (2003/361/EC) about the size of companies, the variable *Size* is composed of three dummies classifying the manufacturing firms in micro (1-9 employees), small (10-49 employees), medium, and large firms (over 50 employees).
Finally, the variable *Sectors* is composed of three dummies which control for the following firms' reference sectors of production: footwear, metals, plastics. The dummies assume the value 1 if the firm is involved in the sector considered, and value 0 otherwise.

Our econometric analysis is based on the estimation of two logit models.

Binary models are considered the best solution to estimate dummy variables, meaning dependent variables having two categories, as in our analysis. In these models, the dependent variable and explanatory factors are in a non-linear relationship with a scaling factor of around 1,7. Any predictions are always bounded between zero and one and the coefficients relate to an underlying latent score. The latent model is described as the following:

$$Y^* = \mathbf{x}\beta + \varepsilon \qquad\qquad \varepsilon|\mathbf{x} \sim \text{Normal}(0,1)$$

According to our analysis we can imagine that firms whose we are observing the status are in a sort of continuous process, ranging from negative infinity to positive infinity. Moreover, let us suppose that firms' status moves them up and down the scale. This represents the latent score. Let us imagine that at some point our firms' status crosses some sort of threshold value (identified by the threshold parameters α_j's to be estimated) that determines the adoption or the refusal of a new technology.

$Y = 0$ if $Y^* \leq \alpha_1$
$Y = 1$ if $< Y^* \leq \alpha_2$
.
.
.
$Y = J$ if $< Y^* > \alpha_j$

Since the latent score cannot be observed, we have to transform the coefficients from the logit model and estimate the marginal effects which are the slope coefficients of the relation between the dependent variables (Y) and the regressors (X). We need to compute a change in Y, given a change in X. However, because of the non-linear transformation that ordered response models undertake, we should be aware that the change in Y can vary depending on X.

The literature has settled on two types of marginal effects: marginal effects at the mean of all variables and average marginal effects. The formers, compute the marginal effect at the mean value of X for all variables, while the average marginal effects used in this paper compute all possible marginal effects along the entire range of X values, and then they average these.

Moreover, it is important to note that in order to test the goodness of the logit models employed, proper post-estimation analyses have been carried on and the results can be seen in the Appendix A (Figure 2.a).

We have used logit models for the following two equations corresponding to the two different 3D-printing adoption status of manufacturing firms working with traditional methods, as described above:

1. $3DP\_Adopters_i = \beta_1 Complexity_i + \beta_2 Small\_Slot\text{-}size_i + \beta_3 Z_i + \varepsilon_i$ (1)

2. $3DP\_Non\text{-}potAdopters_i = \gamma_1 Complexity_i + \gamma_2 Small\_Slot\text{-}size_i + \gamma_3 Z_i + \upsilon_i$ (2)

On the right side of the eq. (1) $Complexity_i$, is a dummy variable standing for the perception of a relative advantage for the firm *i* in terms of an higher ability of 3D-printing to reproduce complex shapes, compared to traditional technologies; $Small\_Slot\text{-}size_i$ is a dummy variable referring to the perception of a relative advantage for the firm *i* in terms of an higher level of effectiveness provided by 3D-printing in low-volume production, compared to traditional technologies; Finally, Z_i is the vector of the control variables, while ε_i is the random error term.

Accordingly, Eqs. (2), complete the analysis referring to the firms in 3DP non-potential adopter category. Parameters β and γ determine the average marginal effects to be estimated, while υ_i is the random error term.

3.3 Econometric analysis' results

The estimation results based on the ordered logit models for 3DP adopters and 3DP non-potential adopters are reported in the Appendix A (Figure 1.a). The average marginal effects reported describe the impact of the two regressor variables on the probability for firms operating with conventional procedures to be classified as 3DP adopters or 3DP non-potential adopters.

While the perception of 3D-printing small slot-size relative advantage seems not to impact on the firms' innovation adoption strategy, the perception of the complexity relative advantage seems to show significant effects in this respect.

In particular, putting the attention on the perceived complexity advantage, we can observe that the perception of 3D-printing as a more convenient technology to reproduce complex geometric shapes compared to conventional methods, seems to have a significant and positive (negative) effect on the probability for manufacturing firms (not) to be in favour of 3D-printing adoption.

In this respect, we can affirm that these results are found to support only our first hypothesis.

Finally, with respect to the control variables *Sector* and *Size*, we can see that manufacturing firms operating in the metals sector and firms with a number of employees ranging from 10 to 49 are less likely to be labelled as 3DP adopters.

As regards to the firms' years of experience, we can note that the variable *Age* affects the likelihood for traditional manufacturing firms to be labelled as 3DP non-potential adopters. In particular, older companies with more business experience (over 30 years of work in a specific sector) seem to be more inclined, compared to their younger competitors, to reject the possibility to adopt 3D-printing in the future. This result could be partially explained by the risk aversion towards new technologies characterizing more experienced firms. Indeed, according to several researchers (Leonard-Barton, 1997; Sorensen and Stuart, 2000) the firms' age negatively impacts on the firms' capability to acquire new competences and thus to innovate. Moreover, Natarajan et al. (2008) declared that the firms' age is negatively associated with innovation and this effect results to be even stronger in technological areas.

4. Multiple-case study analysis

4.1 Methodology

The second part of our research question is focused on exploring how manufacturing firms declaring to be inclined to adopt 3D-printing in the future (3DP potential adopters) perceive their innovation level and if their perceived level corresponds with their real one.

The decision to adopt the 3DP potential adopters' point of view is due to the interest of investigating the level of potential innovation change in the Italian manufacturing setting. To this end, the level of firms' awareness is investigated through the development of a multiple-case study addressing 5 manufacturing companies from May to June 2020.

Firstly, it is worthwhile to clarify that firms' perceived innovation level is determined by the Rogers's adoption categories firms declare to belong to.
Innovation adoption categories are developed by Rogers' DOI (Diffusion of Innovation) theory (Rogers 2003) to describe and explore the different characteristics of innovation adopters. In the classic Rogers' model five adopter groups are identified: innovators, early adopters, early majority, late majority, and laggards.
According to the Rogers' model, differences between adoption categories depend on the way each adopter reacts to a novel idea or practice. *Innovators* and *early adopters* are the first to accept a new idea and are willing to take higher risks, compared to other adoption categories. Their adoption behavior is based almost exclusively on intuition versus established references, and they are willing to encourage radical changes and disruptive technologies (Kirton, 1976; Moore, 1999).
Early majority base their decisions on practicality and tend to take more time to evaluate the benefits from a new technology. They prefer to receive feedbacks from innovators/early adopters before making decisions in favor of the adoption of a new technology. In other words, well-established references have a strong impact on their adoption behavior (Moore, 1999; Rogers, 2003).
Late majority tend to accept an innovation when it becomes standard and when they are confident about using it. Finally, *laggards* are traditionalists and are often the last to adopt an innovation. Their suspicious attitude is shown not only towards innovations, but also against innovators (Rogers, 1983). They usually tend to accept an innovation once it has become a necessity (Yi et al., 2006).

The percentage for each adoption category in a group is about 2,5%, 13,5%, 34%, 34% and 16%, respectively. However, Hsu et al. (2007) suggested that a reduced model should be considered when it is applied to a specific industry (or to a specific group of firms sharing the same characteristics) because of the small number of users in each category. In this respect, our analysis applied the reduced model by combining innovators and early adopters into a single category. As a result, we have classified 3D-printing potential adopters into four groups: innovators/early adopters, early majority, late majority and laggards.

Secondly, once defined the firms' perceived innovation level, we tried to identify their real innovation level by investigating their propensity for 3D-printing adoption.

This propensity is identified through a web survey and several interviews with the firms which are asked to express their opinion about the following 3D-printing perceptual adoption drivers: compatibility, relative advantage and performance expectancy. In particular, each firm was asked to rank from 1 to 5 on a Likert scale its agreement on each perceptual driver above considered.

Respondents perceiving themselves as belonging to the most innovative categories are expected to show a higher final score relating to the perceptual drivers totally considered. In this respect, a correspondence between the score obtained and the adoption category indicated was established to explore if and at what extent the level of firms' self-perceived innovation was in line with firms' real innovation level.

The relevance of these perceptual drivers in determining the firms' propensity to a new technology adoption is supported by previous empirical researches (Agarwal and Prasad, 1997). In more detail, these drivers were found to explain 70% of the variance in the propensity of using an innovation and 50% of the variance in technology adoption (Venkatesh et al., 2012).

Compatibility and relative advantage come from the DOI theory (Rogers 2003), while performance expectancy is borrowed from the unified theory of acceptance and use of technology (UTAUT). All of them have been identified by Schniederjans' empirical research (2017) as significant antecedents of the intention to adopt 3D-printing in manufacturing.

Compatibility relates to the consistency of an innovation "with existing values, needs and past experiences" (Rogers 2003), as well as existing production methods.
Relative advantage represents the extent to which a firm perceives an innovation as providing an advantage in terms of performance, compared to the existing procedures.
Performance expectancy is defined as the level to which using a technology is perceived as providing benefits (Venkatesh et al., 2012).

In order to develop the interview protocol for our multiple-case study, the original Schniederjans' set of questions has been partially modified.

In particular, Perform expectancy was split into two (instead of three) sub-questions regarding the 3D-printing expected capability to help firms accomplish tasks more quickly, and increase productivity, respectively. Compatibility was considered from two (instead of three) different, albeit correlated, points of view: compatibility between 3D-printing and firms' missions and values, and compatibility between 3D-printing and firms' existing manufacturing technologies. Relative advantage was divided into six (instead of five) items. The questions from 1 to 5 consider the same factors analysed in the Schniederjans' interview protocol: quality, ease, effectiveness, control of employees' work and cost reduction. However, in the light of the current disruption occurred in social, economic and industrial settings due to the pandemic situation, an additional variable was added: the ability of 3D-printing to help firms face a global crisis, compared to conventional technologies.

The interview protocol and the profile description of the firms are provided in the Appendix B (Figure 1.b and Figure 2.b).

4.2 Results

According to the Rogers' model analysed in the methodology, we can affirm that the propensity for 3D-printing adoption decreases from innovators/early adopters to laggards. Therefore, innovator/early adopters will be more inclined to 3D-printing use, followed by early majority, late majority and laggards. In line with this, we should expect that firms perceiving themselves as innovators or early adopters will take in a higher consideration the 3D-printing adoption drivers above-mentioned, compared to firms perceiving themselves as belonging to "late majority" and "laggards" groups.

However, our results show a completely different scenario: 4 out of 5 firms interviewed overrate their real innovation level on the basis of their propensity to 3D-printing adoption (see Table 5). In particular, firms A and D show the most marked misalignment between their self-perceived innovation degree and their propensity to adopt 3D-printing:

- Companies A, D and E perceive themselves as innovators/early adopters, while their propensities to adopt 3D-printing would identify them as belonging to late majority (A and

D) and early majority (E) groups, respectively. In particular, company A seems to be closer to the laggards group than to the early majority category.

- Company B has the perception to be an early majority-firm, while its 3D-printing adoption propensity identifies it as belonging to the late majority group.
- C is the only firm with a perception of its innovativeness in line with its 3D-printing adoption strategy (early majority category).

A graphically description of the misalignment explained above is provided in the Figure 3.b in the Appendix B.

Table 5

Firms (3DP potential adopters)	**Performance Expectancy**	**Relative Advantage**	**Compatibility**	**Total score** (based on perceptual integration drivers)	**Self-perceived innovation level** (adoption category perceived)	**Adoption category according to the total score**
A	**3**	**12**	**4**	**19**	Innovator/early adopter	Late majority
B	**3**	**11**	**6**	**20**	Early majority	Late majority
C	**5**	**18**	**7**	**30**	Early majority	Early majority
D	**6**	**14**	**6**	**26**	Innovator/early adopter	Late majority
E	**8**	**18**	**10**	**36**	Innovator/early adopter	Early majority

Moreover, in the relative advantage factor, we tried to take into consideration if and at what extent a resilience development strategy can be supported by the use of 3D printing. In more detail, we tried to understand if 3D-printing is perceived as a significant tool able to increase the resilience capability of a manufacturing firm, in the light of the current global crisis. The benefits from 3D-printing, in terms of flexibility in production and supply chain, are in fact considered crucial to help firms improve their resilience capacity and better face technological turbulence (Beltagui and Candi 2019). According to our results (see Table 6), only company E (4 points out of 5) seems to take into due consideration the 3D-printing benefits in terms of flexibility in response to technological disruptions coming from a global crisis.

Table 6

Firms (3DP potential adopters)	**The use of 3DP would help your firm face the actual global crisis over existing traditional technologies**
A	**2**
B	**2**
C	**3**
D	**2**
E	**4**

5. Conclusions

This study explores the role played by 3D-printing in an innovative Italian manufacturing environment.
In particular, by using data collected from a cross sectional original web-survey, this research examines the effects of the two most critical 3D-printing advantages, identified in the pertinent literature (flexibility and small lot-size advantage), on the likelihood of firms using traditional technologies to be regarded as 3DP adopters or 3DP non-potential adopters. While the adopter-category refers to all manufacturing firms which have integrated 3D-printing in their conventional methods, 3DP non-potential adopters group refers to firms not willing to adopt 3D-printing in the following years.
Moreover, this paper tries to investigate, through a multiple-case study analysis, how manufacturing firms in favour to adopt 3D-printing in the future (3DP potential adopters) perceive their own level of innovation and if this level corresponds with their real one. This way, the reliability of 3DP potential adopters' evaluation of their own level of innovative capacity has been assessed.

Despite 3D-printing advantages in the manufacturing firms have been largely analyzed in the past, the pertinent literature has mainly taken into consideration an engineering and technical point of view (Dimitrov et. al 2006; Boros et. al 2019). Therefore, by adopting a behavioral economics and organizational perspective, this research provides added value to the management innovation literature. Moreover, the focus on an under-investigated market for 3D-printing, composed by almost exclusively micro and small-medium manufacturing firms, provides a more nuanced understanding about smaller organizations' adoption behaviour related to new disruptive technologies.

Concerning our econometric analysis, the findings seem to be partially in line with the 3D-printing literature analyzed. It is confirmed that an higher perceived ability of 3D-printing to provide manufacturing firms with high levels of freedom to reproduce complex geometric shapes compared to traditional methods plays a crucial role. Indeed, in comparison to traditional technologies, the "complexity" relative advantage seems to represent a significant adoption driver, able to influence the firms' 3DP adoption behaviour in a positive way. Differently, the "small lot-size" relative advantage seems not to be a significant factor for explaining 3DP adoption for the manufacturing firms considered. In this respect, it is worthwhile to note that, in the Italian manufacturing context, the implementation of 3D-printing techniques remains extremely lower compared to other digital technologies, such as Cloud computing, Robotics, IoT and Artificial Intelligence. Indeed, approximately 65% of firms declare not to be aware about the ability of disruptive technologies to improving firms' innovation performance and changing the organizational structure of firms' business model (Deloitte 2018).

Through our multiple-case study analysis, we have also tried to explore perceptions on innovation at firm-level. This is extremely important if we consider that perceptions may have a strong impact on firms' decision behavior and are, in turn, proactively affected by management decisions or government policies (Wynekoop et al., 1992).

In particular, when a firm misperceives its own innovation performance and capabilities, as reported in our analysis, probably an asymmetric information problem must be solved inside or/and outside the firm.

Inside the firm, the board management could not have had a realistic perception about the real technical department' needs, and subsequently about how the new digital technologies could be effectively used to create value. Outside the company, an asymmetrical flow of information from 3D-printing providers and potential 3D-printing adopters could have led the firm to wrong decisions about if and how the new technology should be used.

In this respect, initiatives that may help firms alleviate this mismatch and improve a deeper knowledge-sharing environment should be scheduled. The involvement of workers, customers, suppliers, partners, system integrators, along with hardware and software providers in the firm's ecosystem could enable companies to gain more transformative benefits. For instance, the involvement of 3D-printing experts in cross-regional demonstration activities and digital forum should be taken into account, as well as the creation of joint actions and collaborations among relevant stakeholders to build a better connection between supply and demand. Web-based channels and dedicated events could also be considered as available options (European Commision 2016).

While this paper represents a first step in investigating the innovation adoption behavior of Italian manufacturing firms, it is not without several limitations. Firstly, this study, paralleling many other researches on 3D-printing (e.g. Candi 2019, Schniederjans, 2017; Rogers et al., 2016), excludes other additive innovative mould-free techniques (stereolithography, fused deposition modelling and selective laser sintering) and it does not focus on a specific manufacturing sector. The main reason comes from the fact that different additive technologies have similar characteristics, the main one relating to their capability to create an object directly from a digital model. In this respect, future research should address the other additive manufacturing technologies and focus on one specific sector. Indeed, nowadays the use of 3D-printing is vastly documented, especially in the health care sector and it is rapidly attracting a great deal of interest in other industries, such as automotive and aerospace, where it is expected to reach a peak in ten years according to Shanler and Basiliere analysts from the American research company Gartner (Shanler and Basiliere 2015).
Secondly, further investigation in this field should consider a more complete range of variables including for example financial aspects. Finally, a panel dataset at a national or European level could contribute to enrich the analysis.

Appendix A

Figure 1.a

AVERAGE MARGINAL EFFECTS

	3DP Adopters	3DP Not_pot_adopters
Complexity	**2.212**** (0.822)	**-1.578**** (0.494)
Small_Slot-size	-0.0710 (0.692)	-0.207 (0.519)
Plastics	-0.824 (0.861)	0.188 (0.801)
Metals	**-1.895**** (0.934)	0.0352 (0.723)
Footwear	-1.023 (0.866)	-0.218 (0.734)
Micro	-1.230 (0.924)	0.156 (1.003)
Small	**-1.714**** (0.808)	**1.475*** (0.884)
Age (31-40 years)	-0.170 (0.796)	**1.503**** (0.694)
Age (>40 years)	-1.197 (0.848)	**1.440**** (0.655)
N	101	101

Standard errors are reported in parentheses.
*Significant at the 10% level;
** Significant at the 5% level.
***Significant at the 1% level.

Figure 2.a

Logistic model for 3DP Adopters

Classified	True D	True ~D	Total
+	5	2	7
-	15	79	94
Total	20	81	101

Classified + if predicted Pr(D) >= .5
True D defined as Adopters != 0

Sensitivity	Pr(+| D)	25.00%
Specificity	Pr(-|~D)	97.53%
Positive predictive value	Pr(D| +)	71.43%
Negative predictive value	Pr(~D| -)	84.04%
False + rate for true ~D	Pr(+|~D)	2.47%
False - rate for true D	Pr(-| D)	75.00%
False + rate for classified +	Pr(~D| +)	28.57%
False - rate for classified -	Pr(D| -)	15.96%
Correctly classified		**83.17%**

Logistic model for 3DP Non_pot_adopters

Classified	True D	True ~D	Total
+	13	5	18
-	22	61	83
Total	35	66	101

Classified + if predicted Pr(D) >= .5
True D defined as Non_pot_adopters != 0

Sensitivity	Pr(+| D)	37.14%
Specificity	Pr(-|~D)	92.42%
Positive predictive value	Pr(D| +)	72.22%
Negative predictive value	Pr(~D| -)	73.49%
False + rate for true ~D	Pr(+|~D)	7.58%
False - rate for true D	Pr(-| D)	62.86%
False + rate for classified +	Pr(~D| +)	27.78%
False - rate for classified -	Pr(D| -)	26.51%
Correctly classified		**73.27%**

Appendix B

Figure 1.b

Interview Protocol - 3DP Potential Adopters

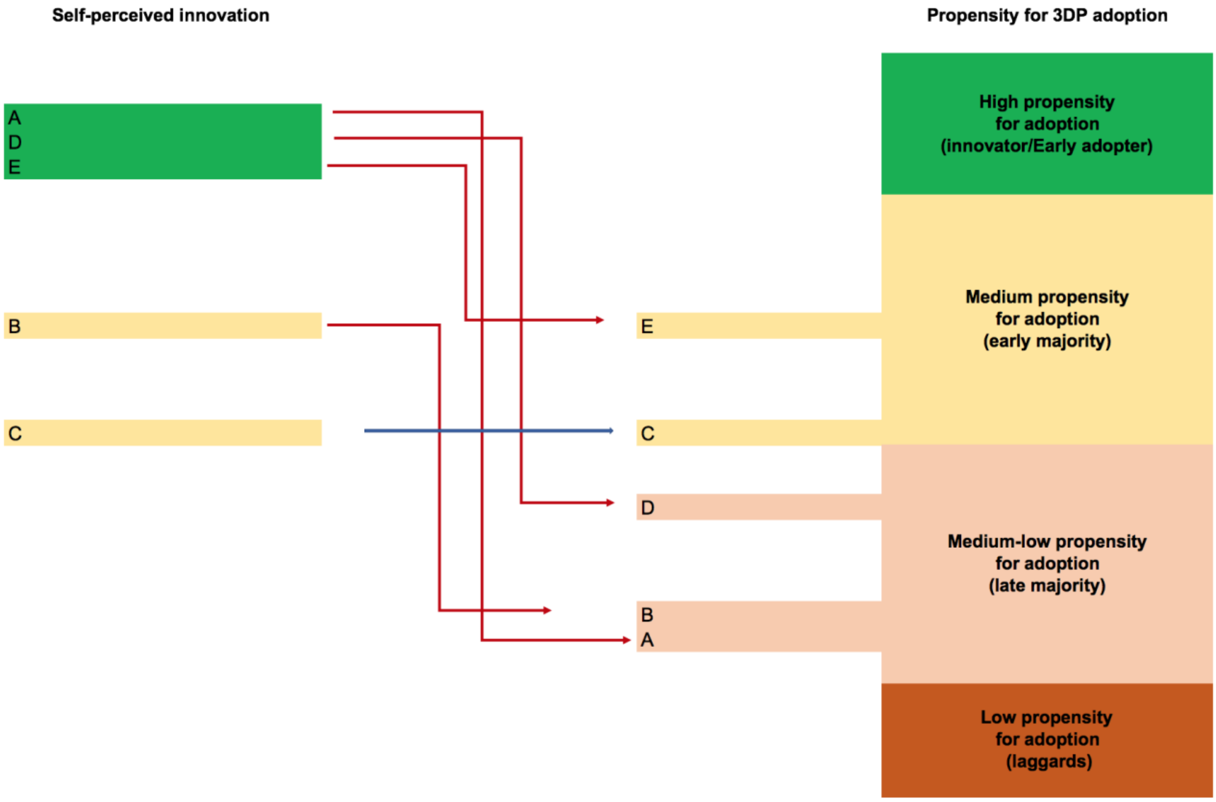
Item	Question	Source
Adoption category	Please indicate to which category you believe you fit in with regards to your stance on technological innovation use for your firm.	Rogers (2003); Schniederjans (2017)
	Your firm is among the first to accept a new technology and its adoption behavior is based almost exclusively on intuition	
	Your firm bases its adoption decisions on practicality and tend to accept a new technology after other firms do it	
	Your firm tends to accept an innovation when it becomes standard and when they are confident about using it	
	Your firm usually accepts an innovation after it becomes a necessity	
Please rank from 1 to 5 your agreement on each of the following statements		
Perceived compatibility		Rogers (2003); Schniederjans (2017)
COMPAT 1	Using 3D printing is compatible with your firm's missions and values	
COMPAT 2	Using 3D printing is compatible with your firm's existing technologies	
Relative Advantage		Rogers (2003); Schniederjans (2017)
REL_ADV1	The use of 3DP would improve your firm's quality of work over existing traditional technologies	
REL_ADV2	The use of 3DP would simplify the work of your firm's employees over existing traditional technologies	
REL_ADV3	The use of 3DP would improve the work effectiveness of your firm's employees over existing traditional technologies	
REL_ADV4	The use of 3DP would provide your firm's employees a greater control over their work over existing traditional technologies	
REL_ADV5	The use of 3DP would reduce the cost structure of your firm over existing traditional technologies	
REL_ADV6	The use of 3DP would help your firm face the actual global crisis over existing traditional technologies	Beltagui and Candi (2019)
Performance expectancy		
PERF_EXP1	The use of 3DP would help your firm accomplish the tasks more quickly	
PERF_EXP2	The use of 3DP would increase your firm's productivity	
Please indicate which type of activities your firms would use 3D printing for		Schniederjans 2017
Typology of use	Prototyping activities	
	End-use products development	
	Spare parts development	

Likert-type scale (1: not considering at all, 2: slightly considering, 3: considering, 4: sufficiently considering, 5: strongly considering).

Figure 2.b

Companies	Brief profile	Turnover	Employees
A	This company was founded in 1974 and it has to do with processing ferrous and non-ferrous metals, the turning of several materials, moulding and mechanical construction in general. It mainly provides manufacturing precision tools for organizations in various sectors: automotive, earth moving equipment, agricultural machinery, hydraulics, pumps, energy. The modern machinery inventory ensures the company a great flexibility in processing various materials: copper alloys, aluminium alloys, free-cutting steels quenched tempered steels, carburised steels, stainless steels in variable dimensions. The company meets customers' needs in the manufacturing context for various batch sizes: including mass production small batch sizes. This company declares to implement an innovation strategy to improve the production process and the quality of products provided.	5 - 10 million	20 - 50
B	This company was founded at the end of 1960s and it operates in the connection systems market at the European level in various sectors: small and big appliances (washing, refrigeration, cooking and coffee machines), vending, automotive spare parts and electro-mechanical applications in general. At the beginning the company'core business included moulding plastics activities and the creation of moulds, as well as the development of connectors for electrical wiring harnesses applications. After a rebranding activity, the company decided to focus on the development of components for electrical connections. It entered the field of small metals production and creates a new department for the development of dies and molding the terminals.The company affirms to encourage investments for the renewal of company's machines and infrastructure as well as the development of new innovative solutions.	2 - 5 million	20 - 50
C	This company was founded in the early Sixties and it operates in the sector of manufacture of mattresses at national and European level. It employs cold moulding methods for plastic materials to create mattresses and customized sleeping systems; its products are periodically subjected to durability and measurement test. The company encourages a low environmental impact in all production development' phases and it is supported in its innovation activities by institutes of ergonomics and scientific sleep research, test labs, and international designers.	2 - 5 million	less than 20
D	This company was founded in the late Seventies and it fabricates moulds and high precision tools, such as components and prototype systems for industrial machines in various sectors: personal care, food and beverage, industrial automation, energy and robotics. The company follows a make-to-order production strategy focused on small production volumes and highly customized components for national and international business customers. Several typologies of ferrous and non-ferrous materials are treated, in particular iron and aluminum making both small and medium-sized components.	2 - 5 million	20 - 50
E	This company was founded in the early Seventies and it is focused on the design, production and sale of a wide range of solutions for power transmissions in the industrial foundry sector. The creation of pulleys and structures in light alloys, moulds and industrial equipment represent the main production activities. The target market is composed mainly of Italian companies, but its products are also distributed on international markets, in particular at European level. The company consider flexibility in the production process the key factor for a long-lasting success.	2 - 5 million	20 - 50

Figure 3.b*



*Rogers' adoption categories proportions are respected

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Business performance drivers in innovative Italian SMEs

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ABSTRACT

The aim of this paper is determining the main factors impacting on the business performance of Italian SMEs with a strong innovation component. In particular, the goal of this research is exploring the impact of firms' business capabilities (management capabilities, workforce skills and technological capabilities) and different types of investments in innovation on the likelihood for innovative Italian SMEs to meet their expectations in terms of profits, sales and customer satisfaction. To this end, we have developed an original dataset through a web survey addressing 125 innovative Italian SMEs. The results from an ordered logit model for several proxies of firms' business performance show that both investments in non-R&D activities and firms' business capabilities play a crucial role for Italian SMEs to meet their innovation goals.

Keywords: SMEs, business capabilities, innovation performance, organizational innovation, workforce skills, technical expertise, new digital technologies

1. Introduction

The aim of this paper is to identify and analyze the main factors which impact on the likelihood for innovative Italian SMEs (small and medium enterprises) to meet their business performance's expectations.
It is widely demonstrated that SMEs play a major role in the process of fostering technical progress and innovation in the economic and social environment (Acs and Audretsch, 1999; Radas and Bozic, 2009; Zygmunt, 2017). According to the latest Eurostat data, SMEs play a prominent part in terms of employment and added value, in Italy even more than in any other European Country, and they turned out to be crucial actors in the new digital innovation environment (European Commission, 2019).

By definition (Italian Ministry of Economic Development, 2015) innovative Italian SMEs refer to SMEs matching at least two out of the following three criteria, regardless of firms' industrial sector or level of experience:

- the firm's expenditure in Research and Development (R&D) has to reach at least 3% of the higher value between turnover and annual costs;
- at least 20% of a SME's total workforce must be composed by PhD holders, PhD students or researchers, or at least 1/3 must have a master's degree;
- the firm has to show a registered patent or an original registered software.

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Italian industrial setting is composed almost totally by SMEs which account for 99% of all businesses and generate almost 67% of overall value added in the "non-financial business economy" (industry, construction, trade, and services),[7] exceeding far away the European average (56,4%) (European Commission, 2019). The overall turnover of the innovative Italian SMEs (approximately 20.000) for which the data is available (99,3% of the total population) amounted to just under 4,1 billion euros in 2018 (Patuanelli, 2020).

Since the global financial crisis 2008-2009, the Italian Government decided to implement several measures to support business capabilities and innovation in SMEs. In 2015 the category of "innovative SMEs" has been introduced and the "Industria 4.0" plan[8] has been launched with the aim to foster innovation in any sector (Decree Law 3/2015). This national strategy represents one of the main incentives for SMEs to increase innovation, fostering industrial digital transformation and vocational-oriented education. In light of this, most manufacturing firms have decided to adopt new digital systems such as IT security, connectivity, cloud computing and collaborative robotics.

It is, therefore, fundamental investigating innovation in SMEs, with a particular focus on their intangible assets and non-R&D activities, in the attempt to better identify the innovative potential of Italian industrial economy.

In light of this context, this research has the aim to investigate which kinds of factors mostly impact on Italian SMEs' innovation performance, taking into consideration those firms with a strong innovation component. This paper tries also to provide strategic recommendations to support the innovation-oriented entrepreneurial culture of Italian SMEs.

Innovation-driven SMEs are essential elements of Italian and European industrial markets, supporting the transition to a sustainable and digital economy. This is also the main reason why both OECD and European Commission demand for more empirical analyses at firm level to explore the main drivers of SMEs' innovation (OECD, 2018).

In order to effectively respond to this request, this paper analyzes the impact of business capabilities (identified by OECD as general management capabilities, workforce skills and technological capabilities) and investments in focal innovations, on business performance (in terms of profits, sales and customer satisfaction) from the innovative Italian SMEs' perspective. According to the most recent OECD guidelines on industrial innovation (OECD, 2018), collecting data on business capabilities is of critical importance for analyzing the effects of innovation on firms' performance. Therefore, we have treated business capabilities and investments in focal innovations as inputs to investigate on the possibility for innovative Italian SMEs to meet their business performance expectations and to increase their profits from focal innovations.

In this respect, the hypotheses formulated are the following:

[7] The "non-financial business economy" includes industry, construction, trade, and services (NACE Rev. 2 sections B to J, L, M and N), but not enterprises in agriculture, forestry and fisheries and the largely non-market service sectors such as education and health. Renamed now "Impresa 4.0". Decree Law 3/2015.

[3] Renamed now "Impresa 4.0"

Hypothesis 1: *General management capabilities* are expected to generate a significant and positive impact on the ability of innovative Italian SMEs to meet their business performance expectations and increase their focal innovations' profits.

Hypothesis 2: *Workforce skills* are expected to have a significant and positive incidence on the ability of innovative Italian SMEs to meet their business performance expectations and increase their focal innovations' profits.

Hypothesis 3: *Technological Capabilities* are expected to show a positive and significant effect on the ability of innovative Italian SMEs to meet their business performance expectations and increase their focal innovations' profits.

Hypothesis 4: *Non-R&D investments* on focal innovations compared to R&D ones are expected to have a more significant positive impact on the ability of innovative Italian SMEs to meet their business performance expectations and increase their focal innovations' profits.

The following sections, based on existing theoretical and empirical evidence, have the aim to describe how the foregoing factors are expected to improve the innovation outcome of innovative Italian SMEs.
The main findings of the empirical analysis can be summarized as follows:

- The achievement of firms' profit expectations: considering the shares of product and business process innovations meeting SMEs' profits expectations, important results can be provided. Firstly, it is shown that even small investments in R&D (below 5%) on focal innovations can affect the satisfaction of SMEs' expectations in a positive way. However, it is worthwhile to note that the expenses in non-R&D activities (creative work) on focal innovations show an even stronger positive effect across all over the investment percentages considered (5%-14%; 15%-30% and over 30%). Moreover, the high level of importance assumed by quality-related competitive strategies, dynamic and innovation management abilities, and the diversification of tertiary-educated workforce play a crucial role in this respect. Finally, in terms of technological capabilities, higher levels of expertise in the use of Robotics, compared to AI and 3D-printing, seems to positively affect the possibility to gain satisfying profits over the year considered.

- The achievement of firms' sales expectations: considering the shares of product and business process innovations meeting SMEs' sales expectations, we can note that several factors play a crucial role. Firstly, significant investments in creative work on focal innovations (more than 30% of total investments for innovation), and high levels of importance recognized to innovation management and design capabilities have a significant and positive effect in the achievement of firms' sales expectations. In addition, while expertise in Cloud Computing (medium-level), in AI (medium and high levels), and 3D-printing (low and high levels) seems to impact in a negative way on the dependent variable, the expertise in Big Data and Robotics seems to positively affect the probability to increase the fulfillment of sales expectations.

- The achievement of firms' expectations in terms of customer satisfaction: our results show that both low and high levels of investments in focal innovations' engineering (less than 5% and more than 30%), as well as the importance taken on innovation management, design capabilities and a highly-educated diversified workforce, impact in a positive and significant way on the probability for SMEs' innovations to reach satisfying customer satisfaction rates. On the contrary, firms with a technological expertise focused on AI seem to be less likely to meet their customer satisfaction standards.

- The amount of profits from focal innovations: according to our figures, even a low percentage (less than 5%) of total financial resources invested in engineering activities for focal innovations could increase the probability to gain satisfying profits. Moreover, competitive strategies focused on quality and branding activities along with the importance of managers' change capabilities, innovation management practices and tertiary-educated employees from different fields, seem to have a significant and positive impact on profits. In terms of technical expertise, we can affirm that SMEs showing a medium level of AI knowledge are less likely to account for high shares of profits from their focal innovation.

This paper is organized as follows. Next section presents the theoretical background. Section 3 describes the data and the methodology used for the empirical analysis. The results are presented and discussed in Section 4, whereas Section 5 concludes the paper discussing the managerial and policy implications.

2. Conceptual background

A large body of evidence demonstrates that SMEs greatly contribute to the innovation system by the introduction of new products and the alignment of existing products to the needs of customers.
In particular, business performance in SMEs has been widely investigated by innovation literature. From a quantitative point of view, several variables have been considered, such as efficiency, financial results, level of production (Anggadwita and Mustafid, 2014), as well as market share, profitability, productivity, revenues, costs and liquidity (Gupta and Batra, 2016; Zimon, 2018).

However, also qualitative variables have been largely analysed: goals achievement, leadership style, employee behaviour (Anggadwita and Mustafid, 2014), customer satisfaction (Alpkan, Yilmaz and Kaya, 2007), product and process innovation, organizational and marketing innovation (Sheehan, 2013). Gopang et al. (2017) have identified several indicators to explain SMEs performance, including reputation, productivity, profits, sales, product quality and product diversification.

In the pertinent literature, human and organizational factors are considered fundamental drivers to enhance firms' competitiveness and performance in an increasing innovative environment, especially for SMEs relying on limited resources. In this respect, organizational and management literature has analyzed various internal factors potentially influencing the performance of SMEs: firms' age and size (Arend, 2014; Nicolini, 2001), intellectual capital and human resources practices (Gomezelj Omerzel, D., & Smolcic Jurdana 2016; Katou, 2012; Sheehan, 2013), entrepreneurial networks (Bratkovic Kregar and Antoncic, 2016;) product, process, organizational and marketing innovation (Altuntas et al., 2018; Wolff and Pett, 2006), planning and strategy (Aragon-Sanchez and Sanchez-Marin, 2005; Leitner and Guldenberg, 2010) and market, entrepreneurial, and learning orientations

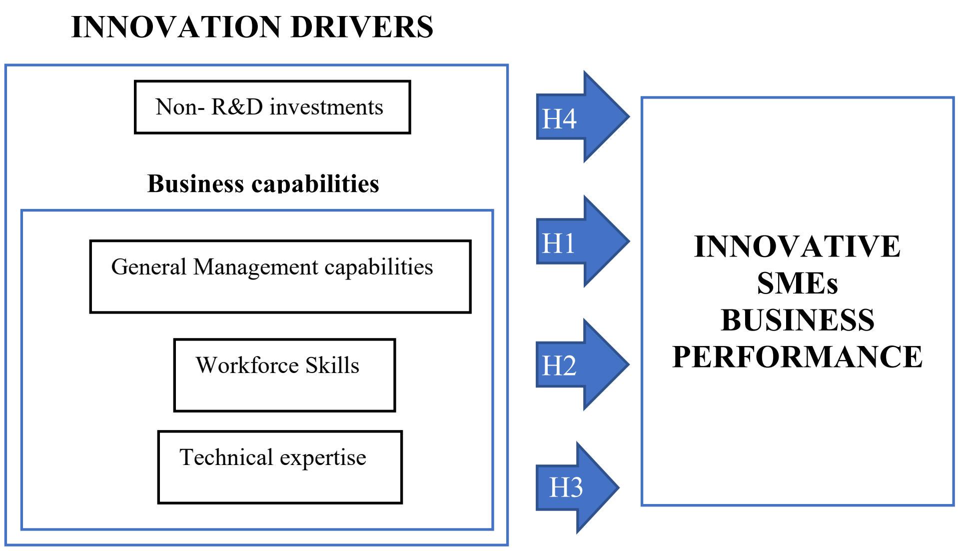
(Lomberg, et al. 2017).

Although, most of the studies mentioned above have investigated the performance of SMEs at an organizational level describing the relations of SMEs' performance with their internal factors, or with a combination of internal and external factors, there is still lack of work on innovative SMEs' business capabilities. These studies can be considered useful to entrepreneurs, in their efforts to come up with the most effective ways to improve business performance. However, they cannot rely on a recent globally recognized framework which could encourage international comparisons among innovative SMEs.

In order to fill these gaps, this paper aims to focus on innovative Italian SMEs' performance expectations in terms of profits, sales and customer satisfaction, in line with the latest CIS (Community Innovation Survey, 2016) exploring innovative enterprises by the level of their meeting expectations towards innovation. Therefore, this research contributes to existing innovation studies by investigating the level of performance of a relevant subset of SMEs, through the development of an empirical analysis with a rich and original dataset. Moreover, this paper relies on the latest OECD guidelines to explore the factors determining the probability for innovative SMEs to meet their performance expectations (OECD/Eurostat, 2018). Such an approach has the advantage of considering, as a whole, both the defining elements of innovative SMEs' performance expectations and their determinant factors.

The Figure 1 below offers a conceptualization of the hypotheses abovementioned. As explained before, this work intends to shed new light on the logics by which different business capabilities and different types of investments in focal innovation (especially expenses related to non-R&D activities), impact on the likelihood for innovative SMEs to increase their business performance.

Figure 1



2.1 Baseline hypotheses

According to the recent OECD guidelines for the measurement of scientific, technological and innovation activities (OECD 2018), business capabilities are identified as knowledge, competencies and resources accumulated by a firm over time in the pursuit of its objectives.
Over the past years, several studies (Bloom and Van Reenen, 2007; Bloom and Van Reenen, 2010) have been carried on to explore numerous firms' business capabilities as drivers of innovation activities and the economic success of innovation. In particular, different studies on industrial and innovation management (Cohen and Klepper, 1996; Kuusisto et al. 2014) have demonstrated how *general management capabilities* can impact on a firm's ability to undertake innovation activities, introduce innovations and generate satisfying innovation outcomes.
General management capabilities include the ability to formulate effective *competitive strategies* and *organizational capabilities* used to put these strategies into action (OECD, 2018).

Firstly, it is widely demonstrated that the development of quality-driven competitive strategies and specific branding activities to differentiate firms' products from those of their competitors can strongly affect the innovation performance of a firm. In this respect, according to the Australian Bureau of Statistics researches (2016), quality-focused firms are more likely to provide new-to-market product innovations. Other relevant elements supporting a long-lasting competitive strategy, such as the improvement of existing products or the introduction of entirely new products, are \ to be crucial in the achievement of business performance's expected targets from innovative firms' perspective.

Secondly, organizational capabilities can be considered "firms' internal abilities, capacities, and competences used to mobilize… and exploit resources in order to meet the firm's strategic goals" (OECD 2018). In particular, organizational capabilities have to do with the management of people, intangibles, physical and financial capital and include *change management capabilities, dynamic managerial capabilities* and *innovation management capabilities* (Helfat and Martin, 2015; Helfat et al., 2007).

Change management capabilities include the ability to identify significant external challenges (responsiveness), the ability to learn from experience (learning), the ability to integrate several processes to reach strategic targets (alignment) and the ability to come up with new knowledge and solutions which can be implemented (creativity).
With the advent of digital transformation, the ability to integrate different resources and process in order to obtain successful business performance has started to be considered so crucial for innovative firms that a particular typology of firms, called system integrators, have acquired a prominent role in this respect (Rivera, 2021). Moreover, creativity is regarded as a critical intangible asset to foster innovation and problem solving skills, and to obtain successful business results in an interconnected and dynamic world (Zollo and Winter, 2002). In this respect, several researches have been carried on about the association between firms' organizational creativity and the skills necessary to be competitive worldwide (Knight and Kim 2009, Vasconcellos et al., 2019).

Finally, the abilities associated with identifying external challenges and learning from experience are widely recognized as the basis of firms' resilience, which is in turn considered crucial in terms of firms' performance (Akgün and Keskin 2014, Audretsch and Belitski 2020;). In this respect, a recent study from McKinsey (2021) has demonstrated that resilient firms are more likely to show consistent balanced performances across a number of metrics, and are more likely to drive value-added growth in the future.

Many innovation researchers have also collected data on dynamic managerial capabilities (Helfat and Martin, 2015) which refer to "the abilities of managers to organize an effective response to internal and external challenges" (OECD, 2018). Borch and Madsen (2007) in their explorative study on 235 SMEs demonstrated that dynamic capabilities facilitate innovative strategies and are crucial for SMEs' competitive advantage. A more recent research by Holzmayer and Schmidt (2020) has taken in consideration the three underpinnings of dynamic managerial capabilities (human capital, social capital and cognition) and has shown that they play a central role for firms' performance. In particular, they analyzed dynamic managerial capabilities as antecedents of related business diversification[9] which, in turn, leads to positive revenue and increase firms' profitability.

Innovation management capabilities (such as encouraging, collecting and assessing new ideas produced inside a firm from employees) have been analyzed by many researchers (Klingebiel and Rammer, 2014; Galindo-Rueda and Van Cruysen, 2016) and are defined as abilities related to "initiate, develop and achieve results from innovation" (OECD, 2018). Moreover, it is widely demonstrated that firms' innovation management capabilities can positively affect firms' business performance (Foroudi et al., 2018; Foroudi et al., 2020; Hafeez et al., 2018; Mazzanti et al., 2006; Hurley et al., 2005). In this respect, a recent study showed the importance of innovation management capabilities on firms' performance from SMEs' perspective (Izadi et. al., 2020).

Thus, devoting great importance to general management capabilities and internal innovation practices is expected to show a positive effect on the probability for SMEs to meet their business performance expectations (both for product and process innovations).

Taking into consideration the literature addressed, the first hypothesis of this paper would read as follows:

Hypothesis 1. General management capabilities are expected to generate a significant and positive impact on the fulfillment of SMEs' business performance expectations.

Among business capabilities, *workforce skills* are found to play a crucial role to foster firms' innovation activities and increase business performance. Employees' educational background and characteristics have been investigated by several innovation studies (Doms et. al., 2010; Østergaard et al., 2011), and according to OECD (OECD, 2018) a key indicator associated with the workforce skills is the composition of the workforce by levels of educational attainment, measured by the share of employed persons with tertiary education. Lund Vinding (2006) has investigated the importance of human capital on the firms' absorptive capacity, in relation to firms' innovative performance. Through the estimation of an ordered probit model on 1544 firms from the manufacturing and service industry, he showed that the share of highly educated employees is positively correlated with the firms' ability to innovate. Moreover, many studies have indicated that workforce diversity can have a strong positive impact on firms' business performance (Lee and Kim, 2020; Won et. al., 2020; Bae and Han, 2019; Bolli et. al., 2018). It is also worth pointing out that several workforce skills and

[9] Related Business Diversification is defined as "Diversification investments which are particularly close to the core business" (Holzmayer and Schmidt, 2020).

competences, beyond formal qualifications, such as team-working abilities play a crucial role in firms' innovation and organizational performance (Avermaete et al., 2004; Markovic 2008; Mendes and MacHado, 2015).

Taking into account these contributions, the second baseline hypothesis is established:

Hypothesis 2. Workforce skills are expected to have a significant and positive incidence on the fulfillment of SMEs' business performance expectations.

In terms of *technological capabilities*, recent innovation management analyses underlined the crucial role played by *technical expertise* and *design capabilities* (Galindo-Rueda, and V. Millot, 2015; Galindo-Rueda and Van Cruysen, 2016) in firms' innovation performance. Design capabilities are defined as those abilities associated with an innovation activities "aimed at planning and designing procedures, technical specifications and other user and functional characteristics for new products and business processes" (OECD, 2015a). Several studies on innovation management have shown how a significant increase in product-design capabilities was able to impact on SMEs' business performance and innovativeness (Gledson and Phoenix, 2017; Peng and Lin, 2017).

According to the Oslo Manual (OECD, 2018), *technical expertise* is identified by "a firm's knowledge of and ability to use technology", in particular new digital technologies, and it comes from skills and qualifications of a firm's workforce. Chen et al. (2016) have conducted an empirical research on Taiwanese SMEs and proved how digitalization significantly influence firms' organizational performance. One of the first research contributions investigating the impact of digital technologies on a large number of European SMEs has been conducted by Bouwman et al. (2018). They have explored how digital technologies have forced SMEs to rethink their business models impacting on firms' innovativeness and performance.
Based on the theoretical and empirical literature described above, a positive direct effect is, thus, expected for technological capabilities on the likelihood of firms to achieve the expected innovation performance:

Hypothesis 3. Technological capabilities are expected to have a positive and significant effect on the fulfillment of SMEs' business performance expectations.

It has been proved that SMEs exclusively focused on R&D activities in their innovations strategies fail to use new sources of value creation, while SMEs which completely overlooking R&D fail to recognize innovation as a source of business renewal, since they associate innovation with R&D (OECD, 2018).

Technical or R&D-based innovation per se does not imply growth, and growth per se does not imply technological innovativeness. Innovation is, therefore, a much broader concept than R&D or product development, since it involves business models, operational and organizational solutions, development of customer experiences.

In order to investigate innovation investments in SMEs, the European Community Innovation Survey (CIS) distinguishes between R&D and non-R&D based innovation. According to the latest CIS data (2018) we can note that innovation in SMEs is mainly non-R&D investment based. Only as firms' size increases, the relevance of R&D investment in innovation rises (0,22% for SMEs in the 10-49 size class; 0,27% for SMEs in the 50-249 size class). As a result, for SMEs, non-R&D expenditures are considered more important and different kinds of investments relating to training, engineering, design and creative work should be taken into account.

Investments in creative work and design innovation regards incremental improvements in products that do not radically modify their function or technological base, but allow companies to better meet their customer needs. In this respect, design innovation and creative work for SMEs deserve greater attention from innovation literature, since represent powerful incentives to improve innovative products. Traditional accounts of R&D, albeit important, largely undervalues the critical implications of innovative design, which requires a deep understanding of product function, in relation to customer requirements; Accordingly, the last hypothesis of this paper would read as follows:

Hypothesis 4. Non-R&D investments on focal innovations are expected to show a significant and positive impact on SMEs' business performance.

3. Data and methodology

3.1 Description of data

Italian SMEs are estimated to be approximately 20.000 all over the Country. However, we have conducted our analysis only on 9% of them (1738) whom have been registered into a special section of the Business Register[10] monitored by the local Chambers of Commerce. According to the 2020 edition of the SME Observatory research, the number of innovative SMEs registered showed an increase of 40% over 2019, and is expected to significantly grow in the following years.
By observing the Table 1 below, we can affirm that our reference sample (125 SMEs have replied to our web-based survey) reflects almost perfectly the Chambers of Commerce dataset in terms of geographical, sectorial and size features.

Table 1

	on 125 SMEs	on 1738 SMEs
Geo 1 (South)	18%	23%
Geo 2: (Center)	24%	21%
Geo 3 (North)	58%	58%
Sector 1 (service)	70%	71%
Sector 2 (trade)	6%	6%
Sector 3 (manufacturing)	25%	24%
Size Micro	56%	51%
Size Small	36%	34%
Size Medium	8%	10%

[10] Decree Law 3/2015: art. 25, paragraph 8

Our empirical analysis is based on an original cross-sectional dataset including rich information at firm level. Data were collected through a web survey composed of three sections and designed according to the OECD guidelines and terminology (OECD 2018). The first section is developed to gather information on the real firms' innovative status, as well as on the share of product and business process innovations successful developed in terms of profits, sales and customer satisfaction results; the second section captures the information relating to firms' business capabilities; the last one relates to focal innovations' data.
The measurement framework employed for selecting the units of our analysis combines an object-based approach (focused on the phenomena of interest: focal innovations) and a subject approach, by taking into account the main actors of innovation outcomes: innovative SMEs. In this respect, general questions about SMEs' strategies and innovation practices (subject approach) are followed by an object-based module, including specific questions on firms' focal innovations, in order to make clear for respondents the type of innovation questions are referring to (OECD 2018).

The contact person was the CIO (Chief Innovation Officer) of the firm, or the general manager. Often it was usually the owner who participated in the survey. A total of 1703 firms were contacted to achieve the target of 125 responses, resulting in a 7% response rate. The sample distribution by firm size and industry is presented in the Table 2 below.

Table 2

	Size			
Sector	**Micro**	**Small**	**Medium**	Total
Service	43	38	6	87
Trade	6	0	1	7
Manufacturing	21	7	3	31
Total	70	45	10	125

In terms of business innovation, it is worth pointing put that the innovation status of a firm depends on two crucial factors: firm's engagement in innovation activities and the introduction of one or more innovations, during a specific observation period (OECD, 2018).

"Innovative firms" are defined by the OECD (2018) as firms having introduced one or more innovations, while "innovation-active firms" are firms engaged in innovation activities. As a result, not just innovative firms, but also non-innovative ones can be considered "innovation-active" since they could have had the possibility to be involved in innovation activities, without having introduced any innovation during the period analyzed.

In this respect, this paper tries to capture SMEs' business performance from process innovation and outcome innovation's perspective, by focusing on the introduction of both innovations and innovation activities, respectively.

In the Table 3 below we can note that 16% of the SMEs interviewed are non-innovative firms: in particular 2,4% are not engaged in innovation activities, nor introduced any innovations in the reference period, while 17 out of 125 SMEs (13,6%) are involved in innovation activities without having developed innovations (innovation-active firms). Less than a half (45,6%) are innovative and innovation-active firms.

Table 3

Innovative status	Freq.	Percent	Cum.
Innov-active	17	13.60	16.00
Innovative	48	38.40	54.40
None of the above	3	2.40	2.40
Both	57	45.60	100.00
Total	125	100.00	

It is also interesting comparing our data to those collected by Community Innovation Survey (CIS, 2018) which is the only one which has investigated so far the innovative SMEs by level of meeting expectations towards innovation. However, a comparison regarding small and medium companies is the only one we can make, since CIS does not take into consideration micro firms. Moreover, CIS considers performance expectations as a whole, while we distinguish them in three groups: profits, sales and customer satisfaction expectations[11].

The tables below shows the share of SMEs meeting their different level of expectations, in terms of their product innovations.

By comparing high expectations levels, our data seem to be in line with the CIS ones, in terms of profits and sales, while in terms of customer satisfaction, our data seem to show a much encouraging situation, especially in small firms.

However, by comparing 2018 and 2019 overall data, we can argue that the best results are achieved by small firms. In particular, regarding the achievement of medium-level expectations, we can note a worsening of SMEs' satisfaction and a strong increase in the share of SMEs with none or low expectations satisfied towards their innovations (especially for firms in 50-249 size category).

[11] In order to compare our data and CIS results we operated these equivalences: none expectations: 0% of innovations meeting SMEs' expectations; low expectation: below 25% of innovations meeting SMEs' expectations; medium expectations: 25% to 75% of innovations meeting SMEs' expectations; high expectations: above 75% of innovations meeting SMEs' expectations.

PROFITS %

High expectations	CIS 2018	Our data
From 10 to 49 employees	**23.0**	18.0
From 50 to 249 employees	**20.1**	20.0
Medium expectations	CIS 2018	Our data
From 10 to 49 employees	**52.9**	46.7
From 50 to 249 employees	**59.9**	40.0
Low	CIS 2018	Our data
From 10 to 49 employees	**14.6**	29.0
From 50 to 249 employees	**13.3**	30.0
None	CIS 2018	Our data
From 10 to 49 employees	**2.6**	6.7
From 50 to 249 employees	**0.9**	10.0

SALES %

High expectations	CIS 2018	Our data
From 10 to 49 employees	**23.0**	22.2
From 50 to 249 employees	**20.1**	20.0
Medium expectations	CIS 2018	Our data
From 10 to 49 employees	**52.9**	40.0
From 50 to 249 employees	**59.9**	30.0
Low	CIS 2018	Our data
From 10 to 49 employees	**14.6**	31.1
From 50 to 249 employees	**13.3**	40.0
None	CIS 2018	Our data
From 10 to 49 employees	**2.6**	6.67
From 50 to 249 employees	**0.9**	10.0

CUSTOMER SATISFACTION %

High expectations	CIS 2018	Our data
From 10 to 49 employees	**23.0**	42.2
From 50 to 249 employees	**20.1**	30.0
Medium expectations	CIS 2018	Our data
From 10 to 49 employees	**52.9**	42.2
From 50 to 249 employees	**59.9**	40.0
Low	CIS 2018	Our data
From 10 to 49 employees	**14.6**	13.3
From 50 to 249 employees	**13.3**	20.0
None	CIS 2018	Our data
From 10 to 49 employees	**2.6**	2.22
From 50 to 249 employees	**0.9**	10.0

3.2 Variables and model specification

3.2.1 Variables

Descriptive statics for all variables are reported in the table 5 in the Appendix. The outcomes are measured by a set of four variables. The first three factors refer to the percentages of innovations meeting the SMEs' expectations in terms of profits, sales and customer satisfaction respectively. Instead, the fourth dependent variable regards the amount of profits generated by SMEs' focal innovations during one-year period (2019).

Specifically the dependent variables in this model are described as follows.

Expectations of profits
(Please indicate the approximate share of your firm's product innovations and/or business innovations in line with your firm's expectations in terms of profits, considering the year 2019)
This ordinal variable regards the share of innovations turned out to be successful according to the expected profits. The variable assumes the following values: 0 (= 0%); 1 (=1%-24%); 2 (25%-49%); 3 (50%- 74%); 4 (75%-99%); 5 (100%).

Expectations of sales
(Please indicate the approximate share of your firm's product innovations and/or business innovations in line with your firm's expectations in terms of sales, considering the year 2019)

This ordinal variable regards the share of successful innovations in terms of expected sale's targets achieved by the firms. The variable assumes the following values: 0 (= 0%); 1 (=1%-24%); 2 (25%-49%); 3 (50%- 74%); 4 (75%-99%); 5 (100%).

Expectations of customer satisfaction
(Please indicate the approximate share of your firm's product innovations and/or business innovations in line with your firm's expectations in terms of customer satisfaction, considering the year 2019)
This ordinal variable regards the share of successful innovations in terms of customer satisfaction's targets achieved by the firms. The variable assumes the following values: 0 (= 0%); 1 (=1%-24%); 2 (25%-49%); 3 (50%- 74%); 4 (75%-99%); 5 (100%).

Focal innovation profit
(Please indicate approximately the contribution of your firm's focal innovation to your firm's overall profits, considering the year 2019)
This ordinal variable regards the share of profits deriving from the focal innovation developed by each firm. The variable assumes the following values: 1 (=0%-24%); 2 (25%-49%); 3 (50%- 74%); 4 (75%-99%); 5 (100%).

Explanatory variables are classified into four categories: management capabilities, workforce skills, technological capabilities and the share of total expenses on firms' focal innovations by typology of investment in R&D and non-R&D activities, such as engineering, creative works and training (see the Table 4 in the Appendix).

With regards to *Management capabilities*, we used two groups of variables that refer to SMEs' abilities potentially affecting innovation performance:

- firms' competitive strategies (*Competitive strategy*);
- organizational and managerial capabilities used to put these strategies into action (*Change management capabilities*, *Dynamic managerial capabilities and Innovation management capabilities*).

Competitive strategy is constructed as an ordered 3-category variable indicating the level of importance (1= low; 2= medium; 3= high) associated with several quality-related strategies, including branding activities to differentiate firms' products from those of competitors, and actions to both improve the existing production portfolio and introduce new products.

Change management capabilities is developed as an ordered 3-category variable indicating the level of importance (1= low; 2= medium; 3= high) associated with the ability of managers to face unexpected changes. *Change management capabilities* include four main dimensions: responsiveness (the ability to perceive important external challenges); learning (the ability to learn from experience); alignment (the ability to integrate different processes to meet strategic targets) and creativity (the ability to create and adopt new knowledge and solutions).

Dynamic managerial capabilities are represented by an ordered 3-category variable indicating the level of importance (1= low; 2= medium; 3= high) associated with the ability of managers to organize an effective response to internal and external challenges. According to the seminal work of Helfat and Martin (2015), dynamic managerial capabilities include three main dimensions: managerial cognition (knowledge structures impacting on managers' biases, for instance, the anticipation of market changes or the awareness of consequences from different choices); managerial social capital (goodwill coming from managers' networking activities to have resources and information) and managerial human capital (learned skills and knowledge developed through prior experience, training, and education).

Innovation management capabilities are described by an ordered 3-category variable showing the level of importance (1 = low; 2 = medium; 3 = high) associated with the use of knowledge management systems, financial and non-financial incentives for employees to provide innovative ideas, as well as actions to involve employees representatives in innovation decisions, and delegate decision-making to innovation project managers.

Regarding to the *Workforce skills*, we used two ordered variables addressing the workforce composition and features: *workforce qualification* and *workforce characteristics*, respectively. The first one accounts for the share of tertiary educated employees in the firm with different qualifications and it ranges from 1 (at least 3 out of 5 workforce categories accounting for less than 10% of tertiary educated employees) to 4 (at least 3 out of 5 categories with more than 80% of tertiary educated employees). On the other hand, for capturing the workforce characteristics we used an ordered 3-category variable ranging from 1 (low level) to 3 (high level), indicating the level of importance attributed by firms to several employees' capabilities: cognitive, social, technical and systems skills, as well as entrepreneurialism, adaptability and flexibility.

In order to capture *Technological capabilities*, we focused on *technical expertise* and *design capabilities*. Technical expertise can be identified as firms' knowledge of and ability to use technology. This knowledge comes from the skills and qualifications of employees, including engineering and technical workforce, accumulated experience in the use of technology and the use of capital goods containing the technology. We constructed five ordered 4-category variables regarding the level of use and expertise (from 0 = "not used or very low level" to 4 = "high level), each associated with an emerging digital technology: Cloud Computing, Big Data, Robotics, AI and 3D-printing. Moreover, in order to take into consideration design capabilities, we developed an ordered 4-category variable indicating the importance of the role played by design activities inside the firms (0 = "no role"; 1 = "occasional role"; 2 = "systematic role" 3 = "crucial role").

In addition, we constructed four ordered 5-category variables in order to account for the share of total investment in terms of R&D and non-R&D activities (training, engineering and creative work) devoted to the development and implementation of firms' focal innovations. Each ordered variable ranges from 0 (0%) to 5 (more than 30%). Questions on expenditures for a single innovation have been considered particularly appropriate for SMEs which usually do not rely on a separate accounting budget in order to organize their innovation activities (OECD, 2018).

Finally, we controlled for firm and environment-specific characteristics related to firms' size (*Size*), sector (*Sector*), regional location (*Geo*) and age (*Age*). In accordance with European Commission Recommendation (2003/361/EC) about the size of companies, the variable *Size* classifies SMEs in micro (1-9 employees), small-medium (10-49 employees), medium – sized (50-249 employees). With regards to *Sector*, an ordered 3-category variable is constructed in ordered to identify firms working in service, trade and manufacturing sectors, according to the ISTAT classification. *Geo* is developed as a 3-category variable identifying firms placed in the North, Center and South of Italy while *Age* captures firms with less than 10 years, from 10 to 20 years and more than 20 years of experience.

3.2.2 Model specification

Over the past years, in order to explore the relationships between several economic or social factors and performance in SMEs, several approaches have been employed: multiple linear regression (Moorthy et al., 2012), regression with panel data (Ipinnaiye et al., 2016), causal analysis (Cahydin, 2017; Heshmati and Loof, 2008) and structural equation modelling (SEM) (Gupta and Batra, 2016; Katou, 2012). In line with Sheehan's approach (2013), our econometric analysis is based on the estimation of an ordered logit model. Ordered response models represent an evolution of binary models and are considered the best solution to estimate dependent variables having multiple ordered categories, as in our analysis. In these models, the dependent variable and explanatory factors are in a non-linear relationship with a scaling factor of around 1.7. Any predictions are always bounded between zero and one and the coefficients relate to an underlying latent score. The latent model is describe as the following:

$Y^* = \mathbf{x}\beta + \varepsilon \qquad\qquad \varepsilon|\mathbf{x} \sim \text{Normal}\ (0,1)$

According to our analysis, we can imagine that SMEs whose we are observing innovation behaviors are in a sort of continuous innovation process, ranging from negative infinity to positive infinity. Moreover, let us suppose that their actions move them up and down the scale. This represents the latent score. Let us imagine that at some point our firms cross some sort of threshold value (identified by the threshold parameters α_j's to be estimated) that changes how they feel about the resulted achieved. For instance, they might go from a status where their expectations are not satisfied to a status where their expectation are fulfilled and we can call those two status "the observed states".

$Y = 0 \text{ if } Y^* \leq \alpha_1$

$Y = 1 \text{ if } < Y^* \leq \alpha_2$

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$Y = J \text{ if } < Y^* > \alpha_j$

Since the latent score cannot be observed, we have to transform the coefficients from the logit model and estimate the marginal effects which are the slope coefficients of the relation between the dependent variables (Y) and the regressors (X). So we need to compute a change in Y, given a change in X. However, we should be aware that, because of the non-linear transformation undertaken by ordered response models, the change in Y can vary depending on X.

The literature has settled on two types of marginal effects: marginal effects at the mean of all variables and average marginal effects. The former compute the marginal effect at the mean value of X for all variables, while the average marginal effects which are used in this paper, compute all possible marginal effects along the entire range of X values and then they average these.

We have used an ordered logit model for the following four equations corresponding to the four measures of business innovation performance as described above:

1. $Prof\_exp_i = \beta_1 Mgt\_cap_i + \beta_2\, WF\_skil_i + \beta_3 Tech\_cap_i + \beta_4 FI\_inv_i + \beta_5\, Z_i + \varepsilon_i$ (1)

2. $Sales\_exp_i = \gamma_1 Mgt\_cap_i + \gamma_2 WF\_skil_i + \gamma_3\, Tech\_cap_i + \gamma_4 FI\_inv_i + \gamma_5 Z_i + \upsilon_i$ (2)

3. $CS\_exp_i = \delta_1 Mgt\_cap_i + \delta_2 WF\_skil_i + \delta_3 Tech\_cap_i + \delta_4 FI\_inv_i + \delta_5 Z_i + \nu_i$ (3)

4. $FIprof\_exp_i = \phi_1 Mgt\_cap_{i\ i} + \phi_2 WF\_skil_i + \phi_3 Tech\_cap_i + \phi_4 FI\_inv_i + \phi_5 Z_i + \mu_i$ (4)

In the Eq. (1) the dependent variable, $Prof\_exp_i$, stands for the share of product and business innovations meeting the expectations of firm *i* in terms of profits generated; Mgt_cap_i is a vector of management capabilities-related factors. It refers to the level of importance associated with business strategies and organizational competencies of firm *i*'s managers, according to the respondents' opinions. WF_skil_i captures the qualifications and characteristics of firm *i*'s workforce, while $Tech\_cap_i$ represents the technical expertise of firm *i* in terms of new digital technologies and design capabilities. Finally, FI_inv_i is a vector including the share of total financial resources invested in R&D and non-R&D activities (training, engineering and creative work) carried on by firm *i* to support the ideation, development and implementation of its focal innovations, and ε_i is the random error term.

Accordingly, Eqs. (2), (3) and (4) complete the analysis referring to the determinants of innovation performance in terms of sales, customer satisfaction, and profits from focal innovations, respectively. Parameters β, γ, δ and ϕ determine the average marginal effects to be estimated, while υ_i, $\nu_{i,}$ and $\mu_{i,}$ are the random error terms.

4. Results

The estimation results based on the ordered logit models for innovative SMEs in our sample are reported in Tables 6. However, in order to take into account a potential endogeneity problem involving the correlation between dependent variables and R&D investments, we decided (in the absence of reliable instrumental variables[12]) to carry on an additional econometric analysis (Table 6a) not including resources invested in R&D among the covariates (see Table 6a) and compare the two results. The two logistic regressions seem to show only slight differences, thus, we are going to comment only about the findings reported in the Table 6a.

Even though it would have been interesting showing estimates of average marginal effects for each level of categorical dependent variables, for the sake of clarity only significant estimation results associated with the highest category of the examined measures of innovative SMEs' performance

[12] Instrumental variables are often used to solve endogenous covariate problem. They need to be correlated with endogenous regressors and uncorrelated with the dependent variable.

relative to the lowest category are reported.

Putting the attention on the firms' age (*Age*), the results we can observe in Table 6a show that older firms (with more than 10 and 20 years of experience) are less likely to obtain satisfying profits from their focal innovations and to meet their innovation expectations in terms of customer satisfaction, compared to the younger ones. These results seems to be in line both with our previous empirical study on manufacturing firms' 3DP-adoption (older companies with more business experience were found to be more inclined, compared to their younger competitors, to reject the possibility to adopt 3D-printing in the future) and with the relevant literature. Indeed, according to several researchers (Leonard-Barton, 1997; Sorensen and Stuart, 2000) the firms' age negatively impacts on the firms' ability to learn new skills and thus to innovate. Moreover, Natarajan et al. (2008) declared that the firms' age is negatively associated with innovation and this effect results to be even stronger in technological areas. However, firms in the middle group (11-19 years) seem to have a higher probability to see their general innovation profits' expectations satisfied, compared to the younger ones. In this respect, it is reasonable to think that young companies may not be able to gain sizeable profits without growing enough first to effectively face their initial cost disadvantages (Steffens et al. 2009).

Focusing on results regarding *General Management capabilities*, we can say that, in line with our first baseline hypothesis, taking in high consideration this kind of abilities positively influences the innovation outcome of Italian SMEs. In more detail, we can note that innovation management activities affect, in a positive and very significant way, the probability for firms to see their expectation satisfied in terms of all the business performance expectation measures taken into account. Moreover, we can see that taking in consideration quality-related competitive strategies (both at high and medium levels) and dynamic capabilities, positively impact on the probability of SMEs' innovations to meet firms' expectations in terms of customer satisfaction, general profits as well to gain sizeable profits from focal innovations. These findings are also perfectly in line with the considerations, emerged in our previous literature review, on the crucial role played by dynamic capabilities in fostering SMEs' firms innovation.

Regarding the *Workforce skills*, we can affirm that while *workforce characteristics* seem not to impact on the dependent variables, the *workforce qualification* does. In particular, our results show that firms showing very high levels of workforce diversity (at least 3 out of 5 different categories) with more than 80% of tertiary educated employees, positively affect the possibility for innovative Italian SMEs to achieve successful profits from their focal innovations, as well as to succeed in meeting their expectations in terms of general profits and customer satisfaction. In this respect, our results seem not to be perfectly in line with the research literature discussed in the previous sections, especially regarding the impact of the workforce characteristics on SMEs' innovation. The fact that workforce characteristics seem not to play a significant role according to our results, would be due to our cross-section dataset which accounts for a limited range of time. Indeed, proper actions mean to nurture different employees' capabilities, such as cognitive, social, technical and systems skills, take often much more time than one year to be effectively implemented and to consequently show their effects. In this respect, firms need time to test and implement different workforce's evaluation procedures according to their tasks, but also in order to create and put in action the appropriate employee recognition programs.

Moreover, with respect to *Technological capabilities*, we can say that our third hypothesis is partially confirmed and interesting findings emerged. Firstly, in terms of SMEs' digital expertise, it is worthwhile to note that Big Data and Robotics seem to represent the most strategic technologies for innovative Italian SMEs to improve their innovation in the short term. Indeed, the implementation of these two disruptive digital assets show a positive and significant impact both in terms of profits and sales expectations, in marked contrast to 3D printing and Artificial Intelligence' variables which show negative effects on all the expectations outcomes. This results might be partially due to the expensive initial investments required by 3D-printing and AI, but also on the lack of awareness among SMEs about their potential value. Indeed, according to the results from our empirical analyses on 3D-printing adoption and the role of system integrators in the digital transformation context, firms have most of time great difficulty to learn how to use and elaborate data for AI, as well as to recognize the innovative potential benefits from 3D-printing use. Secondly, in line with the above-mentioned literature in our previous literature review, in terms of design capabilities, we can note that design activities used to develop the aesthetic form of products, at all implementation levels, show a strong positive effect on almost all the dependent variables considered.

Considering the firms' expenses on their focal innovations, we can observe that investments in non-R&D based activities show in general a positive impact on the fulfillment of innovative SMEs' business performance expectations. In more detail, The more successful investments on focal innovations seem to be represented by creative work: it impacts at all levels (from 5% to over that 30% of total expenses) on profits and sales' expectations. This result seems to be perfectly in line both with the latest Community Innovation Survey analysis and the OECD literature mentioned above. According to our empirical findings, our last baseline hypothesis is also confirmed.

Finally, with respect to the control variable *Sector*, we can see that manufacturing and trade firms are less likely to achieve their expectations in terms of profits, sales and customer satisfaction, compared to firms in the service sector and it is plausible if we consider that firms focused on services are those most impacted by digital transformation disruptive changes. As regards to the number of employees, we can note that it does not affect innovation performance with the exception of profits and sales expectations. In particular, small companies seem to be less likely to meet their expectations compared to micro ones which probably set lower standards in the short term. With regards to geographical area, it seems that innovative SMEs placed in the Northern regions of Italy are less likely to be satisfied in terms of their sales expectations and focal innovations' profits compared to firms in the South areas. This difference might be partially the result of national and regional incentives for start-up, such as the "*Resto al Sud*" initiative[13], implemented over the past years with the aim to improve the southern Italian firms' potential innovation.

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[13] Resto al Sud by Invitalia, available at: http://www.restoalsud2018.it/

5. Conclusions

Despite business performance in SMEs has been largely analyzed in the past, there is still a strong policy demand for empirical evidence on innovation and on the factors influencing it (OECD in Oslo Manual, 2018). In this context, this research focuses on the role of both tangibles and intangible assets in order to explore the firms expectations' fulfillment towards innovations, from the perspective of Italian SMEs defined as "innovative" according to the Decree Law 3/2015. To examine different aspects of SMEs' innovation expected results, we use four main indicators: three of them refer to firms' expectations in terms of profits, sales and customer satisfaction coming from the overall innovation output, while the last one is associated to the amount of profits generated by SMEs' focal innovations. For the empirical analysis, cross-sectional data are used and a web survey involving 125 SMEs has been developed, according to the recent OECD guidelines in terms of collecting and interpreting data on innovation (OECD, 2018). The results from the ordered logit estimations highlight the importance of all the examined factors for the innovation performance expectations of innovative SMEs.

Firstly, it is found that taking management capabilities in high consideration increases the likelihood for innovative SMEs to meet their expectations regarding their product's and business process' innovations.

In particular, *innovation management activities* turned out to be crucial for the achievement of successful expected results across all the business performance measures considered (general profits, focal innovation's profits, sales and customer satisfaction). These findings represent an important practical implication for Italian SMEs' management. In this regard, they encourage the provision of financial and non-financial incentives for employees proposing innovative ideas, as well as a greater involvement of employees representatives in innovation decisions. Moreover, relying on that, innovative SMEs managers could support the establishment and reorganization of specific departments with a specific responsibility for innovation. Our results also show that SMEs highly-focused on quality-related *competitive strategies* are more likely to meet their expectations in terms of the amount of profits from their innovations. In light of this, branding activities to differentiate firm's products should be more supported, as well as actions mean to increase the improvement of existing products and the introduction of new ones. Moreover, it is worthwhile to underline the crucial strategic role played by both the abilities of SMEs' managers to organize change (*change management capabilities*) and to respond effectively to internal and external challenges (*dynamic managerial capabilities*) in terms of innovations profits' expectations. Our results clearly show the importance of organizational abilities and resilience attitude among firms' managers to support innovation.

Secondly, with regard to the *workforce skills* our results indicate that SMEs with high percentages of tertiary educated employees from different background show the best results in terms of overall profits, customer satisfactions' expectations and the amount of profits from focal innovations. In particular, our data show that firms having tertiary educated employees in at least three out of five qualification categories considered (mathematics, ICT, engineering, medical and design) are more likely to see their expectations fulfilled. These results may have interesting managerial implications: for instance, in order to improve their expected innovation performance, SMEs could address their hiring procedures to workers from different fields of education and diversify the workforce composition.

Thirdly, by considering SMEs' abilities in adopting new digital technologies, we can note that technical expertise in Big Data and Robotics leads to successful innovation performance, especially in terms of sales during the one-year period considered. Differently, sales and profits' expectations are less likely to be satisfied in case of SMEs specialised in Artificial Intelligence and 3D-printing. However, the implementation of design activities turns out to be crucial for the achievement of sales and customer satisfaction's expectations. As a result, especially SMEs focused on AI and 3DP should integrate design thinking methods and activities in their business models in order to compensate for their initial low levels of sales.

Finally, it is found that even a low level of expenses in R&D for focal innovations can play a role in increasing general profits expectations. In this respect, we could think that innovation spillovers could have emerged. Moreover, investments in engineering activities both at low and high levels (more than 0% to 4% and over 30%) seem to rise the probability to meet customer satisfaction's target, probably due to the associated improvement in the technical quality of innovations provided. However, it is worth pointing out that the most interesting results refer to medium and high levels of investments (from 5% up) in non-R&D activities such as creative and design work, which should be considered crucial for the fulfillment of profits expectations, in line with the abovementioned findings on the importance of design capabilities.

At the policy level, these findings highlight that high priority should be given to advancing management capabilities in general, especially innovation management activities and quality-focused competitive strategies. In fact, most of micro and small firms do not have the same intangible assets in terms of time, knowledge and skills to adopt concrete innovative strategies as their larger counterparts. To address these issues, policy actions, such as financial and non-financial incentives for involving employees at all levels in the firms' innovation decision processes would facilitate the generation of innovative ideas. Moreover, promoting incentives for fostering branding activities to create unique and long lasting selling propositions should be taken in high consideration.

Furthermore, the positive role of workforce education in SMEs innovation outcomes shows that beyond subsidies or governmental programs that encourage innovation activities, it is also necessary to provide incentives for facilitating the hiring programs in favor of tertiary educated employees from different qualification categories. This will lead to more adequately trained employees to meet SMEs' expectations especially in terms of profits and customer satisfaction. It is also worthwhile to note that policy actions addressed to facilitate the implementation of Big Data and Robotics, as well as non-R&D activities, especially creative work devoted to the development and implementation of firms' focal innovations, would improve the attractiveness and functionality of SMEs' goods and services, enhancing their overall profits and sales. Such policy tools might help in encouraging innovation in Italian SMEs, fostering their value creation and competitiveness.

Concerning the limitation of this study, we have looked at the business performance of innovative SMEs at the microeconomic and organizational level without taking into consideration macroeconomics factors. A more comprehensive picture of innovative SMEs performance could analyze macroeconomic variables, such as the impact of the public policies to business development

(Rashia, 2002), or the impact of foreign direct investments on SMEs' performance (Chi et al., 2008). Moreover, the effects of our analysis may be downward biased, given that results associated with the impact of intangible organizational factors on innovation performance take much more time than one year in order to effectively occur (Damanpour and Evan, 1984; Tavassoli and Karlsson, 2015). However, we should note that our research is just a preliminary investigation of firms-related factors from innovative Italian SMEs' perspective. Future researches exploring business innovation in SMEs should provide an empirical analysis at an international level, taking into consideration a panel data set and a larger reference period.

Appendix

Table 4

Description of independent variables

Category	Variable name	Description
Management Capabilities	Competitive Strategy	The respondent is asked to indicate the level of importance of competitive strategies for innovation purposes. Ordered 3-category variable: (1 = low level; 2 = medium level; 3 = high level)
	Change Management Capabilities	The respondent is asked to indicate the level of importance of change management capabilities for innovation purposes. Ordered 3-category variable: (1 = low level; 2 = medium level; 3 = high level)
	Dynamic Managerial Capabilities	The respondent is asked to indicate the level of importance of dynamic managerial capabilities for innovation purposes. Ordered 3-category variable: (1 = low level; 2 = medium level; 3 = high level)
	Innovation Management Capabilities	The respondent is asked to indicate the level of importance of innovation management capabilities for innovation purposes. Ordered 3-category variable: (1 = low level; 2 = medium level; 3 = high level)
Workforce Skills	Workforce qualification	The respondent is asked to indicate the share of employed persons with tertiary education by field of education and training according to the ISCED-F 2013 classification.
	Workforce characteristics	The respondent is asked to indicate the level of importance of specific workforce characteristics supporting innovation. Ordered 3-category variable: (1 = low level; 2 = medium level; 3 = high level)
Technological Capabilities	Technical expertise	The respondent is asked to indicate the level of firm's expertise associated with the usage of five new digital technologies. There are five ordered 4-category variables (from 0 = "not used" to 4 "high level of expertise"
	Design Capabilities	The respondent is asked to indicate the level of importance of design capabilities for innovation purposes. Ordered 4-category variable: (0 = no design activities; 1 = design activities are occasional; 2 = design activities are integrated; 3 = design activities are crucial)
Investments on focal innovations	Investments in R&D	The respondent is asked to indicate the share of total investments devoted to R&D for the firm's focal innovation. Ordered 4-category variable: (1 = 0-4; 2 = 5-14; 3 = 15-30; 4 = more than 30)
	Investments in training activities	The respondent is asked to indicate the share of total investments devoted to training activities for the firm's focal innovation. Ordered 4-category variable: (1 = 0-4; 2 = 5-14; 3 = 15-30; 4 = more than 30)
	Investments in engineering activities	The respondent is asked to indicate the share of total investments devoted to engineering activities for the firm's focal innovation. Ordered 4-category variable: (1 = 0-4; 2 = 5-14; 3 = 15-30; 4 = more than 30)
	Investments in creative activities	The respondent is asked to indicate the share of total investments devoted to creative activities for the firm's focal innovation. Ordered 4-category variable: (1 = 0-4; 2 = 5-14; 3 = 15-30; 4 = more than 30)
Control Variables	Sector	Ordered 3-category variable according to the type of firms' reference sector (1 = service; 2 = trade; 3= manufacturing).
	Size	Ordered 3-category variable according to the number of employees (1 = micro firms; 2 = small firms; 3= medium-sized firms).
	Geo	Ordered 3-category variable indicating the geographical area where firms are located (1 = South; 2 = Center; 3 = North)
	Age	The number of years that a firm (as an organisational unit) has been economically active. Ordered 3 category variable: (1 = less than 10 years; 2 = 11-20 years; 3 = more than 20 years)

Table 5.

Variable	Obs	Mean	Std. dev.	Min	Max
IMPRESA	0				
Age	125	1.504	.7028054	1	3
Sector	125	1.552	.8656156	1	3
Turnover	125	3.624	1.707025	1	7
Size	125	1.52	.6425755	1	3
Innov_status	125	2.272	.786745	0	3
Sales_Expect	125	2.272	1.427698	0	5
Profit_Exp~t	125	2.336	1.447712	0	5
CS_Expect	125	3.2	1.373716	0	5
SE_Expect	125	2.736	1.561348	0	5
FI_profits	125	2.88	1.208838	1	5
RDExpens_FI	125	3.304	1.017777	0	4
Train_Expe~I	125	1.712	1.134617	0	4
CompStr	125	2.096	.652835	1	3
Change_Mgt	125	2.224	.7390491	1	3
Dynamic_Mgt	125	2.32	.70253	1	3
Innov_Mgt	125	2.136	.7656328	1	3
WF_Qualifi~n	125	2.136	.7864169	1	4
WF_Charact	125	2.376	.6679772	1	3
Tech_Exper~e	125	2.064	.8205427	1	3
Design_Capab	125	1.696	1.071809	0	3
CloudC	125	2.288	1.045852	0	3
Big_Data	125	2.032	1.128344	0	3
Robotics	125	1.12	1.059519	0	3
Art_Int	125	1.768	1.185504	0	3
IoT	125	1.656	1.212196	0	3
Add_Man	125	1.096	1.011419	0	3
Geo	125	2.392	.7818093	1	3
Inn_lev	125	.632	.484202	0	1
FI_training	125	1.712	1.134617	0	4
Collaborat~n	125	.304	.4618337	0	1
FI_design_~p	125	1.664	1.373388	0	4
FI_eng_exp	125	2.288	1.4855	0	4
FI_creativ~p	125	1.616	1.336727	0	4

Table 6
AVERAGE MARGINAL EFFECTS

	Profit_Expect	Sales_Expect	CS_Expect	FI_profits
R&D				
>0-4%	3.734*	-1.679	-1.097	-0.657
	(2.107)	(1.994)	(1.980)	(2.063)
Eng_exp				
>0-4%	0.294	-0.628	2.963**	2.413**
	(0.892)	(0.820)	(0.924)	(0.882)
>30%	-0.133	-0.361	1.858**	0.522
	(0.685)	(0.728)	(0.683)	(0.666)
Creative_Exp				
5%-14%	1.510**	0.530	-0.0628	0.249
	(0.739)	(0.767)	(0.784)	(0.763)
15–30%	1.855**	-0.325	0.308	0.742
	(0.861)	(0.841)	(0.866)	(0.842)
>30%	2.696**	2.611**	0.136	0.444
	(0.918)	(0.938)	(0.873)	(0.947)
Age				
11-19	1.333**	0.711	0.423	-1.031*
	(0.554)	(0.564)	(0.576)	(0.594)
>20years	-1.195	-0.927	-1.616**	-2.076**
	(0.789)	(0.834)	(0.765)	(0.795)
CompStr				
Highlevel	1.835**	0.789	0.240	1.694**
	(0.803)	(0.803)	(0.796)	(0.817)
Change_Mgt				
Med-level	0.0782	0.413	-0.281	1.287*
	(0.620)	(0.639)	(0.623)	(0.657)
Dynamic_Mgt				
Med-level	2.503**	0.583	0.374	1.048
	(0.912)	(0.916)	(0.842)	(0.855)
Innov_Mgt				
Highlevel	1.510*	2.104**	2.153**	1.850**
	(0.824)	(0.926)	(0.810)	(0.826)
WF_Ed				
Med-lev	-0.736	-0.423	0.497	1.465**
	(0.719)	(0.701)	(0.690)	(0.724)
Veryhighlev	3.519**	1.484	3.438**	3.841**
	(1.241)	(1.246)	(1.226)	(1.274)
Cloud_Comp				
Low-lev	-0.553	0.456	0.451	3.495**
	(1.108)	(1.105)	(1.081)	(1.101)
Med-level	-1.419	-2.006*	-0.804	1.945*
	(1.103)	(1.078)	(1.037)	(1.123)
Big_Data				
Low_lev	2.008*	1.981*	0.367	-1.897
	(1.188)	(1.189)	(1.158)	(1.156)
Med-level	0.903	2.229**	1.546	-0.656
	(1.003)	(1.032)	(1.020)	(1.042)
Highlevel	-0.0932	2.487**	-0.577	-1.541
	(0.934)	(1.016)	(0.946)	(0.944)
Robotics				
Med-lev	0.345	2.210*	1.548	1.625
	(1.040)	(1.139)	(1.056)	(1.064)
Highlevel	2.455**	3.110**	1.614	1.187
	(0.925)	(1.001)	(0.986)	(1.009)
Artif_intel				
Low_lev	0.260	-0.550	-1.871**	-0.0760
	(0.891)	(0.847)	(0.883)	(0.827)
Med-level	-1.511	-2.029*	-1.881**	-1.719*
	(0.975)	(1.064)	(0.940)	(0.950)
Highlevel	-1.625**	-2.686***	-1.488**	0.417
	(0.712)	(0.717)	(0.742)	(0.698)

	Profit_Expect	Sales_Expect	CS_Expect	FI_profits
3DP				
Low_lev	-0.247	-1.637*	-0.527	-0.114
	(0.822)	(0.875)	(0.927)	(0.898)
Highlevel	-1.769*	-2.407**	-0.757	-1.001
	(0.937)	(0.986)	(1.008)	(0.941)
Design				
systematic	-0.0799	3.273***	1.771**	0.239
	(0.848)	(0.864)	(0.809)	(0.789)
crucial	-0.497	1.761**	0.956	-0.104
	(0.767)	(0.796)	(0.754)	(0.737)
Trade	-2.505**	-1.122	-2.630**	-0.582
	(1.024)	(1.078)	(1.044)	(1.009)
Manufact	-2.153***	-2.914***	-1.603**	0.536
	(0.588)	(0.637)	(0.609)	(0.574)
North	-0.798	-1.511**	-0.494	-1.259*
	(0.600)	(0.658)	(0.670)	(0.678)
Small	-1.066**	-0.741	-0.447	0.0904
	(0.506)	(0.526)	(0.527)	(0.495)
N	125	125	125	125

Standard errors are reported in parentheses.
*Significant at the 10% level;
** Significant at the 5% level.
***Significant at the 1% level.

LR chi2 (55) =	121.99	128.17	114.46	99.66
Prob > chi2 =	0.0000	0.0000	0.0000	0.0002
Log likelihood =	-152.37781	-145.49265	-144.65856	-141.86849
Pseudo R2 =	0.2859	0.3058	0.2835	0.2599

Table 6.a

AVERAGE MARGINAL EFFECTS

	Profit_Expect	Sales_Expect	CS_Expect	FI_profits
Eng_exp				
>0-4%	−0.680	-1.642*	0.969	0.280
	(0.788)	(0.850)	(0.862)	(0.791)
>30%	-0.0597	-0.253	1.805**	0.642
	(0.677)	(0.726)	(0.677)	(0.660)
Creative_Exp				
5%-14%	1.620**	0.352	-0.284	-0.506
	(0.730)	(0.745)	(0.755)	(0.727)
15–30%	1.561*	-0.152	0.317	0.539
	(0.820)	(0.830)	(0.832)	(0.813)
>30%	2.437**	3.023**	0.662	0.812
	(0.891)	(0.929)	(0.843)	(0.867)
Age				
11-19	1.158**	0.775	0.349	-0.913*
	(0.547)	(0.565)	(0.559)	(0.554)
>20years	-1.031	-0.584	-1.313*	-1.280*
	(0.761)	(0.808)	(0.744)	(0.732)
CompStr				
Med-level	-0.0600	0.785	1.410*	0.842
	(0.707)	(0.707)	(0.724)	(0.713)
Highlevel	1.325*	0.775	0.345	1.510*
	(0.767)	(0.784)	(0.778)	(0.791)
Dynamic_Mgt				
Med-level	2.340**	0.703	0.464	1.543*
	(0.865)	(0.897)	(0.816)	(0.838)
Innov_Mgt				
Highlevel	1.468*	1.808**	1.921**	1.100
	(0.767)	(0.864)	(0.759)	(0.745)
WF_Ed				
Veryhighlev	3.355**	1.115	2.723**	2.509**
	(1.176)	(1.233)	(1.149)	(1.181)
Cloud_Comp				
Low-lev	-0.467	-0.0924	-0.0616	2.511**
	(1.056)	(1.078)	(1.036)	(1.051)
Med-level	-0.610	-1.781*	-0.332	1.619
	(1.063)	(1.050)	(0.998)	(1.032)
High-level	1.262	-0.0276	1.577*	1.273
	(0.867)	(0.866)	(0.858)	(0.820)
Big_Data				
Low_lev	1.400	2.577**	0.927	-0.904
	(1.114)	(1.155)	(1.115)	(1.064)
Med-level	0.0722	2.430**	1.285	-0.196
	(0.975)	(0.981)	(0.968)	(0.966)
Highlevel	-0.460	2.654**	-0.521	-0.991
	(0.915)	(0.970)	(0.906)	(0.885)
Robotics				
Med-lev	0.609	1.990*	1.445	1.498
	(1.000)	(1.094)	(1.032)	(1.021)
Highlevel	2.377**	3.019**	1.501	1.313
	(0.920)	(0.988)	(0.965)	(0.979)
Artif_intel				
Low_lev	-0.405	-0.845	-2.362**	-0.310
	(0.876)	(0.849)	(0.892)	(0.785)
Med-level	-1.786**	-1.438	-1.368	-0.689
	(0.904)	(0.991)	(0.886)	(0.870)
Highlevel	-1.836**	-2.826***	-1.834**	0.246
	(0.706)	(0.717)	(0.730)	(0.666)

	Profit_Expect	Sales_Expect	CS_Expect	FI_profits
3DP				
Highlevel	-1.723*	-1.974**	-0.0000169	-0.505
	(0.906)	(0.969)	(1.945)	(0.891)
Design				
basic	-0.0834	3.310***	1.903**	0.683
	(0.788)	(0.834)	(0.774)	(0.743)
systematic	-0.352	1.832**	1.163	0.536
	(0.729)	(0.760)	(0.725)	(0.690)
crucial	-0.0236	1.481*	1.377*	1.389*
	(0.774)	(0.802)	(0.771)	(0.802)
Trade	-2.090**	-1.678*	-3.085**	-1.465
	(0.934)	(1.008)	(0.955)	(0.932)
Manufact	-2.158***	-3.011***	-2.003***	-0.117
	(0.575)	(0.619)	(0.573)	(0.543)
North	-0.623	-1.572**	-0.624	-1.145*
	(0.577)	(0.647)	(0.637)	(0.621)
Small	-1.233**	-0.919*	-0.786	-0.190
	(0.481)	(0.513)	(0.512)	(0.474)
N	125	125	125	125

Standard errors are reported in parentheses.
*Significant at the 10% level;
** Significant at the 5% level.
***Significant at the 1% level.

LR chi2 (51) =	111.75	121.86	104.91	71.88
Prob > chi2 =	0.0000	0.0000	0.0000	0.0286
Log likelihood =	-157.49477	-148.64514	-149.43362	-155.76013
Pseudo R2 =	0.2619	0.2907	0.2598	0.1875

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System integrators in the digital transformation era

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ABSTRACT

This paper focuses on determining the key drivers impacting on system integrators' business performance during digital transformation era. In particular, the aim of this analysis is investigating the main factors influencing the probability for system integrators to experience increases in their annual total revenue, and to play a role in their customers' business model innovation. To this end, we designed a cross-sectional original survey and a useable sample of more that 160 responses is drawn from different system integrators worldwide. The results from logit models show that all the variables we have considered (internal and external stakeholders' engagement, geographical proximity between system integrators and their customers, and the use of different new digital technologies) increase the likelihood for system integrators to experience positive results in their total annual revenue and in their customers' business model innovation. The results appear to be robust across the measures analysed.

Keywords: System integrators, Artificial intelligence, Digital Transformation, Organizational innovation, new digital technologies, Business performance

1. Introduction

The aim of this paper is to provide a preliminary analysis of the main factors impacting on the business performance of specific high-tech solution providers operating in the current innovation ecosystem: system integrators. In particular, the exploration of the main drivers of system integrators' ability to innovate their customers' business model and to increase their own total annual revenue, would shed new light on the role of one of the most important digital transformation players.

Over the last decade, system integrators have started to acquire a prominent role in supporting end-user companies facing digital transformation challenges. The global system integration market size has reached 330 billion dollars in 2020 and it is expected to expand at a compound annual growth rate (CAGR[15]) of 8,5% over the 2021-2027 period (Wadhwani and Gankar 2021). System integrators are technological solution providers, able to offer to end-user companies the possibility of integrating software and hardware components into a functioning system in several environments (Davies et al., 2007). In this respect, they are considered as much more than assemblers of product components. Rather, they are regarded as crucial partners to review old business models in a more digital perspective.

It is unquestionable that the spread of new digital technologies and the resulting disruption of technological products' supply value chain, have resulted in more demanding requirements for the

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[15] CAGR represents the rate of return of an investment over a period of time, expressed in annual percentage terms.

implementation of digital applications. However, most of time, end-user companies turn out to be more able to imagine the outcome resulting from the final integrated solution than effectively obtain it. As a consequence, an increasing number of end-user firms without a core competency in system integration have started to rely on system integrators' ability to integrate components, skills, and knowledge from other firms (including suppliers, users, and partners). Thus, the system integrators' support in identification and implementation of proper technological applications, future systems upgrades, as well as access and visualization of real-time data has enabled end-user companies to develop innovative and long-lasting business strategies, in compliance with their own expectations.

Moreover, system integrators are, most of time, in charge of several organizational aspects, including general system design, as well as selection and coordination of networks of external component suppliers. Indeed, networking represents a fundamental area of system integrators expertise, requiring solid managerial and organizational skills. It is, thus, extremely important for economists and organizational theorists investigating these aspects to fully understand the evolution of an innovation-driven and competitive marketplace. That is particularly true if we consider that technological aspects of systems have become more and more sophisticated over the recent years, and so have the organizational and managerial aspects of systems integrators.

In the light of this, most of the novelty and the originality of this research consists in exploring system integrators' performance both in terms of their annual total revenue increases, and their ability to contribute to business models of their customers.
System integration has been largely investigated so far from an engineering point of view (Bartlet and Burzlaff 2018), through qualitative analyses (Davies et al., 2007; Brusoni and Prencipe, 2011; Erbil et al., 2013) and before the advent of digital transformation (Pavitt, 2002). However, few contributions exist which take into account an organizational and strategic perspective after the spread of new digital technologies.
In this respect, the baseline hypotheses formulated are the following:

1) The need of new digital technologies integration showed by end-user companies is expected to have a positive impact on system integrators' ability to innovate end-user companies' business models and to increase system integrators' total annual revenue.
2) System integrators' internal and external networking activities are expected to have a positive impact on system integrators' ability to innovate end-user companies' business models and to increase system integrators' total annual revenue.
3) Geographical proximity between system integrators and end-user companies is expected to have a positive impact on system integrators' ability to innovate end-user companies' business models and to increase system integrators' total annual revenue.

The following sections will describe the way in which the abovementioned factors are expected to affect system integrators' performance taking into due consideration existing theoretical and empirical evidence.

The main findings of the empirical analysis in this paper can be summarized as follows:

- Significant increases in annual total revenue: our results highlight that relevant increases in system integrators' performance are positively associated with high levels of geographical proximity and high levels of networking activities. In particular, the number of internal and external stakeholders involved in system integrators' networking activities, and geographical proximity between system integrators and regional customers seem to result in significant improvements of system integrators' total annual revenue.

- Slight increases in annual total revenue: our findings show that the need of integrating Artificial Intelligence (AI), Internet of Things (IoT) and Cloud computing showed by end-user firms seems to have a positive and significant effect on the likelihood for system integrators, especially in the energy and food and beverage sectors, to show increases, albeit slight, in their total annual revenue. Geographical proximity and external networking activities play also a role in this respect.
- Customers' business model innovation: according to our results, system integrators' internal and external networking activities seem to show a significant positive impact on system integrators' ability to innovate their customers' business models. Moreover, medium-sized system integrators seem to be more willing to impact on their customers' business model innovation.

This paper is organized as follows. Next section presents the theoretical background. Section 3 describes data and methodology employed in the empirical analysis. Final results are presented and discussed in Section 4, whereas Section 5 concludes the paper discussing the managerial and policy implications.

2. Conceptual background

2.1 System integrators' skills and competences

The origins of system integrators can be traced back to 1940s and 1950s in the military and engineering field, and benefits of specialization at systems integration and component levels have been widely demonstrated in the past (Brusoni and Prencipe, 2011; Hobday et al., 2003; Hobday et al., 2005).

However, with technological advancements driven by IoT, Cloud computing solutions, Big data management software and AI applications, the solution scope of most end-user companies' projects has expanded beyond the integration of conventional systems. With the increasing of end-user companies' scope, system integrators started to strengthen their own partnership management skills and their ability to participate or lead an alliance to meet solution requirements for their customers.
As a result, system integrators have recently come back in the spotlight in order to support end-user firms in coping with digital transformation challenges and business complexity.
On one hand, moving towards a data-driven culture has represented for many manufacturing firms the first critical challenge to face. The spread of new digital technologies and the emerging of new functions too difficult or expensive to integrate in the past, such as AI-driven algorithms, have led system integrators to renew the services provided. If many aspects of technology have become simpler to understand and more intuitive, in particular from a user experience's perspective, integration overall has become much more complicated. Moreover, most manufacturing plants and machines had not been designed to comply with data capturing and sharing, and have been found unable to provide the streams of data at the proper speeds.
Thanks to the spread of Robotics and AI, many modern industries underwent a great transformation

from social, political and business perspectives. A research paper by Frey and Osborne (2017) estimated that 47% of all jobs in the United Stated are at "high risk" of becoming automated during the following twenty years. In particular, AI is expected to have a big impact on the way companies perform, produce and provide value. Indeed, it has the ability to read and learn through data captured from the environment by means of specific technologies or devices, such as data analytics or sensors.

Two of the most crucial challenges for end-user companies are, therefore, trying to adopt sensors in order to deliver their value, and learning how to use and elaborate data for AI, once the technology has been adopted. In this regard, the empirical research carried on by Ransbotham et al. (2017) showed that, most of time, end-user companies are not fully aware about which kinds of resources are needed to train new digital technologies. It is, thus, extremely difficult for them to combine the software part and the hardware one to develop the proper application for their business. That implies that most manufacturers struggle in putting their data in relation to their assets and look for system integrators' services to make their data contextualized. In this respect, system integrators are not just required to collect time-series, but they need to put data into context to achieve effective results. For instance, they should be able to provide machine operators with key indicators for their machines and for the overall production to help them make more effective decisions.

Among system integrators' crucial skills, flexibility to follow real project demand cycles, and the capability to identify and mitigate risks are also of strategic importance, as well as the ability to deal with project definition and project execution.

2.2 The evolution of system integrators' role after the advent of digital transformation

Digital transformation has been disrupting the way system integrators generate business value, bringing their opportunity for value creation to a new high level. According to an article written by the CEO of CSIA (Control System Integrators Association), Jose Rivera, on the ISA (International Society of Automation) website, we can distinguish three types of system integrators considering the evolution of their role over time: product-centric, solution-centric and transformation-centric's system integrators. Firstly, the product-centric group includes all system integrators operating almost exclusively as a sort of bridge among different kinds of software and hardware vendors, in order to deliver proper technical solutions to end-user companies.

Even though this core function is still of strategic importance today, standardization and digital applications have been made the integration process much more straightforward and automated, and consequently reduced the value added at this level. Moreover, as already explained, with the advent of digital transformation, the solution scope delivered by system integrators has expanded in order to meet the demand for ever-more interconnected systems.

Secondly, at the solution-centric level, the value added by system integrators consists in their ability to improve not only the understanding of specific technologies, but also the expertise of their customers' underlying assets and applications. System integrators acquire a new key role in the first steps of customers' digital processes as crucial partners and advisors. In this respect, deep knowledge of their regional, national and global target market becomes fundamental.

Finally, it is at the transformation-centric level that organizational aspects come to play by creating essential value to end-user firms which enjoy digital transformation's opportunities. Indeed, with the advent of digital transformation, system integrators have started to rethink their organizational structure and their business model, as well as their value propositions and services. The redefinition of system integrators' business models through the improvement of strategic management and human resource management skills, has allowed them meet customers' needs more effectively.

They have switched from traditional control projects to digital transformation ones and consequently from *customized* solutions to *productized* ones. In the first type of projects, the only aspects system integrators had to do with were about respecting deadlines avoiding errors and omissions. Customized solutions were implemented to solve specific problems for single companies and system integrators operated with a great amount of data, in the attempt to find the right balance between the speed-to-market need and the desire for the best technical performance. However, after the spread of new digital technologies, some system integrators decided to focus on a specific set of customers and exploit the advantages from scalability to create productized solutions able to be configured directly by the users.

With the development of productized solutions, system integrators have become more aware about the specific market needs, and improved their capability to reach a broader set of prospect customers.

System integrators have also improved their ability to prototype quickly and to effectively face the failure in order to learn as soon as possible from their mistakes, and move on.

Moreover, in the productized solution environment, close relationships with their customers and other stakeholders have increased system integrators' ability to manage ideation processes, which has never represented a peculiar area of system integrators' traditional expertise. This way, system integrators have improved the understanding of underserved customers' needs and started to provide proper solutions for the target market on all aspects, not just from a technical point of view.

To our knowledge, there is no contribution to date which examines how the adoption of new digital technologies and the introduction of innovative changes in organizational structure impact on the probability of obtaining improvement in system integrators' business performance. It is, thus, paramount to analyse at what extent these changes could impact on system integrators' activities and which are the main drivers of their business performance's results.

2.3 The key drivers of System integrators' business performance

It is recently demonstrated that the increasing adoption of AI and IoT in industrial automation, as well as the advancement in Cloud computing, turned out to be fundamental drivers for system integration industry's growth and system integrators' performance (Wadhwani and Gankar, 2021). The increasing use of IoT and AI by end-user companies in the attempt to implement the automation of complex processes, has given to them the possibility to solve safety and security problems and improve low-cost energy-saving production processes.

The spread of IoT and AI-integrated technologies, (such as processors, sensors, analytics software and vision system) has resulted in low-cost industrial automation system designing alternatives. This way end-user companies were offered the opportunity to improve the performance of their technological systems achieving cost-savings in the long term, and innovating their traditional business models at the same time. In this respect, the global market of AI-driven sensors has experienced a great increase over the past years, and it is expected to reach a market value of approximately 241 billion dollars in 2022 with a CAGR of 11,3% (Chitkara et al., 2017).

However, a lot of companies are not yet confident in leveraging on AI-driven sensors, since data to be used for the AI processes, once collected, must comply with specific features in terms of elaboration and organization (Rogati, 2017). The services provided by system integrators have turned out to be crucial in this regard.

Similarly, IoT has also shown a relevant impact on industrial automation and control across the countries. The industrial automation market driven by IoT is expected to increase at a CAGR of 7,9% over 2016–2022 (Wadhwani and Gankar, 2021). Industrial IoT has been largely adopted in every industry, with technology giants having integrated IoT as a core component of their businesses, especially in process industries such as energy, oil and gas, chemical and petrochemicals.

In addition, the growth of Cloud computing technology, along with increased public initiatives to support prominent vendors in the introduction of technological advancements, are also expected to drive system integrators' business performance.

The main advantages deriving from Cloud computing integration concern utility-style costing, absence of single point of failure, scalability, location independence. Moreover, lack of investments in hardware encourages client firms to innovate their business models through the adoption of cloud integration solutions and services provided by system integrators in several industries, such as financial services and software organizations.

Taking into account these facts, the first baseline hypothesis is established:

Hypothesis 1. The need of new digital technologies integration showed by end-user companies is expected to have a positive impact on system integrators' ability to innovate end-user companies' business models and to increase system integrators' total annual revenue.

In order to encourage system integrators' innovation performance, and the resulting innovative impact on their customers' business models, the adoption of technological innovations is considered crucial but not sufficient if not supported by the implementation of organisational resources.

However, while organizational features are considered fundamental factors of business performance, little empirical research exists on innovative firms' organizational aspects. Brusoni and Prencipe (2001) in their seminal work declared that "The principle of systems integration is manifested in the organizational capability of firms, individually and networked, collectively fostering rapid technological change".

Indeed, organizational assets are regarded as one of the most difficult factors to imitate, and consequently a key driver of firms' competitive advantage and business performance (Evangelista and Vezzani, 2010; Martin-Rios and Parga, 2016). Among all system integrators' skills, networking represents a fundamental organizational area of their expertise.

Extensive research literature has demonstrated that networking can have a positive impact of business performance (Johnsen and Johnsen, 1999; Möller and Halinen, 1999; Tsai, 2001; Wincent, 2005; De Klerk and Krron, 2007). For instance, Tsai (2001) demonstrated the existence of linkages between networks and business performance, through a dataset including petrochemical and food manufacturing companies. He focused on the so called "network position" and explained how sharing knowledge and exchanging information could have a positive effect on firms' innovation and business performance.

Networking scholars describe networking behaviours as attempts to develop and maintain relationships with others in order to achieve mutually beneficial outcomes (Baker, 2000; Forret and Dougherty, 2001). In this respect, we have decided to measure internal and external system integrators' networking through the number of internal and external stakeholders' categories involved in the system integration process. Indeed, the ability to interact with other firms has been identified as a crucial factor in numerous studies of the innovation process. Kastelle and Steen (2010) have shown as better performance's results can directly derive from actively managing networks mean to improve innovation outcomes. Moreover, Ahuja (2000) and Burt (2004) have demonstrated that both the number and structure of connections in collaboration networks can enhance innovation outcomes. Based on the theoretical and empirical literature described above, the second hypothesis of this paper would read as follows:

Hypothesis 2. System integrators' internal and external networking activities are expected to have a positive impact on system integrators' ability to innovate end-user companies' business models and to increase system integrators' total annual revenue.

From the perspective of end-user companies, as we have explained above, the value added by system integrators increases with their expertise in specific applications, in response to customers' needs. Therefore, they play a fundamental role as trusted advisors, especially in the early stages of digital transformation plan development. For example, most of time, they provide cost estimates and technology solutions to innovate their customers' business models. They also support manufacturers to assess the level of human resources and the current state of facilities through the use of the Smart Industry Readiness Index[16] audits. In this respect, Jose Rivera, (Rivera, 2021) has affirmed that geographical proximity between system integrators and their end-user clients, albeit important in the past, becomes secondary in the current data-driven environment.

However, it is showed that geographical proximity between firms facilitates direct interactions, fostering innovation performance (Feldman 1994) and the exchange of high quality information and tacit knowledge (Boschma 2005), especially in the first phases of firms' interactions. Moreover, it is affirmed that geographical proximity turns out to be crucial at specific steps of firms' collaboration process, such as negotiation, or when tacit knowledge acquisition is critical (Knoben and Oerlemans 2006). A great amount of literature research on industrial districts has demonstrated how physical proximity in a district context improves companies' innovation performance (e.g. Capello and Faggian 2005; Muscio 2006). Furthermore, geographical proximity is often assimilated to cognitive proximity, which regards how actors perceive, understand, and evaluate the world (Wuyts et al., 2005). In this respect, Krause et al. (2007) have demonstrated, albeit with limited empirical evidence, that cognitive proximity, in terms of shared objectives and values, is a key driver of firms' innovation performance. Therefore, both types of proximity show a complementary effect for improving knowledge and innovation performance (Boschma, 2005) and are acquiring an increasing value in the study of knowledge and innovation processes (Nooteboom, 2000; Boschma 2005). In the light of this, it is also shown that higher levels of shared values and common culture are linked to higher

[16] According to the World Economic Forum, the Smart Industry Readiness Index is a diagnostic tool created by a network of leading technology companies and experts to support manufacturers in their digital transformation process. It enables companies to better understand the current state of their facilities and offers pragmatic analysis across the three fundamental pillars– process, technology and organization.

levels of innovation (Dakhli and de Clercq, 2004), facilitating the knowledge acquisition of the environment, as well as its assimilation and exploitation, thanks to firms' absorptive capacity (Exposito-Langa et al., 2011).

Taking into account these contributions, the last baseline hypothesis is established:

Hypothesis 3. Geographical proximity between system integrators and end-user companies is expected to have a positive impact on system integrators' ability to innovate end-user companies' business models and to increase system integrators' total annual revenue.

3. Data and methodology

3.1 Description of the survey

The aim of this project is to identify and analyse the main variables determining the likelihood for system integrators to improve their business performance in terms of annual total revenue.
The empirical analysis is based on an original dataset including rich information at firm level. After excluding some enterprises which could not be strictly classified as system integrators, a total of 2.503 firms were contacted to achieve the target of 161 responses (mainly small-sized one as shown in the Table 2 below), resulting in a 6% response rate. Data were collected on companies affiliated with the CSIA, through a web survey with distinct sections referring to respondents and companies' profiles, adoption of new digital technologies, networking activities and relationships with customers. The management board of CSIA has given its full support and collaboration to spread the survey among its members. However, the system integrators interviewed cannot be considered statistically representative of system integrators all over the world, since 80% are from North America or European countries (see Table 2 below). As a consequence, the population under-represents Latin America, Asian and African system integrators.
In spite of this, we believe that the qualitative findings of our survey are very likely to hold in a much broader setting, since our sample has all the characteristics to be considered an ideal candidate to represent system integrators from developed countries.
Moreover, by observing the Table 1 below, we can affirm that our dataset reflect almost perfectly the CSIA database in terms of reference sectors. The distribution of our data by size and country of origin is presented in the Appendix (see Table 5).

Table 1

SECTORS	CSIA sample		Survey sample
Automotive	19%		21%
Chemicals and petrochemical	26%		25%
Energy	20%		33%
Food & beverage	47%		47%
Government	6%		8%
Industrial machinery	23%		33%
Life sciences	20%		17%
Metals & glass	16%		16%
Mining, & agriculture	8%		14%
Pulp, paper & textiles	4%		14%
Transportation	4%		9%
Water and wastewater	30%		30%
Packaging and material handling	16%		24%
Entertainment	0.4%		1.9%

A pilot web-based survey addressed to a group of system integrators was initially conducted, leading to 30 filled questionnaires. The contact person was the CIO of the firm, or the general manager. Specifically, in the case of small firms, it was usually the owner who participated in the survey.

Table 2

```
        Size |      Freq.     Percent        Cum.
------------+-----------------------------------
       micro |         35       21.74       21.74
       small |         67       41.61       63.35
      medium |         35       21.74       85.09
       large |         24       14.91      100.00
------------+-----------------------------------
       Total |        161      100.00
```

```
          Geo   |      Freq.     Percent        Cum.
--------------+-----------------------------------
           RoW |         12        7.45        7.45
            EU |         32       19.88       27.33
 Latin_America |         21       13.04       40.37
North_America |         96       59.63      100.00
--------------+-----------------------------------
         Total |        161      100.00
```

3.2 Variables and model specification

In order to explore if system integrators' business performance has experienced significant or slight increases during the year considered, two dummy variables were developed.

The dependent variables are described as follows:

Bf_sigincr
(Please indicate if your company's annual total revenue has significantly increased over the year 2019, compared to the sectoral average).

The *Bf_sigincr* dummy assumes the value 1 if system integrators' total annual revenue has experienced a significant increase, and the value 0 otherwise.

Bf_slincr
(Please indicate if your company's annual total revenue has slightly increased over the year 2019, compared to the sectoral average)

The *Bf_slincr* dummy assumes the value 1 if system integrators' total annual revenue has experienced a slight increase, and the value 0 otherwise.

Cust_busmod
(Please indicate if the system integration activities of your firm have contributed to its customers' business model innovation, over the year 2019)

The *Cust_busmod* dummy assumes the value 1 if system integrators' activities have played a role in their customers' business model innovation, and the value 0 otherwise.

According to our data, (see Tables 3; 4 and Tables 3a; 4a below) we can note that approximately fifty percent of system integrators interviewed have experienced slight increases in their annual total revenue during the year considered, and more than seventy percent played a role in their customers' business model innovation. It is also interesting to note that European system integrators, compared to those from other countries, have recorded the best improvement in their annual total revenue (more than forty percent showed a significant increase in their business performance, versus twenty-two percent from North America, thirty-eight percent from Latin America, and twenty-five percent from the rest of the world). By observing the two-way tabulation of frequencies between business performance and size of system integrators, we can note that the majority of system integrators with a significant increase in their total annual revenue, are grouped in the small-size category (more than fifty-three percent), while only about six percent are included in the large-size class. Moreover, the relative majority of system integrators, which have been proved to be impact in their customers' business model innovation, are small-sized firms.

In line with the three baseline hypotheses above-mentioned, we have considered the following explanatory variables: five new digital technologies integrated by system integrators in response of end-user firms, the level of system integrators' internal and external networking, and the level of geographical proximity between system integrators and end-user firms (see Figure 1 in the Appendix).

Table 3

Ann tot revenue _variable	**Geo** RoW[17]	EU	Latin_Ame	North_Ame	Total
No increase	3	8	2	22	35
	8.57	22.86	5.71	62.86	100.00
	25.00	25.00	9.52	23.16	21.88
Slight_incr	6	11	11	52	80
	7.50	13.75	13.75	65.00	100.00
	50.00	34.38	52.38	54.74	**50.00**
Significant_incr	3	13	8	21	45
	6.67	28.89	17.78	46.67	100.00
	25.00	**40.62**	**38.10**	**22.11**	28.12
Total	12	32	21	95	160
	7.50	20.00	13.12	59.38	100.00
	100.00	100.00	100.00	100.00	100.00

Table 3a

Cust_busmod	**Size** micro	small	medium	large	Total
no impacted	11	23	4	10	48
	22.92	47.92	8.33	20.83	100.00
	31.43	34.33	11.43	41.67	29.81
impacted	24	44	31	14	113
	21.24	**38.94**	27.43	12.39	100.00
	68.57	65.67	88.57	58.33	**70.19**
Total	35	67	35	24	161
	21.74	**41.61**	21.74	14.91	100.00
	100.00	100.00	100.00	100.00	100.00

Table 4

Ann tot revenue	**Size** micro	small	medium	large	Total
No increase	9	14	8	4	35
	25.71	40.00	22.86	11.43	100.00
	26.47	20.90	22.86	16.67	21.88
Slight_incr	17	29	17	17	80
	21.25	36.25	21.25	21.25	100.00
	50.00	43.28	48.57	70.83	**50.00**
Significant_incr	8	24	10	3	45
	17.78	53.33	22.22	6.67	100.00
	23.53	35.82	28.57	12.50	28.12
Total	34	67	35	24	160
	21.25	41.88	21.88	15.00	100.00
	100.00	100.00	100.00	100.00	100.00

[17] RoW stands for "Rest of the world" and include Africa, Asia and Australia.

Table 4a

Cust_busmod	**Geo** RoW	EU	Latin_Ame	North_Ame	Total
no impacted	2	6	6	34	48
	4.17	12.50	12.50	70.83	100.00
	16.67	18.75	28.57	35.42	29.81
impacted	10	26	15	62	113
	8.85	23.01	13.27	54.87	100.00
	83.33	81.25	71.43	64.58	**70.19**
Total	12	32	21	96	161
	7.45	19.88	13.04	59.63	100.00
	100.00	100.00	100.00	100.00	100.00

New digital technologies

This is a vector composed of five binary dummies indicating the adoption of five new disruptive technologies: Cloud computing, Big data, Robotics, AI and IoT. They assume the value 1 if the technology considered has been integrated in response to the needs of system integrators' customers, and the value 0 otherwise.

Internal and External networking

In terms of internal and external networking we have considered two numerical variables, proxied by the number of system integrators' internal and external stakeholders involved in the integration process, respectively. Internal stakeholders were represented by an ordered 5-category variable (1=1; 2=2; 3=3; 4=4; 5= from 5 up) referring to the number of internal functional areas involved in the integration activity associated with new digital technologies adoption. Twelve functional areas were considered (HR, Marketing/Promotion, Customer service support, Sales, Accounting and Finance, R&D, Distribution, Administrative/Management, Production, Operations, IT support and Legal Department). External stakeholders were represented by an ordered 4-category variable (0=0; 1=1; 2=2; 3=more than two) referring to the number of external stakeholders' categories involved in each phase of the system integration project life cycle (Gann and Salter, 2000): pre-bid negotiation phase, planning and budgeting phase, project implementation phase and handover to the customer. According to the pertinent literature (Kar et al., 2018) six stakeholders' categories (technology researchers, hardware developers, embedded system programmers, software developers, data scientists, consumers) were taken into account.

Geographical proximity

This is an ordered 3-category variable developed according to the level of geographical proximity between system integrators and end-user companies taking advantage of system integrators' services. It assumes the value 1 if geographical proximity is at its highest, with system integrators focused on regional markets; value 2 and 3 if national and international markets are considered, respectively.

We also controlled for firm and environment-specific characteristics related to firm size (*Size*), sector

(*Sector*) and location (*Geo*). With regards to *Geo*, an unordered 4-category variable is constructed by distinguishing system integrators placed in North America (=4), Latin America (=3), European countries (=2) and the rest of the world (RoW=1) including Asia, Africa and Australia.

In accordance with European Commission Recommendation (2003/361/EC) about the size of companies, the variable *Size* classifies system integrators in micro (1-9 employees), small-medium (10-49 employees), medium-sized (50-249 employees) and large firms (over 249 employees).
Finally, the variable *Sector* is composed of two dummies which control for the system integrators' reference sectors of production. The first dummy assumes the value 1 if system integrators are involved in Food & Beverage sector, and value 0 otherwise. The second dummy assumes the value 1 if system integrators are involved in the Energy sector, and value 0 otherwise. Food & Beverage and Energy have been chosen as discerning sectors because are found to be the most popular sectors for system integration according to the last CSIA survey.

Our econometric analysis is based on the estimation of three logit models.

Binary models are considered the best solution to estimate dependent variables having two categories, as in our analysis. In these models, the dependent variable and explanatory factors are in a non-linear relationship with a scaling factor of around 1.7. Any predictions are always bounded between zero and one and the coefficients relate to an underlying latent score. The latent model is described as the following:

$$Y^* = \mathbf{x}\beta + \varepsilon \qquad\qquad \varepsilon|\mathbf{x} \sim \text{Normal}(0,1)$$

According to our analysis we can imagine that system integrators whose we are observing business performance's changes are in a sort of continuous process, ranging from negative infinity to positive infinity. Moreover, let us suppose that their performance moves them up and down the scale. This represents the latent score. Let us imagine that at some point our system integrators' performance cross some sort of threshold value (identified by the threshold parameters α_j's to be estimated) that changes how they act.

$Y = 0$ if $Y^* \leq \alpha_1$
$Y = 1$ if $< Y^* \leq \alpha_2$
.
.
.
$Y = J$ if $< Y^* > \alpha_j$

Since the latent score cannot be observed, we have to transform the coefficients from the logit model and estimate the marginal effects which are the slope coefficients of the relation between the dependent variables (Y) and the regressors (X). We need to compute a change in Y, given a change in X. However, we should be aware that because of the non-linear transformation undertaken by ordered response models, the change in Y can vary depending on X.

The literature has settled on two types of marginal effects: marginal effects at the mean of all variables and average marginal effects. The formers, compute the marginal effect at the mean value of X for all variables, while the average marginal effects used in this paper compute all possible marginal effects along the entire range of X values and then they average these.

Moreover, it is important to note that in order to test the goodness of the three logit models, post-diagnostic tests have been carried on and the results are shown in the Appendix (Table 6).

We have used logit models for the following three equations corresponding to the two different types of increases of system integrators' total annual revenue and the impact of system integrators' activities on their customers' business model innovation (left-side of the equations):

1. $Bf\_sigincr_i = \beta_1 Digital\_tech_i + \beta_2 Network_i + \beta_3 Geo\_pro_i + \beta_4 Z_i + \varepsilon_i$ (1)

2. $Bf\_slincr_i = \gamma_1 Digital\_tech_i + \gamma_2 Network_i + \gamma_3 Geo\_pro_i + \gamma_4 Z_i + \upsilon_i$ (2)

3. $Cust\_busmod_i = \delta_1 Digital\_tech_i + \delta_2 Network_i + \delta_3 Geo\_pro_i + \delta_4 Z_i + \phi_i$ (2)

On the right side of the eq. (1) $Digital\_tech_i$ is a vector of digital technologies-related factors referring to the type of the digital technology integrated in system integration activities to meet end-user companies' requests; $Network_i$ is a vector composed of two numerical variables referring to the level of internal and external networking associated with the system integration activity; Geo_pro_i is a categorical variable identifying the level of geographical proximity between end-user companies and system integrator *i*. Finally, Z_i is the vector of the control variables, while ε_i is the random error term.

Accordingly, Eqs. (2) and (3), complete the analysis referring to the determinants of slight increases in system integrators' annual total revenue and the impact of system integrators activities on customers' business model innovation. Parameters β, γ and δ determine the average marginal effects to be estimated, while υ_i and ϕ_i are the random error terms.

4. Results

The estimation results based on the logit models for the system integrators in our sample are reported in the Appendix (Table 5). In the Table 5 are reported only the average marginal effects of the regressors which show significant impacts on each of the three dependent variables (the probability associated with the presence of important increases and slight increases in system integrators' annual total revenue, and the presence of business model innovation in system integrators' customers).

By focusing the attention on the digital resources integrated by system integrators to respond to their customers' needs, we can notice that according to the literature above-mentioned, AI, Cloud computing and IoT show a significant and positive impact on the likelihood of system integrators to experience short term increases, albeit slight, in their total annual revenue, while customers' business model innovation seems not to be impacted. In this respect, our first hypothesis has been only partially confirmed and a plausible explanation might be that higher improvements in system integrators' profits, as well as impacts on their customers' business model innovation, take much more time than 12 months to effectively occur, especially in small and medium system integrators with more limited available resources, compared to their larger competitors.

In addition, in line with the relevant literature discussed above and our second hypothesis, both internal networking (represented by system integrators' functional areas involved in the integration process) and external networking (the number of external stakeholders' categories involved in each phase of the integration process) show a positive and statistically significant effect on the probability for system integrators to experience both slight and relevant increases in their business performance, as well as to produce an innovative impact on their customers' business models.

Moreover, we can note that system integrators showing higher levels of geographical proximity with their end-user companies seem to be more likely to experience increases in their business performance, compared to system integrators interacting with their customers at national and international levels. These findings support our last hypothesis and the described research literature on geographical proximity.

Finally, with respect to the control variables identifying size and sectorial system integrators' characteristics, we can see that small, medium and large system integrators are more likely to show an improvement (albeit slight) in their business performance, compared to micro-size system integrators. We can observe the same for system integrators operating in Food & Beverage and Energy industries. These results are in line with the research by MarketsandMarkets (2017) showing that Food & Beverage is an industry where system integrators play a crucial role by providing services related to automation. Indeed, in this sector, companies are in a constantly need to adopt automation process, especially for homogenization and pasteurization activities, where specific temperature measurement and monitoring are crucial to increase the shelf life of products.
As regards to the geographical area of system integrators' countries of origin (Geo), it seems not to have a significant impact on their performance during the 12 months considered. However, it is likely that the analysis of a larger time period would have shown different significant results. In fact, according to the Global System Integration Market Share Report, 2019-2025 (Grand View Research, 2019), system integrators from North America (United States, Canada and Mexico) were found to hold in 2018 the largest market share (above 30%), in terms of their annual revenue. Latin America, Middle East and African regions are also expected to make relevant investments in the market. In particular, system integration market share of Latin America is expected to show growth rate of more than 10% CAGR from 2021 to 2027. In this respect, Latin America is experiencing a rise in the number of IT firms, e-commerce companies, and digital media market players. Thanks to the increasing internet penetration, consumer spending growth, rising middle-class customer base and technology acceptance, end-user firms are relying on system integration to streamline all their operations to a single platform, which can be more effectively managed in real-time.

5. Conclusions

Over the past few years, the high speed of technological development and the scarcity of competent resources have led system integrators to acquire an increasingly strategic importance by advising and guiding end-user companies to effectively face digital transformation challenges.

Despite the benefits from new digital technologies and organizational aspects have been well recorded in all innovative firms in terms of business performance, the evidence from system integrators is still rather limited.

In this context, this research focuses on the role played by digital technological resources, networking activities and geographical proximity in determining different levels of increase in system integrators' business performance. Logit models referring to the existence of slight and relevant improvements in the system integrators' annual total revenue, as well as the role played by system integrators' activities in their customer business models, have been developed. For the empirical analysis, a new dataset is constructed based on an original web survey involving 161 systems integrators worldwide.

The findings from the logit estimations highligth the importance of the examined factors for system integrators' activities and business performance.

Firstly, with regard to internal digital resources, our results indicate that specific new digital technologies integrated in response to end-user companies' needs, have a significant and positive impact on system integrators' performance. In line with the research literature above-mentioned, we can note that system integrators taking advantage of AI, Cloud computing and IoT are more likely to improve their total annual revenue.

Secondly, in terms of organizational resources, it is found that networking activities affect system integrators' business performance in the short-run. Indeed, being involved in internal and external networking seems to increase the likelihood of showing both relevant and slight increments in system integrators' annual total revenue and to impact on their customer business model innovation. On one hand, the involvement of external stakeholders (two and more than two) in the planning and budgeting phases, and in the project implementation phase, seem to show a positive impact on the possibility to experience both slight and relevant increases in system integrators' performance, as well as on the possibility to play a role in customers' business model innovation. On the other hand, in terms of internal networking, we can see that the number of system integrators' functional areas involved in the adoption of new digital technologies, seems to show a positive impact on their business performance' levels. In particular, system integrators having two or more innovative functional areas seem to be more likely to experience strong increments in their annual total revenue and customers' business model innovation. Therefore, we can say that over a specific threshold, greater the number of functional areas involved, higher the likelihood for system integrators to show a positive result in their business performance.

Relying on that, system integrators, in the attempt of improving their business performance, should become more aware about how to allocate their tangible and intangible factors to increase their internal and external networking activities. These results may have also other interesting managerial implications: the mere adoption of new digital technologies is a necessary but not sufficient condition for system integrators to improve their short-term business performance (it seems to lead to just slight revenue's increases). Rather, they should improve their internal and external networking activities by ideating and implementing more customized and target-oriented stakeholders' engagement strategies as to enhance the number of external and internal stakeholders' categories effectively involved into the different phases of their system integration process. To this end, system integrators' managers should schedule periodical meetings with their stakeholders to update them about value creation activities, giving to them an amount of information proportional to the importance of the role played by each stakeholders' category in each integration process's phase.

In addition, our results indicate that geographical proximity between system integrators and end-user companies enjoying digital transformation, shows a significant and positive impact on the improvement of system integrators' performance. More precisely, system integrators providing integrated solutions to geographically closer end-user companies (regional customers) are more likely to experience improvements in their business performance. Therefore, according to these findings, more resources should be initially saved to capture the customers' cultural, psychological and linguistic sensitivities through the development and implementation of regional marketing strategies, much less expensive than national or international ones.

At the policy level, these findings indicate that high priority should be given to increase the awareness of end-user companies about the strategic value coming from AI, Cloud computing and IoT. In fact, most of end-user firms ignore the high potential of these digital technologies and consequently avoid asking for system integrators' services. To address this issue, policy actions, such as developing flexible training programs and e-learning courses for employees at all levels, especially for innovation managers, should be implemented in a more structured and intensive way. Furthermore, the significant and positive impact of internal and external networking strategies on system integrators' business performance, indicates that beyond subsidies or governmental program promoting the adoption of AI, Cloud computing and IoT among end-user firms, it is also necessary to encourage the implementation of more comprehensive knowledge-sharing strategies involving the different system integrators stakeholders' categories. This would lead to an increase in the internal and external system integrators' stakeholder engagement rate and consequently to a more successful system integrators' business performance. Therefore, policies that simply focus on improving digital technologies awareness from a demand-side perspective are not enough if they are not coupled with activities promoting the value of networking strategies from a supply-side point of view. Such policy tools may help in weakening the cost barriers to new digital technologies adoption among end-user firms, and to innovative activities focused on system integration. As a result, they may effectively enhance value creation in the system integration market, supporting one of the main actors in the digital transformation process.

Concerning the limitations of this study, the effects may result to be downward biased. Indeed, it is important to consider that the full intended effect of new organizational measures usually takes time since its implementation (Damanpour and Evan, 1984; Karlsson and Tavassoli, 2015), and most of the innovative changes described above could take much more than one year to effectively impact on system integrators' business performance. However, it is worth pointing out that our research is just a preliminary investigation on system integrators' business performance. Future researches exploring organizational and strategical aspects in system integrators should take into account a panel data set and a larger reference period to add value. Moreover, future investigation in this field could focus on the potential effects of financial variables, such as the share of system integrators' expenditure in Research and Development, marketing or product innovation.

Appendix

Figure 1

Description of independent variables

Category	Variable name	Description
Explanatory_variables	Digital_Tech	The respondent is asked to identify the digital technology most adopted by the system integrator to satisfy customers' needs during the year considered. Unordered 5-category variable (1 = Artificial Intelligence; 2 = Big Data; 3 = Cloud computing; 4 = Robotics; 5 = IoT)
	External_networking	The respondent is asked to indicate the number of external stakeholders' categories involved in each phase of the system integration project life cycle during the year considered. Ordered 4-category variable(0=0; 1=1; 2=2; 3=more than two)
	Internal_networking	The respondent is asked to indicate how many system integrators' functional areas have been involved in the integration process of new digital technologies during the year considered. Ordered 5-category variable(1=1; 2=2; 3=3; 4=4; 5= from 5 up)
	Geo_proximity	Ordered 3-category variable developed according to the level of system integrators' target market (1= Regional; 2=National; 3=International)
Control variables	Geo	Unordered 4-category variable indicating the geographical area where system integrators' headquarters are located (1=RoW;2=EU;3=Latin America;4=North America)
	Sector_Fb	The respondent is asked to specify if the system integrator operates mainly in the Food & Beverage sector or not. Binary variable (1=Food&Beverage; 0= other sectors)
	Sector_En	The respondent is asked to specify if the system integrator operates mainly in the Energy sector or not. Binary variable (1=Energy; 0= other sectors)
	Size	Ordered 4-category variable developed according to the number of employees working in a system integrator. (0 = micro firms; 1 = small firms; 2= medium-sized firms; 3 = large firms)

Table 5

AVERAGE MARGINAL EFFECTS

	Bf_sigincr	Bf_slincr	Cust_busmod
AI	-0.444	1.809*	1.605
	(1.205)	(1.075)	(1.300)
Cloud_comput	-1.835**	1.735**	-0.112
	(0.890)	(0.817)	(0.819)
Robotics	-0.559	0.567	-0.338
	(0.825)	(0.815)	(0.816)
IoT	-0.691	1.436**	0.155
	(0.715)	(0.707)	(0.723)
Ext_network_Ph2			
2 stakeholders	-0.235	1.041*	0.340
	(0.704)	(0.603)	(0.552)
>2 stakeholders	3.449**	-1.785	-0.555
	(1.276)	(1.158)	(1.099)
Ext_network_Ph3			
>2 stakeholders	0.174	0.516	1.239*
	(0.638)	(0.602)	(0.643)
Intern_Network			
1area	1.376	-1.244*	0.978
	(1.233)	(0.723)	(0.729)
2areas	3.661**	-2.841***	1.197
	(1.219)	(0.756)	(0.732)
3areas	1.949	-1.224	1.313*
	(1.252)	(0.784)	(0.758)
4areas	2.149*	-1.345*	2.521**
	(1.304)	(0.798)	(1.026)
From5 areas up	3.577**	-2.355**	0.204
	(1.296)	(0.864)	(0.812)
Geo_proximity			
National	0.561	-0.123	-0.421
	(0.584)	(0.463)	(0.533)
Regional	1.586**	1.111*	-0.928
	(0.763)	(0.627)	(0.634)
Sector_Energy	-0.748	0.845*	-0.401
	(0.529)	(0.463)	(0.516)
Sector_F&B	-0.265	1.124**	0.133
	(0.467)	(0.427)	(0.447)
Size_Small	-0.0108	1.215**	0.185
	(0.680)	(0.597)	(0.596)
Size_Med	-0.316	1.752**	1.863**
	(0.793)	(0.771)	(0.855)
Size_Large	-0.468	1.521**	-0.605
	(0.842)	(0.763)	(0.743)
Geo_Eu	0.229	-0.222	0.0274
	(0.980)	(0.851)	(1.046)
Latin_Amer	-0.0679	-0.657	-1.155
	(1.026)	(0.908)	(1.081)
North_Amer	-1.194	-0.140	-0.998
	(0.959)	(0.785)	(0.960)
N	161	161	161

Standard errors are reported in parentheses.
*Significant at the 10% level;
** Significant at the 5% level.
***Significant at the 1% level.

Table 6

Logistic model for Bf_sigincr

```
              -------- True --------
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |        24             8  |         32
     -     |        22           107  |        129
-----------+--------------------------+-----------
   Total   |        46           115  |        161

Classified + if predicted Pr(D) >= .5
True D defined as Bf_sigincr != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   52.17%
Specificity                     Pr( -|~D)   93.04%
Positive predictive value       Pr( D| +)   75.00%
Negative predictive value       Pr(~D| -)   82.95%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)    6.96%
False - rate for true D         Pr( -| D)   47.83%
False + rate for classified +   Pr(~D| +)   25.00%
False - rate for classified -   Pr( D| -)   17.05%
--------------------------------------------------
```
Correctly classified 81.37%

```
--------------------------------------------------
```

Logistic model for Bf_slincr

```
              -------- True --------
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |        60            24  |         84
     -     |        20            55  |         75
-----------+--------------------------+-----------
   Total   |        80            79  |        159

Classified + if predicted Pr(D) >= .5
True D defined as Bf_slincr != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   75.00%
Specificity                     Pr( -|~D)   69.62%
Positive predictive value       Pr( D| +)   71.43%
Negative predictive value       Pr(~D| -)   73.33%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)   30.38%
False - rate for true D         Pr( -| D)   25.00%
False + rate for classified +   Pr(~D| +)   28.57%
False - rate for classified -   Pr( D| -)   26.67%
--------------------------------------------------
```
Correctly classified 72.33%

```
--------------------------------------------------
```

Logistic model for Cust_busmod

```
              -------- True --------
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |       102            28  |        130
     -     |        11            20  |         31
-----------+--------------------------+-----------
   Total   |       113            48  |        161

Classified + if predicted Pr(D) >= .5
True D defined as Cust_busmod != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   90.27%
Specificity                     Pr( -|~D)   41.67%
Positive predictive value       Pr( D| +)   78.46%
Negative predictive value       Pr(~D| -)   64.52%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)   58.33%
False - rate for true D         Pr( -| D)    9.73%
False + rate for classified +   Pr(~D| +)   21.54%
False - rate for classified -   Pr( D| -)   35.48%
--------------------------------------------------
Correctly classified                        75.78%
--------------------------------------------------
```

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