IT Investment Decisions in Industry 4.0: Evidences from SMEs

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Abstract Organizational processes, production, business strategy, value creation and value delivery are undergoing significant change as a result of emerging new technologies in industry 4.0 context. This has drawn attention across many countries and not only organizations, but also stakeholders and policy makers as the fourth industrial revolution. While Industry 4.0 has been widely investigated in large enterprises, yet to date, little is known about how SMEs with limited financial resources make strategic decisions in particular about IT investment on diverse emerging technologies. To close this gap, this paper focused on the propensity of SMEs in IT investment in an industry 4.0 context. We analyze the responses of 1889 Italian SMEs to Government policies designed to facilitate SMEs in adopting technologies for Industry 4.0. This study aims to contribute to alignment literature by highlighting the importance of IT investment as a strategic decision in Industry 4.0. Moreover, the paper offers a set of practical implications.

Keywords Industry 4.0 · IT alignment · IT investment · SMEs

1 Introduction

Organizational processes, production, strategy, value creation and value delivery are undergoing significant change as result of emerging technologies. The deep impact of these technologies on business processes [12, 41] highlight the integration of IT strategy with business strategy [9, 16]. Considering the fast-changing and diverse emerging technologies, recent research emphasizes that IT alignment is a continuous process [49]. Organizations need to consecutively align their IT strategy with business strategy through investment and development their organizational IT resources and

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infrastructures. IT investment and developing digital infrastructure enable organizations to enhance their innovation performance, however, organizations have struggled to opt and invest on the right technologies in consistent with their business objectives which may create a path dependency and constrain the future organizational capability to innovate [40]. Moreover, when an organization has invested on a specific technology and integrated it with the legacy system, adopting another technology will be complex and costly.

Despite the increasing interest in Industry 4.0, our understanding of how firms invest and align their IT strategy with business strategy in industry 4.0 is limited. In particular, while the concept of Industry 4.0 has been widely investigated in large enterprises [3], few studies focus on SMEs [34]. SMEs having limited resources and capabilities face challenges in making IT investment decisions to align its IT strategies with business strategies. Thus, in this paper, we examine the IT investments made by SMEs in Industry 4.0.

In this study we focus on Italian SMEs investments on industry 4.0. Our rationale behind our research design is that Italian government has launched a strategic plan in 2016 to accelerate technology adoption and boost the Italian production system.[1] Therefore, access to financial aids remove financial barriers to invest on industry 4.0. This provides us with a unique occasion to examine IT investments and typology of technologies on industry 4.0 across different industrial sectors and geographic dimensions.

Based on accessing to a large-scale dataset including 1889 Italian SMEs benefiting from the Italian financial incentive for Industry 4.0, the purpose of this paper is to analyze IT investment by SMEs focusing on industry 4.0. The findings illustrate the propensity of IT investments by SMEs and invested technologies. More specifically, since the financial incentive targets SMEs from all sectors, an analysis of the technologies and assets that SMEs acquired for Industry 4.0 can provide us with more detailed insights on IT alignment in SMEs.

The structure of paper is as follows. First, we present related studies on industry 4.0. Second, we present and discuss the importance of IT investment decisions in business strategy and alignment. Third, we present the results of analysis conducted on 3670 purchases by SMEs who benefit from industry 4.0 initiative. Finally, we present the discussion and theoretical and managerial implications.

[1] Looking at data reported on digital economy society index in 2017, although Denmark, Ireland, Sweden and Belgium are leading in digital economies in the EU, the rank of Italy is 25th among 28th EU member states. To fill this gap and support digital transformation by SMEs, thus, Italian government has launched a strategic plan for digitalization in 2016.

2 Relevant Literature

2.1 Industry 4.0

The German government initiative known as Industry 4.0 refers to integration of cyber and physical systems through interconnection of sensors, machines and systems to create connected and smart value chain beyond a single firm's boundaries. The businesses have undergone significant change due to embedded systems that create hybrid physical-cyber systems [38]. Following Rüßmann et al. [42], we consider industry 4.0 as combination of different technologies See Fig. 1.

Advances in technologies enhance capability of firms to generate, collect and analyze big amount of data. Capturing and processing real-time data enhance organizational capabilities in decision making and create new value creation opportunities for firms [37].

The evolving robots allow firms to reduce cost and flexibility due to automation and decentralization of decision making, for example, automated guided vehicles (AGVs).

Cloud computing technologies enable organizations to remotely access scalable digital resources: applications, platforms and infrastructures [31]. The potential benefits of cloud-based services for organizations are cost convenience, business agility

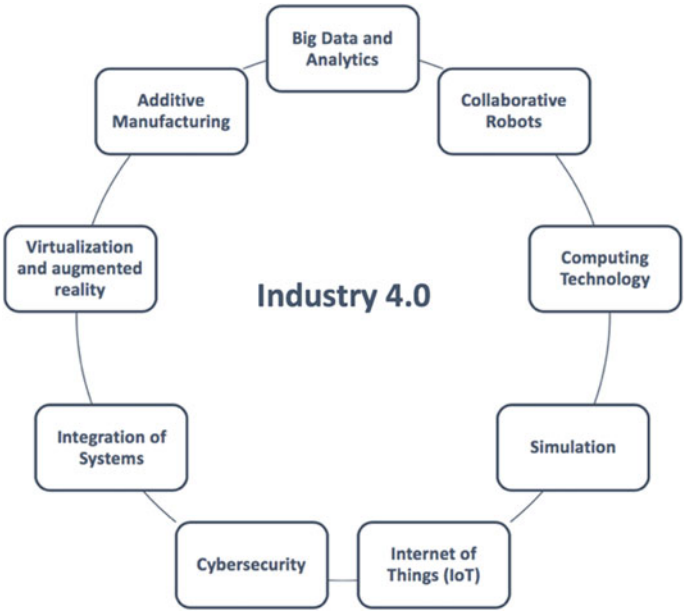

Fig. 1 Industry 4.0 as combination of different technologies. Adapted from Rüßmann et al. [42]

and scalability of resources [30], that have led to a growing trend in adopting cloud-based solutions in recent years [35], specifically for small and medium enterprises [23].

Simulating production process leverage by availability of massive real-time data can allow firms to optimize process settings in terms of time and quality.

Internet of Things (IoT) refers to a network of interconnected machines, devices and sensors with capability to communicate via standard protocols. Devices with embedded computing systems connect via the internet, and enable to collect and exchange data, and interact together. Real-time information can be captured and exchanged through embedded systems which enhances productivity and facilitates interoperability [50].

Prototyping and producing products in small batches with high level of customization is feasible by using additive manufacturing like 3-D printing. The cutting-edge technology enhances flexibility to produce customized products.

Augmented reality provides information via devices such as augmented-reality glasses for better decision making.

Integration of systems refers to platforms and data-integration networks that allow firms to access and exchange data across different processes, departments and also across supply chain.

With increased connectivity among systems and devices, firms are more dependent on management and protection systems to imitate cyberthreats. Cyber-connected systems collect huge amount of data from devices, sensors and actuators which facilitate real-time monitoring flow of materials and data along the supply chain. In adoption of cutting-edge technologies, firms need to pay particular attention on emerged vulnerabilities and security threats. As to adopting cloud, multi-tenant characteristics of cloud that contains data of multiple organizations increase the risk of direct attacks on cloud infrastructures [4]. Poorly-secured systems make firms prone to cyber security threats, especially when new IT technologies are integrated with the legacy systems [20]. Thus, firms need to ensure security in terms of: (1) accessibility of data only by authorized actors and protection of sensitive data i.e. confidentiality; (2) controlling any modification i.e. integrity (3) continuity of operations i.e. availability [2].

The combination of these technologies is extensively expanding the span of the services and products and business networks [9]. The embedded and connected sensors, microprocessors, software and systems with in physical artifacts allow organizations to expand the value of products and services [38] and more room for product differentiation. At the same time, the on-demand resources e.g. cloud computing enhance organizational scaling ability [9]. When it intertwines with availability of real time data it allows rapid mass customized production and highly customized services [41]. The expanded span of data collection (e.g. data created by embedded sensors or digital actions by individuals knowing as Big data), analysis and monitoring capabilities across value chain enable organizations to manage the whole business processes more efficiently and effectively. Moreover, the hybrid physical-cyber systems facilitate integration of organizations (vertically and/or horizontally) across

the value chain. The plug-and-play concept in products and services, automation and standardized processes facilitate integration of value chain.

Furthermore, industry 4.0 enhances the flexibility through decentralized control, autonomous robots, and data-driven decision making across value chain networks [12]. Simultaneously, automation and integration of value chain across organizations enable organizations to reduce the time to market –named Smart supply chain [22]. Organizations aim to meet the needs of customers and adopt available technologies to create new value propositions. Industry 4.0 introduces a paradigm shift in the way organizations create value: offered services and products, customer interface, required resources, core competences, partner network, and capture value [12, 36].

In sum, industry 4.0 enables firms to enhance flexibility, quality and productivity and can facilitate monitoring and controlling of energy consumptions, thus, improve sustainability [13]. However, research stresses on considering the overall sustainability view since for instance some technologies such as automation and robots are expected to challenge social aspects of sustainability such as employment [7].

2.2 IT Investment and Alignment in SMEs

One of the dominant topics in the IS research relates to alignment of IT strategy with business strategy. The traditional view of IT alignment is limited to alignment of IT strategy at IT functional level strategy with business strategy [21]. The recent IS research highlights the peculiar characteristics of new emerging technologies and the embeddedness of digital technologies in organizational operations which influence and transform the business operations and business models of many organizations [12, 41]. Consequently, the IT strategy is not apart from business strategy anymore. Instead, it is intertwined and integrated with business strategies [9, 16]. Moreover, the changes in IT landscape and emerging new technologies require that organizations consecutively align the IT strategy with business strategy [49]. This means that organizations need to develop and change organizational IT resources and infrastructures in consistent with business strategy. In particular, organizations need to align the business resources and IT investment [33]. IT investment decisions influence organizational and innovation performance [26]. For example, Kleis et al. [25] emphasize on the link between investment on IT infrastructure and innovation. At the same time, making IT investment decisions and opting typology of IT and infrastructure create a path dependency that may constrain and influence the future capability of organizations to develop new resources, processes, and even business models [40]. Therefore, considering the complex and fast changing IT landscape, managers need to make sense [48] of IT trends and diverse emerging technologies in order to make the proper IT investment decisions [1].

As reported by Gartner, organizational IT spending is expected to increase also in 2019 [17], yet it is challenging for organizations to align IT investment decision with business strategy and adopt proper IT resources and infrastructure to create and add value. In particular, the SMEs may face difficulties in aligning and integrating IT

strategies with business strategies due to several reasons. First, SMEs mainly focus on short-term strategy [32]. Second, the characteristics of SMEs lead to different IT adoption rates in comparison with large organizations [19], since SMEs usually target a niche market in order to sustain their competitive position in the market [15]. Consequently, even high-tech SMEs have adopted very specific technologies to meet the niche demands. Third, the decision of what technology to adopt in SMEs is influenced by external environmental factors such as competitive supply side [43]. Moreover, SMEs are usually characterized by limited knowledge and capabilities of managers who making strategic decisions [28], limited IS skills of workforce, lack of financial resources, and IT infrastructures [11, 45]. The lack of financial resources also acts as barriers for SMEs to use external knowledge sources or to develop internal IT skills. The uncertainty regarding the technologies and level of capability of managers in seeing long-term benefit of IT investments influence IT adoption by organizations [43]. However, Levy et al. [28] present evidence that managers of SMEs align their IS investment with business strategies: either to focus on efficiency and cost reduction or on added value strategies.

To develop new emerging technologies, SMEs require to invest on IT infrastructures, IT services, and train or hire new workforce in an industry 4.0 context. However, the lack of sufficient resources may limit SMEs capabilities to adopt new technologies. For instance, SMEs face difficulty in successful implementation of Enterprise Resource Planning software which relies on high level of IS skills [14]. Another example is decisions related to cloud service level (Software-as-a-Service, Platform-as-a-Service or Infrastructure-as-a-service) which is based on organizational IT skills and expertise level: Platform-as-a-Service or Infrastructure-as-a-Service solutions demand higher IT capabilities to maintain and upgrade the systems, while Software-as-a-Service requires less efforts and expertise from firms [44].

As evidence shows 58% of firms who are victims of cyber-attacks are small organizations [47]. Thus, in aligning IT with business strategies, IT governance [10] and investments is prerequisite in order to not only support business strategy in short and long term, but also mitigate associated risks.

3 Dataset and Data Description

The significant influence of Industry 4.0 on businesses makes it an inevitable concept in future industrial operations. For the purpose of our study, we focus on Italian SMEs investment on industry 4.0. Our rationale behind our research design is that Italian government has launched strategic plan in 2016 to accelerate technology adoption and boost the Italian production system. As the major part of Italian enterprises are SMEs, they have limited financial resources and face difficulty to access finance from banks. Thus, the Italian Government has designed a number of direct and indirect aids, among which an incentive for bank loans for SMEs investing on new assets related to industry 4.0. The new policies following the National Plan for Business 4.0 embrace two types of incentives and supports: (1) tax benefits and credits for

organizations investing in new technologies, developing research projects, driving incomes from intellectual properties (IPs), or investing in training workforce in an industry 4.0 context, (2) bank loans and guarantee for organizations investing in new technologies and innovation project (Piano Nazionale Impresa 4.0 by the Italian ministry economic development).

We had access to a unique database including SMEs requests for IT investments, funded IT investments and the typology of invested technology. We analyzed the responses of SMEs to Italian Government policies designed to facilitate SMEs in adopting technologies for Industry 4.0. The original database contains 3670 accepted applications (1889 Italian SMEs) for bank loan support package out of 5130 applications made in 11 months from February 15th, 2017 to April 13th, 2018. All registered SMEs (1) operating in production sectors and (2) considered as low risk of bankruptcy/not in difficulty were eligible to apply. This incentive includes physical assets such as plant and machinery, industrial and commercial equipment, as well as, intangible assets like software and digital technologies that support industry 4.0. The loan ranges from 20.000 € and 2.000.000 € with maximum 5-year duration. For all 3670 confirmed financial aid, our database includes also the type of purchased asset/s based on Budget Law in 2017,[2] in total 42 categories.

The database, then, was merged with data extracted from AIDA[3] (Italian Digital Database of Companies) which provides detailed data on Italian companies such as size, industrial sector, region, foundation year and some financial information.

In order to further analysis of the technological investments, we initially adopt the nine pillars in Industry 4.0 following Rüßmann et al. [42]. Since not all of assets can be categorized based on the nine pillars in Industry 4.0, we identify another category named "advanced manufacturing" referring to a various set of advanced machineries, devices, equipment and systems for production processes.

4 Data Analysis and Findings

In total 5130 SMEs applied for financial aids through banks or intermediaries which 1889 of them granted for the financial incentive to purchase assets. For SMEs received loans, Table 1 illustrates the demographic characteristics.

The majority of firms are located in the north part of Italy that around 44.5% of them are small-sized: 21.9% North West and 22.49% North East (Fig. 2). The number of SMEs located in South (2.4%) is much lower than in Center of Italy (16.3%).

[2] Annex 6a, Annex 6b, INTERMINISTERIAL DECREE—List of Capital Goods eligible for the incentive, January 25th 2016.

[3] AIDA is the Italian provider of the Bureau Van Dijk European Database. The database contains structured information on over 1,000,000 Limited Companies operating in Italy, providing updated information such as shareholding, personal data, financial and economic information, investments and M&A etc.

Table 1 Demographic characteristics of SMEs

Foundation year	(%)
Before 1970	4.37
1970s	12.33
1980s	21.94
1990s	23.94
2000s	24.16
2010 and After	13.26
Total	100
% Of craft companies	**36.13**
% Of startups	**0.36**
No. of employees	
Less than 10 employees	20.79
10-49 employees	62.01
50-249 employees	17.19
Total	100

Bold indicates main headings

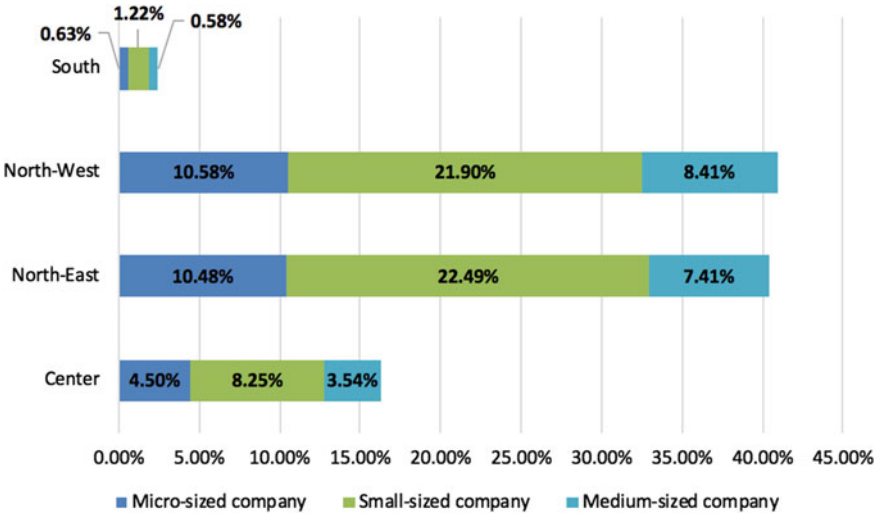

Fig. 2 Size and regional distribution of SMEs

Our findings show that around 89% of firms gained financial benefits belong to manufacturing sector. In particular, SMEs from manufacturing sector are concentrated in the following industrial subsectors:

- 33.5% manufacture of metal products (excluding machinery and equipment);
- 8.7% manufacture of machinery;

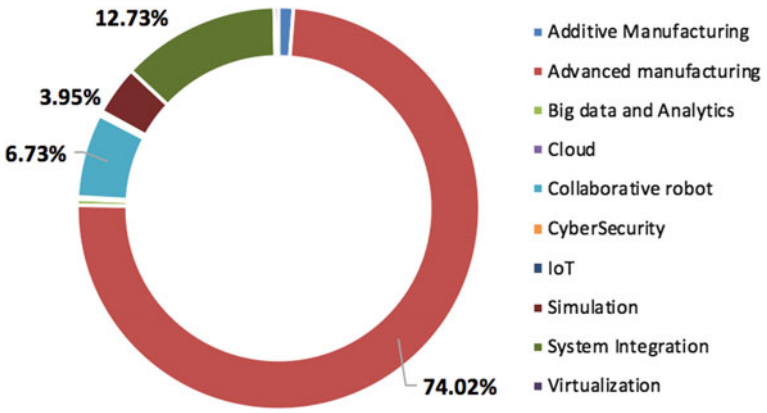

Fig. 3 Percentage of investments by technology category (purchases in 11 months period)

- 7.4% manufacture of rubber items and plastic materials.

It is important to highlight that firms operating in other industrial sectors are very few, less than 5% for each industrial sector. Thus, the companies operating in manufacturing sector may perceive the investment on new assets and technologies as an opportunity to enhance operational effectiveness and productivity.

The main results of our analysis show the distribution of technology investments on advanced technologies in context of industry 4.0. By looking at acquired assets, as shown in Fig. 3, 74% of the investments in industry 4.0 are related to advanced manufacturing. More than 12% of the firms invested on system integration. System integration allows firms to monitor and control products by data exchange, not only across different departments such as manufacturing and maintenance or inventory, but also across supply chain; with suppliers, customers and other actors. Thus, one of the main criteria to allocate financial aids emphasizes on standards and communication protocols. This not only allows infra-firm data exchange but also is fundamental for future connectivity at inter-firm and industrial level.

Although the majority of investments are on advanced manufacturing and system integration, firms have also shown the propensity to invest on collaborative robots (6.73%) and simulation technologies (3.95%).

As for cloud computing, according to findings, however, only few firms have invested in cloud computing (0.2%). Cloud-based solutions are based on multi-tenancy and standard solutions which allow cloud providers to offer services lower than in-house investment by a single firm. Pay-per-use model enables SMEs to use computing resources with very low cost by reducing significantly IT administration and maintenance costs. Thus, SMEs can access to IT resources with little investment [39]. That is why although the general trend in cloud adoption is increasing

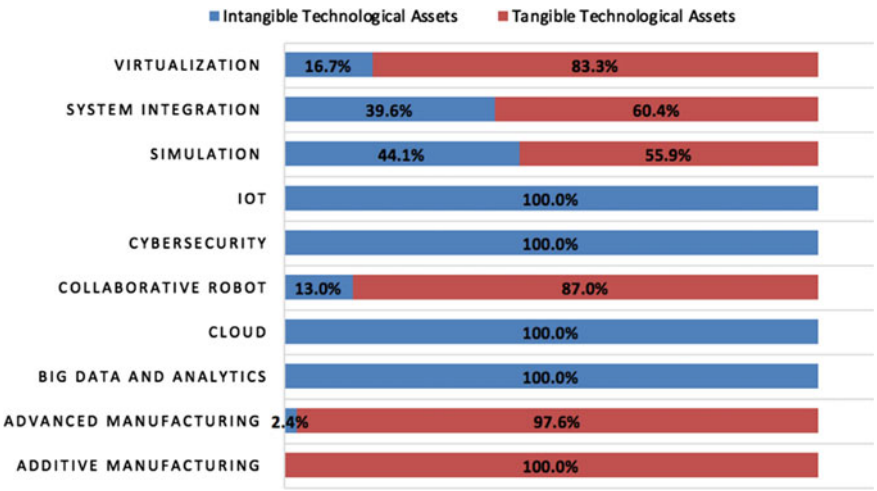

Fig. 4 Percentage of tangible and intangible investments for each technologies

specially by SMEs,[4] the findings of this study reveals that SMEs have seldom used this financial aid to invest in cloud.

Surprisingly, evidence from this analysis shows the low propensity of SMEs in investing on cybersecurity. Only few SMEs requested financial aid to invest on cyber security. This is particularly an important issue, since insufficient attention to IT security may lead to significant financial consequences and reputation damage for firms. Specially, the increased connectivity resulted from adoption of cloud resources and IoT increases the risk exposure of production and service systems [5].

For collaborative robots, SMEs purchased machines, tools and devices for un/loading, handling, weighing, sorting materials and automated lifting and collaborative robots. As for simulation technologies, major purchase orders belong to 3D modeling, simulation, experimentation and prototyping that allows organizations to test production processes and optimize process settings in terms of time and quality.

In total, SMEs invested mainly on physical assets (90%), while only few invested on digital assets such as platforms, systems and software (10%). Figure 4 shows the investments of firms in each technology based on tangible and intangible assets.

Additionally, based on detailed description on each purchase, four industrial performance objectives were identified. As shown in Fig. 5, about 74% of SMEs have invested on new assets to improve productivity of which 72% are dedicated to acquisition of tangible assets. Around 15% of the firms invested to enhance flexibility: 12.6% for physical assets. Even if results show significant investment to enhance productivity and flexibility, it is interesting to see that SMEs concern with sustainability and energy consumptions (4%). For instance, to improve sustainability,

[4]Europe's Digital Progress Report (EDPR) 2017, Country Profile Italy.

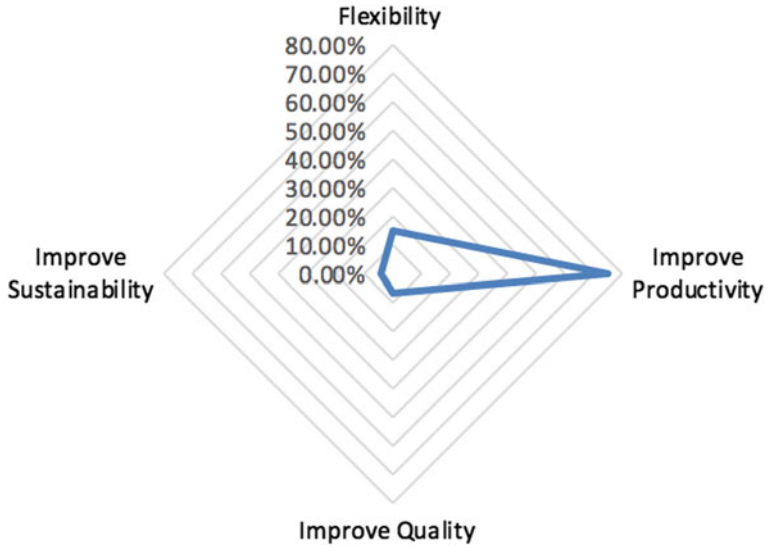

Fig. 5 Percentage of investments by performance objective

the three main asset acquisitions are related to waste tracking, recovery and treatment, and intelligent human-machine interfaces (HMI) that assist the operator in safety and efficiency of processing, maintenance and logistics operations.

The evidence revealed concern by SMEs on sustainability and energy consumptions. Although the number of purchases is not as significant as for productivity and flexibility, it sheds light on increased concerns of SMEs respect to regulations and laws related to energy consumptions and waste management.

5 Discussion and Conclusion

The ways organizations create, and capture value have undergone a significant change due to emerging new technology and the embeddedness of such technologies in business operations. Hence, as pointed out in literature, aligning organizational IT strategy with business strategy is pivotal for business [8]. Moreover, the pace and breadth of emerging new technologies induce challenges for firms in making decisions about what technology to invest and how to align IT strategy with business strategy [1].

In particular, for SMEs the challenges mainly refer to limited financial resources, IS skills and knowledge. As for the financial challenge, given that the significant contribution of Italian SMEs in economic growth, the Italian Government has introduced the National Plan for Industry 4.0 aiming at removing financial barriers and facilitating SMEs in adopting new technologies. However, SMEs face difficulty in

making strategic decisions about technologies due to limited skills and knowledge, especially considering the wide range of cutting-edge technologies, the substantial influence on the organizational performance and future development capability due to path dependency [40]. For instance, having complex legacy systems makes integration of the new system challenging and influences organizational performance. Thus, SMEs need to make sense of fast pace of new technologies [48] and understand what technology to invest in order to better align IT strategy with business strategy.

The findings of this study present a detailed insight on SMEs' investments on industry 4.0 supported by the Government following the National Plan. While digital technologies are transforming business processes and business models, the findings show that SMEs mainly invest on tangible assets e.g. plant, machinery, industrial equipment. One plausible explanation for the current trend is that Italy is lagged behind in digitalization of enterprises[5] respect to the European average. Thus, we can see that SMEs that mainly operating in manufacturing industry invest to develop advanced production systems aiming at improving productivity. Our findings are aligned with previous studies that highlight SMEs have a high tendency to keep the existing business model [24], and by investing on technologies they pursue efficiency goals [27] in current business which requires less efforts to realize.

Moreover, a negligible number of firms invest on IoT, virtualization, big data and analytics. Since digital technologies have significant influence on business processes, firms need to carefully assess and adopt these technologies aligned with the overall business strategy. Thus, SMEs may need to better understand how they can reap benefits from new technologies before any investment. It is worth noting that limited resources are main barriers for SMEs to explore different technologies and access to external knowledge. While large companies have sufficient resources to allocate for exploring different technologies and innovative projects even in different markets, SMEs mainly focus on specific technologies to meet demands in specific markets. The limited IT skills and knowledge in SMEs act as a barrier in exploring new technologies and strategic IT investment by managers [11–28, 45].

In particular, we found few SMEs invest on cybersecurity which might be due to lack of awareness of managers making IT strategic decisions. Another reason for that can be the security expectation of SMEs is lower than large enterprises, since the lack of proper protection on IT infrastructure has higher financial consequences for large enterprises [46]. Large organizations may be willing to pay more for customized service level agreements to increase security measures. For SMEs, however, there is a trade-off between security and cost [18, 29]. Lack of sufficient investment on cybersecurity technologies can lead to significant financial consequences and reputation damage for firms. Considering the fact that significant number of SMEs are victims of cyber-attacks [47], proper information security strategies necessarily entail employing practices for predictable and unpredictable security threats [6]. In particular, investment on cybersecurity technologies is crucial for organizations adopting system integration since integrating information systems such-as supply chain-blurs organizational boundaries which consequently increases exposure to cyber risks [5].

[5]Source: Europe's Digital Progress Report 2017—Research & Innovation.

While main stream of literature has focused on benefits of industry 4.0 [12–22, 41], in this study we argue that the lack of investment on cybersecurity and adequate knowledge of impact on technologies limit associated benefits of new technologies and may lead to negative consequences.

To align IT investments with business strategy, possess IT skills and access to external knowledge play an important role for SMEs. Thus, in the following year, significant effort was dedicated by the Italian Government to operationalize digital innovation hubs and competence centers to further support SMEs in innovation investments through raising awareness and facilitating access to external knowledge such as universities and other actors. This will allow SMEs to not only explore and exploit new technologies, but at the same time be aware of security challenges, and consequently wisely invest on IT technologies in industry 4.0 context.

The paths in technology adoption by SMEs are different from large organizations [19]. While the concept of Industry 4.0 has been widely investigated in large enterprises [3], this study on Italian SMEs provides a useful insight into the actual investments on digital technologies. The findings illustrate the propensity of SMEs in embedding advanced technologies for Industry 4.0 across different industrial sectors and regions.

While the incentive by Italian government to some extent remove the financial barriers for SMEs in investing and acquiring new technologies, this study aims to contribute to alignment literature by highlighting the importance of IT investments as strategic decisions in Industry 4.0. Moreover, the implications of this paper for practice are twofold. First, the results can help policy makers understand how SMEs are likely to embed new technologies in an industry 4.0 context. Second for practitioners, the results highlight the importance of integration of IT investment in new emerging technologies with business strategy.

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