Technological Forecasting & Social Change 194 (2023) 122731

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

SMEs and open innovation: Challenges and costs of engagement

Alessandra Costa [a,1], Antonio Crupi [a,*], Chiara Eleonora De Marco [b], Alberto Di Minin [b]

[a] Department of Economics, University of Messina, Messina, Italy
[b] Institute of Management, Scuola Superiore Sant'Anna, Pisa, Italy

ARTICLE INFO

Keywords:
Open innovation
Costs
SMEs
Financial performance
Digital innovation

ABSTRACT

Traditional literature in terms of Open Innovation broadly explored the potential benefits firms might achieve in collaborating with external partners. However, in such a recognized framework, the investigation of the costs firms face remains an underexplored field. Understanding the immediate economic impact of Open Innovation strategies is crucial, especially for SMEs that usually suffer from a structural lack of financial resources. To fill this gap, the present study explores the costs sustained by SMEs in the short run while implementing Open Innovation's strategies. Moreover, in line with the new challenges introduced by new technologies, the study explores how Open Innovation costs vary for digital and non-digital SMEs. In doing so, the study relies on a sample of 377 digital and non-digital European SMEs. In general terms, results show that Open Innovation represents a short-term cost for both types of SMEs. However, in investigating the different Open Innovation challenges addressed by SMEs, findings reveal that especially digital SMEs may limit costs by reducing their external activities and keeping their activity focused on the core business. These findings have implications for both SMEs and scholars, which are expected to lead to further investigations.

1. Introduction

The massive diffusion of digital technologies (such as Internet of Things, cloud computing, blockchains, big data, artificial intelligence, algorithms, virtual reality, etc.) is forcing firms to confront an external environment characterized by unprecedented levels of complexity and velocity (Crupi et al., 2022; Troise et al., 2022). While on the one hand, digital technologies are accelerating the speed at which innovations develop and diffuse, on the other hand, they are reducing products' life cycles obliging firms to accelerate their innovation processes (Mubarak and Petraite, 2020) to keep up with state of the art of progress. In this scenario, firms, especially SMEs, struggle to keep pace with the fast-evolving environment by only relying on their internal capabilities. One way of addressing this problem, is to collaborate with external partners to gain external knowledge resources (Crupi et al., 2020). Indeed, some of the most important drivers that push firms to engage in Open Innovation (OI) are linked to the expansion of their capacity to create knowledge spillovers and the development of innovation capabilities, both internally and in partnership with external partners (Cappelli et al., 2014; Granstrand and Holgersson, 2020; Griffith et al., 2006). Recently, Madhavan et al. (2022) highlighted the critical role of collaboration and information exchange activities of SMEs in global value chains for both trade expansion and sustainable growth in turbulent environments.

For many firms, engaging in OI has become a vital innovation strategy since it allows them to expand their knowledge complementarities and increase their productivity by enlarging their portfolio of innovation activities (Audretsch et al., 2021). However, while the collaborations' outputs in terms of benefits represent a potential gain, the costs to sustain are immediate. The price to pay to deploy OI represents a crucial point to consider, especially for SMEs, due to their financial constraints (Van de Vrande et al., 2009). Since the introduction of the OI concept (Chesbrough, 2003), scholars extensively investigated strength, positive implications, and benefits gained through external collaborations by reaching the widely recognized conclusion that the more a firm collaborates with external partners, the more is the likelihood of goal achievement (Audretsch and Belitski, 2020). Nevertheless, a lot remains to explore regarding the downside of OI, in terms of costs of establishing new collaborations, managing internal resources, protecting internal assets, and absorbing external knowledge across different contexts. In this regard, several scholars addressed the underexplored field of the OI's limitations and recognized the importance of having a clearer and

* Corresponding author.
E-mail address: crupi.antonio@unime.it (A. Crupi).
[1] Authors are listed in aphabetical order, and they have equally contributed to the study.

https://doi.org/10.1016/j.techfore.2023.122731
Received 16 June 2022; Received in revised form 21 June 2023; Accepted 25 June 2023

better understanding of the risks and costs to advance updated theories and practices (e.g., Faems et al., 2010; Praest Knudsen and Bøtker Mortensen, 2011; West and Bogers, 2017; Greco et al., 2019; Obradović et al., 2021; Costa et al., 2022).

In general terms, previous literature observed that the relationship between OI and firms' financial performance follows an inverted U-shaped curve, meaning that firms encounter undisputable benefits in opening to the external environment until the point where they start to encounter diminishing returns (Laursen and Salter, 2006; Leiponen and Helfat, 2010). Nevertheless, despite the increased interest demonstrated by scholars and practitioners toward the challenges of openness faced by firms (e.g., Radziwon and Bogers, 2019; Spithoven et al., 2013; Van de Vrande et al., 2009), the rising impact of digital technologies on firms' strategies leaves open relevant questions about the effects on OI, especially for SMEs (Barrett et al., 2021; Obradović et al., 2021). Moreover, while studies on OI have traditionally examined its effect on performance from a broad perspective, only a limited number have delved into the specific effects of different OI practices (e.g., Lu and Chesbrough, 2022; Ahn et al., 2015; Cheng and Huizingh, 2014; Mazzola et al., 2012). Additionally, many of these assessments have been conducted using survey or qualitative methods, which are prone to limitations such as self-reported bias (Zobel et al., 2016). In line with these considerations, the present study mainly looks at the different impacts of OI on non-digital and digital SMEs' financial performance in the short run. The relevant question is not whether digital and non-digital firms have different engagement in the OI dimensions. Instead, we answer the question: what are the costs faced in the short run by SMEs when implementing OI? Indeed, we argue that the engagement in OI implies costs that firms need to cover in the short run. Also, according to their different nature, we considered that these costs impact digital and non-digital firms differently. In other words, do digital SMEs benefit more or in a different way from OI compared to non-digital firms?

In this context, in defining OI as the commitment demonstrated by firms in engaging with external partners, we draw upon De Marco et al. (2020). By using the OI challenges identified in that study, we investigate the impact of OI on SMEs' financial performance, first by considering the general level of OI and measuring the costs faced by digital and non-digital firms, and then by examining the four OI challenges (*DeMarkers*), namely Internal Assets Protection, Management of External Relations, Relatedness, and Business Model Innovation, to disentangle the effect of such dimensions. In doing so, we relied on a database consisting of 377 European digital and non-digital SMEs whose projects, submitted to the European SME Instrument funding scheme between January 2014 and March 2017, were positively evaluated by the European Commission. We consider *digital* the SMEs presenting projects involving the development of solutions embedding digital technologies ranging from AI, Machine Learning, Big Data, to IoT, data analytics and data intelligence tools, and/or the integration of such digital technologies (RFID, blockchain, control and management systems, web/online/smart apps, etc.) in more traditional solutions and business strategies, in a variety of sectors. The *non-digital SMEs* included the companies that did not factor digital technologies in their project.[2]

The novelty of this study lies in the use of a proprietary micro-level dataset about European SMEs, to filling the existing gap in the available research, allowing us to identify and discuss the short-term impact of OI on SMEs' financial performance by comparing digital and non-digital firms. Overall, the study's contribution is twofold. First, we contributed to the OI and strategic management literature, and we extended the methodological implementation of the OI challenges provided by De Marco et al. (2020) to empirically disentangle the impact that OI has on SMEs' financial performance in the short-term, advancing the knowledge in terms of costs of OI for SMEs. Second, we confronted two different sets of firms that allow us to increase the understanding of the challenges and costs faced by SMEs navigating the fast-evolving digital environment, thereby enhancing the literature in terms of OI, SMEs, and digital innovation.

The paper is structured as follows. The second session introduces the theoretical background and enlists the research hypotheses. Section three explains the research strategy implemented and describes the methodology adopted. Section four presents and discusses the results of the analysis. Section five highlights the conclusive remarks and suggests managerial implications of the study.

2. Theoretical background

2.1. Open innovation and firms' performance

Since Chesbrough's seminal work in 2003, the concept of OI has attracted growing attention from both scholars and practitioners. As noted by Obradovic et al. (2021, p. 2) in their recent literature review on OI within the manufacturing industry, since its inception, the increasing attention toward OI has resulted in "more than 4,000,000 documents indexed on Google Scholar in 2020." In the early stages of OI research, the focus was primarily on the strategies employed by large companies to pursue OI. However, as the field matured, scholars began to dissect various levels of analysis, "including the micro-foundations of OI (Bogers et al., 2018a), non-profit organizations, and the public sector (Bogers et al., 2018b; Chesbrough and Di Minin, 2014), and SMEs (Laursen and Salter, 2006; Vanhaverbeke, 2017)" (De Marco et al., 2020, p. 2).

Previous studies on OI have generally highlighted its positive impacts while also investigating potential drawbacks and the trade-off between its beneficial and limiting effects. Nonetheless, evidence remains limited, particularly at the micro-level of analysis (Salge et al., 2013; Knudsen and Mortensen, 2011; Chesbrough and Bogers, 2014; Kobarg et al., 2019; Saura et al., 2023).

Prior research has explored the relationship between OI and firm performance, mainly in terms of innovation performance. In a recent study, Lu and Chesbrough (2022) conducted a comprehensive review of studies on this topic, by shedding lights on the high levels of heterogeneity in terms of statistical techniques employed for assessing firms' innovation performances, many of which were survey-based (e.g., Grimpe and Sofka, 2016; Laursen and Salter, 2006). In contrast, our study aims at deepening the understanding of the short-term costs firms face when implementing OI strategies, that could influence the firms' financial performances. Understanding the link between OI and firms' financial performances, based on the associated short-term costs of engagement is challenging due to the diverse range of practices encompassed by OI, which can manifest in different forms, making measurement difficult (Chesbrough, 2003; Dahlander and Gann, 2010; Huizingh, 2011).

Scholars have examined various activities falling under the OI umbrella, such as crowdsourcing, partnerships with universities, prize competitions, collaborations with start-ups, corporate venture capital, co-creation with customers and/or suppliers, intermediaries, and user innovation. Furthermore, most of the existing studies have used survey data to create variables for different OI practices (e.g., Greco et al., 2016; Kohler et al., 2012; Sisodiya et al., 2013). The same OI practice was often measured in different ways, leading to inconsistent results (see Lu and Chesbrough, 2022 for a detailed review). Specifically, while some individual practices inspired by OI have yielded positive results in several studies, more negative results have been reported when a more nuanced classification of OI practices was conducted (Ahn et al., 2015; Lichtenthaler, 2015; Mazzola et al., 2012).

[2] The analysis started from a manual screening of all proposal abstracts including keywords "digital" and other words describing digital economy; then the analysis used NVivo software for individuating the most cited expressions associated with "digital" and the selection of the most relevant association among the first 100 results. Finally, a new manual screening was conducted for selecting proposals including the new keywords.

It is worth noting that the limitations of OI may vary across different industries and geographical contexts (Annamalah et al., 2022; Audretsch and Belitski, 2023). Actors may incur coordination costs when monitoring, controlling, and managing knowledge transfers, and they strive to optimize collaboration governance. Moreover, differences in absorptive capacity across industries with various levels of R&D investments result in significant heterogeneity between industries in terms of coordination and effective collaboration abilities (Vural et al., 2013). Such transaction and coordination costs are higher in more knowledge-intensive sectors (Cassiman and Veugelers, 2002; Dahlander and Gann, 2010; Hall et al., 2014). If these costs are associated with higher knowledge transfer costs and more structured intellectual property protection, they could result in limitations of OI.

Even though much has been discussed about OI strategies, much remains to be explored about the costs SMEs face in the short term when engaging in OI practices.

2.2. Open innovation in SMEs

Literature has demonstrated particular interest in the realm of OI and SMEs, especially those involved in digital innovation. Digital technologies, indeed, are profoundly reshaping firms' strategies, innovation perspectives, and business models, thereby disrupting organizations (Crupi et al., 2022; Cutolo and Kenney, 2021; Nambisan et al., 2019). According to Yoo et al. (2012, p.1398), "a defining characteristic of pervasive digital technology is the incorporation of digital capabilities into objects that previously had pure physical materiality". Digital innovation emerges from applying digital technologies to ordinary physical objects, thereby offering new functionalities that enhance their use and broaden their field of application (Yoo, 2010). Consequently, digital innovation not only relies on the digitization of physical and analog solutions but also on the digital transition of traditional processes toward more efficient ones, facilitated by the application of advanced digital technologies. Therefore, digital innovation is perceived as a cross-domain innovation enabling firms to develop modular innovation strategies. This flexibility fosters agility and opens new business opportunities while challenging firms to adapt their structures, strategies, and business models and to pursue external knowledge more vigorously (Crupi et al., 2020; Warner and Wäger, 2019; Autio et al., 2018).

Traditional literature on SMEs and innovation acknowledges their essential role in boosting the innovation ecosystems' development, through their contributions to job improvement and economic growth (Acs et al., 1999; Storey, 2016). However, SMEs are most vulnerable when dealing with collaborative innovation projects due to their traditional lack of resources, both human and financial, compared to their need to stay abreast of innovation developments to maintain their competitive advantage. SMEs' limitations (i.e., *liability of smallness*, Spithoven et al., 2013) drive them to explore the external environment and implement OI practices to compensate for the missing assets (Van de Vrande et al., 2009). Previous studies have stressed that while large companies adopt OI to better exploit complementary assets and abilities performed by partners, SMEs resort to OI to counterbalance the scarcity of internal assets (Di Minin et al., 2016; Hossain and Kauranen, 2016; Spithoven et al., 2013). However, although cost-benefit analyses of collaborations for innovation are underdeveloped in theories of organizational learning and OI, collaboration is frequently presumed to be a superior approach in achieving strategic objectives such as innovation (Tartari and Breschi, 2012). Specifically, such collaborations positively impact SMEs' innovation capabilities (see Castellaci et al., 2005).

Implementing OI poses challenges to firms, especially SMEs, as they must confront hidden costs determined by the needs of identifying and absorbing external knowledge and adapting organizational strategies and structures. In their study, Marullo et al. (2018) shed lights on the hidden costs that may hamper and differently shape the paths of OI implementation, through three different theoretical dimensions: 1) the overlap between OI approaches and the company's governance mode; 2) the type of knowledge exchanged; 3) the sectorial innovation system to which the company belongs. In the same spirits, Greco et al. (2019) highlighted the costs that firms encounter when adopting inbound and outbound OI strategies. On one hand, firms may face financial and organizational costs to scout for external knowledge and implement it within the organization's boundaries. These costs mainly relate to improving specific internal abilities, transactional activities, and the Not-Invented-Here (NIH) syndrome. On the other hand, firms face costs of identifying suitable sources of external knowledge to absorb. Simultaneously, they must prevent these partners from gaining one-way advantages from such knowledge exchanges. These costs encompass the ability to enhance internal abilities for scanning the external environment, identifying suitable sources of external knowledge, implementing strategies to protect internal assets, and potential costs triggered by possible losses of competitive advantage caused by the diffusion of critical internal knowledge.

To further understand these costs, the relationships between various OI practices, and their impacts on firm performance, more nuanced studies are needed, particularly within the context of SMEs. Several questions persist, such as how SMEs can strategically manage the costs and risks related to their engagement in and implementation of OI practices, how they can balance the acquisition and protection of knowledge, and how they can effectively measure and capture the short and long-term benefits of OI.

In conclusion, while OI has the potential to significantly enhance the innovation capabilities of SMEs, there are considerable challenges and costs associated with its implementation. Further research in this area is necessary to provide a more comprehensive understanding of OI's costs and benefits, particularly for SMEs operating in the digital innovation universe. Understanding these dynamics can offer valuable insights for both scholars and practitioners, enabling more effective strategies for fostering innovation and growth in SMEs.

2.3. Hypotheses development

Identifying OI costs is not a simple task and determining how SMEs engage in OI is even less straightforward. For this reason, the present study relies on the framework proposed by De Marco et al. (2020). In their study, De Marco et al. (2020) explored the inclination toward OI adoption demonstrated by a subset of innovative European SMEs (those that received a positive evaluation in the SME Instrument funding scheme, financed by the European Commission[3] under the Horizon 2020 Framework Programme). In their study, De Marco et al. (2020) aimed to capture SMEs' propensity toward OI, through the identification of the challenges faced by firms in implementing OI, by explicitly focusing on what they referred to as external challenges. Consequently, their study identified internal OI challenges related to organizational and cultural changes, along with external challenges connected to internal assets protection, business model innovation, relatedness, and management of external relations. Given their agile and flexible structures at the internal level, SMEs are well-positioned to address potential internal challenges., while they often grapple with numerous resource deficiencies when tackling external challenges.

In their empirical analysis, De Marco et al. (2020) focused on external challenges, intended as "*proxies of non-observable engagement of SMEs in challenging dimensions of conducting OI strategies*" (De Marco et al., 2020, p. 3). These dimensions, referred to as *DeMarkers*, are: OI1) Internal Assets Protection, OI2) Management of External Relations, OI3) Relatedness, and OI4) Business Model Innovation (Fig. 1).

Specifically, Internal Assets Protection involves the challenge of safeguarding internal knowledge during OI activities and securing the

[3] More information about the SME Instrument available at https://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/sme_en.htm

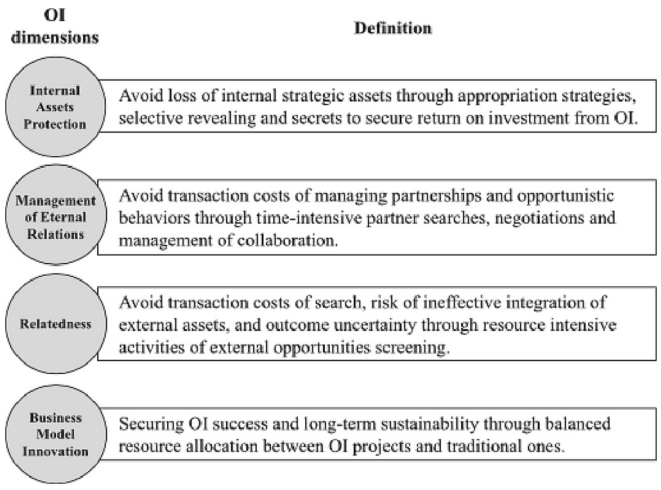

Fig. 1. The four challenging dimensions of OI according to De Marco et al. (2020, p. 4).

returns on investments from OI, by implementing appropriation strategies to mitigate the risk of losing crucial internal assets. Management of External Relations encompasses the task of managing agency and transaction costs of managing partnerships and opportunistic behaviors through time-intensive external partners searches, negotiations, and management of collaborations. Relatedness addresses the costs of excessively broad exploration of the external environment which can lead to ineffective exploitation of identified opportunities and to inefficiencies in the asset integration processes Finally, Business Model Innovation refers to the challenge of securing OI success and long-term sustainability through balanced firms' resources allocations between the OI projects and the traditional ones, to bring innovation projects to the market and capture value from them.

As previously stated, the current literature on OI costs has primarily focused on large, high-R&D-intensive companies. This focus has enabled us to identify the main constructs of OI and to acquire a comprehensive understanding of the innovation challenges faced by large corporations, allowing for the translation of these constructs to the SME context. Furthermore, prior studies have largely centered on the relationship between OI and innovation performance, estimating the effects of various openness-related constructs on both R&D intensity and patent counts. They have also examined the depth and breadth of innovation to elucidate the intensity of OI practice.

Building on the framework of De Marco et al. (2020), we embraced the distinction between digital and non-digital SMEs. As mentioned earlier, these two categories of firms were chosen based on projects providing evidence of their activities in the digital sector, revealing differing digital orientations. Specifically, the researchers selected SMEs that base their businesses on designing and integrating digital technologies for mobile and web applications, software systems, data and business analytics, cloud computing, RFID and real-time information solutions, as well as developing business intelligence tools, information and content management systems, software as a service, automation, and intelligent systems.

Considering that digital orientation reflects a firm's decision to digitize its organizational functions (Kindermann et al., 2021) and enable the digital transition of its processes to leverage the opportunities presented by new digital technologies (Quinton et al., 2018), we aimed to bridge the research gap in the literature on the evolution of the OI paradigm in the context of digitalization and digital transformation by separately considering digital and non-digital SMEs.

Despite the predominant literature highlighting the positive effect of open innovation on firms' innovation performances, such as R&D intensity, patent production, share of sales from new products, total sales, and cost reduction (Lee et al., 2010), findings on the link between OI and financial performance are mixed. Some studies underscore the positive relationship between OI and firm profitability, attributing it to the continual introduction of new technologies that bolster profit growth. Others suggest that OI does not necessarily lead to superior firm performance or higher profitability (Rosenbusch et al., 2011). These results are highly context-dependent.

Given that digital and non-digital SMEs rely on varying inbound and outbound strategies to achieve positive and sustainable growth, and have heterogeneous organizational and human structures, we argue that even if they could potentially benefit more from OI than larger companies (Spithoven et al., 2013), the negative impact of openness may be significant. Consequently, SMEs could be more susceptible to detrimental effects in terms of their chances to perform positively.

This aligns with Laursen and Salter (2006), suggesting that in the early stages of openness, firms are better equipped to handle external knowledge and convert it into profits. However, with the acquisition of more technology, firms face higher costs of knowledge integration and transformation processes, which could escalate the costs of openness and thereby reduce the benefits from OI. Furthermore, considering the differing degrees of digital orientation between digital and non-digital SMEs, we posit that the negative effect of open innovation on financial performance is greater for digital SMEs due to the increased challenges they face in exploiting digital-based knowledge as a sustainable competitive advantage in rapidly evolving environments.

Thus, we establish the first set of hypotheses as a foundation for subsequent exploration by proposing that:

H1a. *Digital SMEs' engagement with openness has a negative effect on the probability of positive financial performance.*

H1b. *Non-digital SMEs' engagement with openness has a negative effect on the probability of positive financial performance.*

Additionally, we utilize *DeMarkers* indicators for each dimension of OI, namely OI1, OI2, OI3, and OI4, to gain a deeper understanding of how firms' financial performance responds to various OI practices.

Specifically, OI1 reflects SMEs' engagement in Internal Asset Protection. It might be expected that both digital and non-digital firms engaged with this OI challenge would exhibit positive performance as a means of protecting against knowledge loss. However, asset protection remains a significant concern that deters SMEs from engaging in open innovation strategies, especially those requiring collaboration. Firms, in general, and SMEs, in particular, display a lack of trust in collaborative innovation due to uncertainty surrounding knowledge appropriability. Moser (2005) and Jaffe and Lerner (2006) argued that IP protection could hinder innovation processes, especially in those industrial sectors where knowledge is shared among multiple parties, and complementary and alternative strategies are available. This is especially true when SMEs aim to protect crucial internal know-how and maintain control over the innovation process. Furthermore, as IP mechanisms are costly, SMEs typically patent their inventions when they anticipate a reasonable likelihood of profiting from this protection and achieving commercial success (Van de Vrande et al., 2009). This is potentially true for non-digital companies that typically engage in IP protection as a safety strategy for commercial success. For these companies, formal IP mechanisms also serve a signaling function to the market and potential partners and are favored tools for managing external collaborations.

Conversely, when considering digital SMEs as firms with a higher digital orientation, they are more likely to encounter the disclosure paradox (Arrow, 1972; Dahlander and Gann, 2010). Given the inherent openness of digitally-oriented technologies and activities, which are predicated on integration and interoperability requirements, these firms must devote more managerial attention and effort to protect and decide how and to what extent disclose their knowledge in order to appropriate the benefits derived from innovation. Therefore, while every firm must define a balanced appropriability strategy to profit from knowledge

protection, it is reasonable to expect that increasing levels of internal asset protection and an excessive emphasis on appropriability will result in negative performance due to a negative signaling effect to the external environment. The primary risk is that a robust IP strategy could inhibit the establishment of certain collaborations, particularly when there is a high fear of legal infringement (Dahlander and Gann, 2010). Furthermore, digital SMEs are more likely to consider certain alternative approaches to appropriability, thus maintaining competitive advantage, which can be viewed as substitutes for formal IPs.

Therefore, although the ultimate decision regarding asset protection is a strategic business choice, it is reasonable to anticipate that non-digital firms would experience a positive effect from IP protection, as a guarantee of successful commercialization of their innovation. Conversely, for digital SMEs, a strong IP strategy could easily translate into negative financial performance. We test the following hypotheses:

H2a. *Digital SME's engagement in the Internal Asset Protection practices has a negative effect on the probability of positive financial performance.*

H2b. *Non-digital SME's engagement in the Internal Asset Protection practices has a positive effect on the probability of positive financial performance.*

OI2 represents SMEs' engagement in the Management of External Relations. Researchers have studied the general role of external relationships as a source to add to or complement firms' internal knowledge and innovation-producing capabilities that they lack (Chiang and Hung, 2010), thus enhancing firms' financial performance. Since SMEs typically suffer from a critical lack of financial and human capital resources, managerial and technical skills, and know-how (Spithoven et al., 2013; Bigliardi and Galati, 2018), they view networking as a way to broaden their technological competencies. Considering the resource constraints of SMEs, research suggests that SMEs tend to prefer networking and informal knowledge sourcing rather than complex transactions, such as acquisitions and in-licensing (Brunswicker and Vanhaverbeke, 2015). Leveraging external collaborations, SMEs could succeed in reducing the costs associated with innovation investments and in adapting and reconfiguring innovation processes. However, while the benefits of managing external relationships are more apparent, there are significant costs as well. Lee et al. (2010) highlighted the potential negative effect of external relationships: managing external partnerships is costly and increases the likelihood of core knowledge being leaked. Additionally, SMEs may exhibit different patterns of sourcing (Brunswicker and Vanhaverbeke, 2015), and the diversity and combination of different sources require significant effort to benefit from new value creation, with the value in each case potentially varying significantly.

Thus, using and managing more complex and research-based relations might negatively affect firms' performance: being involved in an extensive search for, selection of the right partners, and management of relationships might significantly challenge the sustainability of firms' organizational capabilities. Moreover, Laursen and Salter (2006) found that beyond an optimal level, firms with an increasing variety and complexity of external relationships face decreasing returns in terms of innovation performance.

When evaluating the trade-off between costs and benefits arising from managing multiple external collaborations with different types of partners for digital and non-digital SMEs, findings are mixed.

Non-digital SMEs, operating in low R&D-intensive sectors, are more likely to engage in exploitation activities and in demand-sided collaborations, so that benefits arising could be higher than the associated management costs. This is particularly true when firms search downstream to access new knowledge because they are more interested in the commercialization phase of it, rather than in its experimental phases (Verbano et al., 2015). Conversely, digital SMEs tend to strengthen innovative research-based relationships for exploration activities, with supply-side partners, characterized by higher risks and uncertainty that allow them to be competitive in more complex and globalized environments. The ability to explore external partnerships involving universities and research organizations, focused on effective knowledge transfer, would help SMEs to seize and adopt opportunities and achieve long-term sustainability, even if in the short run this could translate into worse financial performance, being riskier than long-term oriented ones (Parida et al., 2016). Consequently, we hypothesize that:

H3a. *Digital SME's engagement in the management of external relations has a negative effect on the probability of positive financial performance.*

H3b. *Non-digital SME's engagement in the management of external relations has a positive effect on the probability of positive financial performance.*

The third *DeMarkers* indicator, namely OI3, is relatedness, which reflects SMEs' ability to balance the external flows of knowledge with the firm's priorities within their organizational boundaries (De Marco et al., 2020). Traditional literature emphasizes that SMEs are generally less likely to conduct formal R&D, compared to large companies that clearly have an advantage in R&D because of the larger output over which they can apply their R&D expenditures (Ortega-Argilés et al., 2009). Moreover, when exploiting the concept of relatedness, as a theoretically grounded construct in the resource-based view (RBV) of diversification, OI3 underlines the ability of a firm to leverage synergies and economies, starting from internal resources (Tanriverdi, 2005). Since exploration is a double-edged sword, exploration of new opportunities could be perceived as a second-best option to pursue, resulting in an opposite firm's reaction: the over-commitment toward internal resources (Dahlander and Gann, 2010; De Marco et al., 2016). Accordingly, we argue that SMEs' engagement in R&D relatedness (OI3) could be positively related to their financial performance, because it allows them to focus on their core competencies and gain efficiency (Laursen and Salter, 2014). Consequently, we test the following hypotheses:

H4a. *Digital SME's engagement in Relatedness has a positive effect on the probability of positive financial performance.*

H4b. *Non-digital SME's engagement in Relatedness has a positive effect on the probability of positive financial performance.*

Finally, OI4 is related to Business Model Innovation (BMI), a source of sustained value creation and competitive advantage (Chesbrough, 2010). Since BMI requires both the quest for new business logic and approaches to capture value (Casadesus-Masanell and Zhu, 2013) as well as new distribution channels, literature shows that many SMEs still fail in BMI processes. Resource constraints and organizational inertia represent two main factors that hinder BMI (Guo et al., 2017). In addition, SMEs have to simultaneously balance the allocation of resources among different activities and inter-organizational relationships with resources that are neither wholly internal nor external.

Companies engaged in BMI have to deal with strategic objectives regarding the exploration and exploitation of new knowledge and the planning of BM reconfiguration (Clauss et al., 2019). Therefore, we expect that given the scarcity of resources, SMEs' BMI-related efforts may not yield the expected outcomes (Chesbrough, 2010).

Thus, we formulate the following hypotheses:

H5a. *Digital SME's engagement in Business Model Innovation has a negative effect on the probability of positive financial performance.*

H5b. *Non-digital SME's engagement in Business Model Innovation has a negative effect on the probability of positive financial performance.*

3. Research strategy and methodology

3.1. The research context

Considering the unique role played by SMEs in boosting innovation and economic growth, recently European Union has progressively improved the policy support for SMEs' innovative projects (Mina et al., 2021). One policy that explicitly supports SMEs in developing

innovation is the SME Instrument (SMEi). This policy was introduced in 2013 "under the eighth Research and Innovation Framework Program, Horizon 2020, and it targets the Schumpeterian Mark I type of companies, small-sized innovators, defined as the EU innovation champions" (De Marco et al., 2020, p. 2). The policy awards firms' ambitious business innovative ideas with a potentially disruptive impact on the European innovation ecosystem, with a specific preference toward close-to-market innovations. Also, the SMEi tends to mitigate SMEs' financial constraints in developing innovative projects and bridge the equity gap as a reduction risk tool to attract external private investments. The policy delivers subsidy-type investments with no obligation for firms to repay the grant. The policy provides three possible outputs for the submitted projects: the rejection, the Seal of Excellence (a special recognition for those projects considered valuable but below the available budget), and the financing. Until 2020 SMEs had the choice to apply to two different phases of the policy. Phase 1 aimed to finance the idea generation (e.g., business plan redaction) with a lump sum of €50 K, and Phase 2, to promote the business idea implementation financed up to €2.5 M.

3.2. Database construction

To evaluate the cost of openness for SMEs, we rely on an existing dataset about small and medium sized companies that applied to the SME-Instrument between January 2014 and March 2017. It consists of a set of 377 SME Instrument (SMEi) applicants, extracted from eCORDA database,[4] whose different engagement in OI challenges was evaluated applying the *DeMarkers* (De Marco et al., 2020) and for which a further integration of data was needed. In particular, the final dataset was built by integrating the original one with ORBIS Bureau van Dijk's companies database (for firms' level financial information), ORBIS Intellectual Property Bureau van Dijk database (for information about the number of patents related to the sample firms) and with Intellectual Property Portal of Questel Orbit Company database, as a primary data source to retrieve other firms' patent information: publication numbers, owners and applicants BvD Identification numbers (BvDIDs), and citations.

We preliminary matched SMEi and ORBIS BvD databases by using BvDID. Then, we matched all the publication numbers of patents using both applicants and owners' BvDIDs as queries, and filtered the dataset by discarding duplicates, controlling for patent families. This avoids any duplication in the analysis of patent documents, which generally occurs when companies patent the same invention in multiple countries (Karvonen, 2016). Our final dataset, that includes both proposals and firms' levels information for all the 377 companies, is completed with the *DeMarkers* indicators (De Marco et al., 2020). Because their complex nature, the indicators were computed through the aggregation of elementary indicators according to an AND/OR logic defined a priori by the team and validated with a multiple-investigators strategy including 7 scholars.[5]

Among our 377 SMEi applicants, 238 have been classified as digital-oriented based on keywords within their SMEi proposals; the remaining 127 are considered non-digital-oriented firms, while 12 companies have been discarded because of dissolved or missing records on BvD database for all the observations.

3.3. Dependent and exploratory variables

The goal of this work is to investigate the costs of engagement in open innovation strategies for SMEs, in terms of financial performances. Performances are captured through a binary variable, namely POS_PFM, that takes value 1 if the firm experienced positive revenues each year and 0 in case of negative or null revenues, in the corresponding year.

The main variable of interest of our study is Open Innovation.

It has been noted that the most common measures of OI practices are based on surveys (Podmetina, 2014; Jones-Evans, 2018). Even if literature pointed out that the composite measure could lack theoretical justification, the use of composite indicator when measuring OI has proven to be highly useful in applied research. Accordingly, we define our main explanatory variable, namely *Openness*, by summing up the four *DeMarkers*, with values going from 0, in case a firm is not engaged in any of the OI challenges, to 4, when a firm is engaged in all the four OI dimension, so that:

$$Openness_i = \sum_{k=1}^{4} OI_{ki} \; \forall_i$$

with $OI_{ki} = \{1 \; if \; the \; i- \; firm \; is \; engaged \; in \; the \; k_{th} \; OI \; dimension \; and \; 0 \; otherwise$

3.3.1. Explanatory variables

In addition, together with OI measures, we include in our dataset *RD_int*, a proxy for Research and Development intensity, obtained as a ratio between intangibles and total assets. This variable is often adopted as an innovation output measure, being independent of size effects. In our study, it represents the firm's effort in R&D and its absorptive capacity. Allowing for the possibility that $RD\_int_{it} = 0$ (distinguishing it from missing values) we compute firm i's *RD_int* as $log(1 + RD\_int_{it})$. The stock of *RD_int* is lagged 1 year, in line with most of the literature suggesting that the most significant effect of R&D on productivity occurs with a 1-year lag.

SMEs firms tend to patent more per unit than large firms (Pavitt, 1985), and it is well known that R&D and patents capture different aspects of the innovation processes.[6] Accordingly, we also include another firm-level innovation indicator, represented by the log count of patents. When modeling patents, traditional literature relates to the log count of patent held by a firm-i in each period, whose distribution is highly skewed. In our study, we rely on an indirect measure reflecting patent value by focusing on the quality-adjusted knowledge stock built from the citation-weighted annual patent counts. More specifically, in the indicator construction, we used all the 3414 patent publication numbers-extracted from ORBIS Intellectual Property BvD- related to our sample of analysis, that we matched with our firms' BvDID through both applicant's and owner's BvDIDs, with the corresponding forward citations. Thus, we computed log_wPAT_{it} as:

$$log\_wPAT_{it} = log\left(1 + \sum\nolimits_{s=1}^{t} FC_{is} P_{is} (1-\delta)^{t-s}\right)$$

For $t = 1, \ldots, T$ where P_{is} denotes the number of patent for the i-firm in period s, FC_{is} is the number of forward citations received from each patent, for firm i and in period s. We used FC_{is} as a correction to weight

[4] The preliminary operationalization of the dataset came from De Marco et al. (2020), p. 4. The authors started from the universe of 33.056 proposals submitted to the SMEi between January 2014 and March 2017, by manually screening proposal abstracts including keywords "digital" and other common words describing "digital economy" and then, through the selection of proposals including the most cited expressions associated with "digital" (based on results of NVivo software) and data cleaning, they defined a sample of 377 companies (317 SMEi awardees and 168 SoE). Data enrichment protocol followed by the authors is shown in De Marco et al. (2020) at pg. 4 Figure 2. Among them, on the basis of the sector in which they were active, the authors defined a dummy variable, allowing us to distinguish between companies operating in digital and non-digital sectors.

[5] For further details about *DeMarkers* indicators, see Table 1 of De Marco et al. (2020), p. 5.

[6] If R&D is an indicator of the amount of internal resources devoted to the innovation processes, patents reflect one output of the innovation process, and a channel with which a SME firm protect profits originating from new products or processes from imitation by potential competitors.

Table 1
Summary statistics.

	Non-digital SMEs ($N = 127$)		Digital SMEs ($N = 238$)		Mean. Diff
	Mean	SD	Mean	SD	
Dependent variable					
POS_PFM	0.572	0.495	0.488	0.500	0.084***
Model indep. variables					
Openness	1.575	1.147	1.684	1.200	−0.109**
OI1	0.197	0.398	0.253	0.435	−0.056***
OI2	0.220	0.415	0.165	0.371	0.056***
OI3	0.724	0.447	0.688	0.464	0.037**
OI4	0.433	0.496	0.578	0.494	−0.145***
RD_int	0.314	0.871	0.376	0.764	−0.062
log_wPAT	3.041	1.663	3.472	1.726	−0.431***
log_WCR	1.425	5.339	1.142	3.902	0.283
Size	2.290	1.245	2.238	1.307	0.052
Age	2.203	0.999	1.981	0.993	0.221***

***, **, * Significance at 1, 5 and 10 % levels, respectively, from *t*-test.

patent counts (Hall et al., 2005; Lanjouw and Schankerman, 1999), trough the number of forward citations. This allows us to account for the evidence that patents at the end of the sample period have less chance to receive citations from later patents than earlier ones: a patent published, for example, in 2017, can receive citations in our sample up to 2019, but it will be probably cited in subsequent years. This introduces a well-known truncation bias, for which we correct by using a traditional accepted annual depreciation rate δ of 15 % for accounting for the decreasing value of past knowledge accurately. When dealing with SMEs, financial capital plays an important role in enhancing performance Compared with large companies, SMEs obviously faced more financial constraints in the innovation processes: difficulty in accessing external capital is the main barrier to the adoption of technological innovation, even if they are more likely to access financial support for working capital rather than for firm growth strategies, so that in our analysis we include a variable able to keep track of short-term liquidity. Consequently, for each i-firm in period t, we define the log working current ratio (WCR) as follows:

$$log\_WCR_{i,t} = \frac{log\left(Current\_Assets_{i,t}\right)}{log\left(Current\_Liabilities_{i,t}\right)}$$

Based on the literature and given the traditionally not efficient SMEs managing of the current ratio, we expect a negative effect on the probability of having a positive financial performance for SMEs.

Moreover, as a control variable, we introduce the variable *size*, to control for firm size, obtained as the log number of employees, and the variable *age*, computed as the log difference between each period t and the i-firm year of incorporation.

3.4. Estimation method

Since our dependent variable, POS_PFM, is a binary variable, with a value of 1 in case of positive financial performance and 0 otherwise, ordinary least square (OLS) regression is inappropriate because of violations of the critical normality and homogeneity assumptions and because of likely out of range predictions. To address this issue, we report the results of two sets of probit regressions, testing the effect of independent variables and controls on this performance measure. More precisely, Model I examines the effect of the composite indicator of OI, obtained by summing up the four *DeMarkers* (OI1, OI2, OI3, and OI4), and Model II accounts for the separate effect of each OI practice.

4. Results

4.1. Sample description

Table 1 shows the composition of our sample of analysis. Specifically, we computed the mean value and standard deviations for both non-digital and digital SMEs for all the variables. In addition, the table shows whether the differences in mean computed are significant.

The results provide some useful preliminary information about non-digital and digital SMEs.

Concerning our dependent variable POS_PFM, we have a dummy variable equal to 1 in case of positive financial performance and 0 otherwise. We can observe that non-digital SMEs have a higher probability of getting a positive financial performance than digital ones (57.2 % vs. 48.8 %, respectively). In general, we can argue that even if digital SMEs are more able to operate in dynamic environments with respect to non-digital ones, the higher ability to innovate and identify a sustainable long-run competitive advantage requires a reconfiguration of most of the organizational processes. Consequently, more time is needed to translate them into higher firms' profitability (Ferreira et al., 2019).

Digital SMEs are more engaged in Openness with respect to non-digital, and their difference in the mean is significant. When separately considering the four different OI practices, we can see some differences between the two SMEs groups. Even if for all the four dimensions, we found significant differences between the two groups of firms, we can easily note that digital SMEs are more engaged in OI1-Internal Asset Protection, and OI4- Business Model Innovation (25.3 % and 57.8 % against 19.7 % and 43.3 %, respectively). The opposite happens for OI2-Management of External Relations and OI3- Relatedness, which show a higher engagement of non-digital companies (22 % and 72.4 % against 16.5 % and 68.8 %, respectively).

When focusing on *RD_int*, a proxy of R&D intensity, we can see that the difference in the mean between the two groups of companies is not statistically significant, even if, as expected, digital SMEs are more research-intensive than non-digital companies (37.6 % vs. 31.4 %). According to the evidence on OI1 practice, digital SMEs significantly have a higher knowledge stock represented by weighted-citation log counts, with respect to non-digital firms (*log_wPAT*). There are no significant differences between the two types of companies, in terms of (log) working current ratio, even if this is higher for non-digital firms, and size. Finally, there is a statically significant difference in Age variable. It is higher for non-digital SMEs, but this is in line with the expectation of digital companies to be younger.

4.2. Results

The correlation matrix is shown in Table 2. Among the explanatory variables, *Openness* and both innovation output measures (*RD_int* and *log_wPAT*) are negatively correlated with the dependent variable (*POS_PFM*). Since we report both the composite OI indicators and the four *DeMarkers* (OI1, OI2, OI3 and OI4), it is not surprising that their correlations are significant, ranging from 58.9 % (for OI1) up to 73.9 % (for OI4). The *log_WCR* is positively correlated to the probability of a positive performance of SMEs. Finally, when focusing on the two control variables, Size and Age, for both the correlations is positive, and in line with the traditional literature. The effect of Size on POS_PFM is significant.

Models including all the four dimensions of OI could suffer from multicollinearity problems, so variance inflation factors (VIFs) were computed. For Model I, including the composite indicator of OI, VIFs ranges from 1.01 to 1.29. At the same time, for Model II, which separately account for the four *DeMarkers*, VIFs go from 1.02 to 1.54. Based

Table 2
Pairwise correlations.***, **

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) POS_PFM	1.000										
(2) Openness	−0.047*	1.000									
	(0.010)										
(3) OI1	−0.013	0.589*	1.000								
	(0.492)	(0.000)									
(4) OI2	−0.033	0.620*	0.247*	1.000							
	(0.068)	(0.000)	(0.000)								
(5) OI3	−0.050*	0.729*	0.174*	0.300*	1.000						
	(0.006)	(0.000)	(0.000)	(0.000)							
(6) OI4	−0.030	0.739*	0.218*	0.229*	0.434*	1.000					
	(0.102)	(0.000)	(0.000)	(0.000)	(0.000)						
(7) RD_int	−0.076*	0.116*	0.076*	0.014	0.125*	0.093*	1.000				
	(0.001)	(0.000)	(0.001)	(0.559)	(0.000)	(0.000)					
(8) log_wPAT	−0.140*	0.172*	0.177*	0.004	0.149*	0.115*	0.200*	1.000			
	(0.000)	(0.000)	(0.000)	(0.910)	(0.000)	(0.001)	(0.000)				
(9) log_WCR	0.006	0.029	0.028	0.026	0.009	0.019	−0.013	−0.054	1.000		
	(0.798)	(0.183)	(0.199)	(0.240)	(0.694)	(0.376)	(0.592)	(0.191)			
(10) Size	0.162*	0.257*	0.170*	0.193*	0.180*	0.164*	−0.087*	−0.022	−0.055*	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.611)	(0.025)		
(11) Age	0.036	0.000	0.082*	0.051*	−0.105*	−0.012	−0.176*	−0.176*	−0.033	0.330*	1.000
	(0.056)	(0.985)	(0.000)	(0.007)	(0.000)	(0.528)	(0.000)	(0.000)	(0.134)	(0.000)	

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

on the rule of tumble, multicollinearity is ruled out.

As anticipated, to test our hypotheses, given the binary codification of our dependent variable POS_PFM, probit models were specified. To address the concerns of heterogeneity, we used a random effect panel model because 1) our sample of analysis has been extracted from a large population so that we can consider individual-specific error terms as randomly distributed; 2) we run our analysis over a short period (between 2013 and 2020), in which fixed effect estimates could be biased.

Table 3 shows the estimated coefficient of the regressions. Since the coefficients from the non-linear model could be difficult to interpret, the marginal effects at the means (MEMs) were computed. That is, we used the mean of independent variables as reference points. Moreover, the computation of marginal effects could be complicated by including dummy variables.[7]

Model I shows the effect of the composite indicator of OI on the dependent variable, POS_PFM. Even if Openness negatively affects the probability of having a positive financial performance, both for non-digital and digital SMEs, the effect is statistically significant only for the latter companies. This support Hypotesis 1a. In particular, the corresponding marginal effect- highly significant at the 1 % level-suggests that digital SMEs with higher engagement in OI practices are 9 % less likely to have positive financial performance. On the contrary, Hypothesis 1b is not supported from our estimates. More specifically, even if higher levels of openness results in a lower probability of having positive financial performance (by 1 %), its impact is not statistically significant. When dealing with OI implementation strategies, SMEs with lower digital orientation are less likely to adopt attitudes and behaviors supporting the generation and the intensive use of technological innovation and the openness to new ideas (Quinton et al., 2018). Consequently, in the implementation of OI strategies, non-digital SMEs mainly focus on market-based relationships, which are very sensitive to knowledge proximity (Aslesen and Freel, 2012). This means that non-digital SMEs privilege a clear managerial focus on the target market (Brunswicker and Vanhaverbeke, 2015), that implies fewer risks associated with the management of external relationships and lower transaction costs concerning excessive broad exploration of the external environment (De Marco et al., 2020), therefore preserving firms' profitability in the short term. The results for other variables are mixed. When considering the innovation output measures, we can see a positive impact of R&D intensity on the dependent variables, even if not significant for both types of companies: R&D investments act as fundamental engine for productivity growth and firms' profitability (Griffith et al., 2004), even if their effects could exhibit a time lag before reaching maturity and translating into higher business performances. Additionally, when focusing on *log_wPAT*, we can observe a significant negative effect only for digital firms: for those companies, an increasing patents' value is associated with an 8.23 % decrease in the probability of positive performance. This result is in line with Artz et al. (2010), highlighting that for many SMEs, especially for digital ones, the goal of patenting is not simply improving innovations, but always more often to enhance competitiveness, by blocking competitors' innovation processes (de Rassenfosse, 2012; Griliches, 1990). Additionally, since we considered a weighted-citations log count of patents, we can argue that most of the valuable patents of SMEs should be considered as strategic innovation tool for creating a competitive long-run advantage, rather than an innovation output that immediately boosts profitability.

Working capital ratio negatively affects the probability of having financial performance for both types of SMEs. The results show the significance of the coefficient only for digital SMEs, meaning that a gain in the short-run liquidity triggers a reduction of the likelihood of positive financial performance, thus supporting the thesis of a trade-off between liquidity and profitability. This could be related to the reduced ability of the management to search for profitable investment opportunities: if having an optimal level of liquidity ensures the continuity of the production processes, allows maintaining solvency and supports daily operation, an excessive rise of current liabilities to face financial constraints or a reduction of current assets could lead to the opposite effect, by lowering profitability likelihood (Martínez-Solano and García-Teruel, 2006).

However, corresponding marginal effects at the means are insignificant, meaning that the magnitude of this impact is not significant for non-digital SMEs, as well as for digital ones. Finally, when focusing on the two control variables, the results are mixed and point to differences between the two different types of SMEs. Size negatively impacts the dependent variable for non-digital companies, while the opposite happens for digital ones. For the latter, marginal effects are statistically

[7] For OI practices, separately considered, the marginal effects are built on the change of one category, whereas for the other variables, the marginal effects depend on a change of one standard deviation.

Table 3
Estimated coefficient of panel data probit regressions.

Dep.variable:	Model I				Model II			
POS_PFM binary coded 0/1	Non-digital SMEs		Digital SMEs		Non-digital SMEs		Digital SMEs	
	Coeff.	Marginal Effects	Coeff.	Marginal Effects	Coeff.	Marginal Effects	Coeff.	Marginal Effects
lRD_int	0.397	0.00316	0.126	0.0251	0.338	0.00115	0.271	0.0332
	(0.883)	(0.00806)	(0.153)	(0.0305)	(0.893)	(0.00391)	(0.534)	(0.0662)
log_wPAT	−0.0904	−0.000719	**−0.415*****	**−0.0823*****	0.0802	0.000274	**-0.894****	**−0.109***
	(0.444)	(0.00380)	(0.0973)	(0.0198)	(0.506)	(0.00182)	(0.375)	(0.0594)
log_WCR	**−4.267***	−0.0340	−0.514	−0.102	−5.290	−0.0181	0.573	0.0701
	(2.391)	(0.0537)	(0.787)	(0.156)	(3.433)	(0.0423)	(1.858)	(0.230)
Size	−0.203	−0.00161	**0.611*****	**0.121*****	0.0460	0.000157	0.777**	**0.0951***
	(0.574)	(0.00586)	(0.130)	(0.0273)	(0.671)	(0.00233)	(0.362)	(0.0523)
Age	**3.535*****	0.0281	−0.0741	−0.0147	**4.960*****	0.0170	0.261	0.0320
	(1.188)	(0.0375)	(0.216)	(0.0427)	(1.719)	(0.0385)	(0.872)	(0.109)
Openness	−0.175	−0.00139	**−0.496*****	**−0.0984*****				
	(0.706)	(0.00562)	(0.131)	(0.0266)				
OI1					**−5.305***	−0.269	**−1.407***	**−0.161***
					(2.865)	(0.229)	(0.831)	(0.0833)
OI2					3.008	0.0590	**−4.128*****	**−0.323****
					(2.460)	(0.150)	(1.490)	(0.129)
OI3					0.308	0.00109	**2.881****	**0.230****
					(3.823)	(0.0154)	(1.330)	(0.109)
OI4					−2.829	−0.0357	−0.978	−0.118
					(2.636)	(0.100)	(0.880)	(0.104)
lnsig2u	3.501***		0.748***		3.665***		3.064***	
	(0.551)		(0.212)		(0.552)		(0.622)	
Constant	2.592		2.352**		1.833		1.716	
	(3.642)		(1.103)		(5.394)		(2.497)	
N	127	127	238	238	127	127	238	238

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

significant- at 1 % level- and an additional employee increases the probability of having a positive financial performance by 12.1 %. This could be explained in terms of the usually higher productivity per higher-skilled workers.

Finally, while older SMEs are typically more profitable if they are non-digital and tend to operate in more traditional industries, the younger the digital SMEs are, the higher is their probability of having positive financial performance. This difference (based on both estimated coefficients and MEMs) is significant (*p*-value of 0.039 and 0.0224, respectively).

Model II shows the effect of the four OI practices represented by *DeMarkers* indicators on the likelihood of positive financial performance.

More precisely, SMEs engaged in OI1-IP protection- and OI4- Business Model Innovation (BMI) - are more likely to experience a decreasing probability of having financial performance: if intellectual property engagement increase, the average predicted probability of positive financial performances reduces by 26.9 % for non-digital and 16.1 % for digital SMEs, even though for the formers, the magnitude, highlighted by MEMs, is not significant. These findings support Hypothesis 2a, predicting a negative impact of higher digital SMEs' engagement in OI1 strategies on their financial performances, due to the preeminent negative signaling effect to the external environment (Dahlander and Gann, 2010) that easily could inhibit the establishment of productive collaborations. Conversely, Hypothesis 2b is not supported for non-digital SMEs. It seems, therefore, that increasing internal protection is not subject to translate into higher positive financial performance. This does not support the idea of IP protection in non-digital SMEs as an effective way to exploit the results of their innovations (González-Álvarez and Nieto-Antolín, 2007; Arundel, 2001) and of a deterrent for competition imitation (e.g., MacDonald, 2004; Graham et al., 2009). In addition, our findings suggest that non-digital SMEs could engage in OI1 strategies for protecting inventive activities that do not necessarily are embedded into new products/services, but for targeting the protection of the existing businesses. Finally, because many of the protection mechanisms are costly, IP protection easily becomes one of the major financial bottlenecks for SMEs, firms with lower digital orientation and that are not at the forefront of technology, may not be able to use such IP protection as a strategic mechanism to counter unfavorable appropriability conditions of extreme dynamic industries, still preferring the use of more informal protection strategies (Paula and Da Silva, 2019).Our results do not offer support to the Hypotheses 5a and 5b: even if digital and non-digital SMEs engaged in BMI challenges are more likely to incur a leakage of profitability, the corresponding impacts are not statistically significant. Marginal effects show that the negative impact of BMI is larger in magnitude for digital SMEs, whose engagement in BMI decreases the likelihood of having positive financial performance by 11.8 % compared to non-digital SMEs (3.57 %). BMI is a double-edged sword that could have positive or negative consequences (Latifi et al., 2021). SMEs can experience either sustainable growth or financial difficulties when approaching BMIs, depending on how each company implements them (Hartmann et al., 2013): since BMI is often closely related to the transformation of the entire organization, a profound change in the organizational culture is a pre-requisite of a successful organizational transformation (Audzeyeva and Hudson, 2016). In addition, these changes usually are time and effort-consuming, and SMEs' lack of organization capabilities and resources could hinder the support to such processes. The non significance of findings also suggests that both non-digital and digital SMEs engaged in BMIs may not be able to statistically benefit in short term from new value creation and new value appropriation pathways, because of, differently from large companies, they often do not have an explicit BMI strategy and tend to do BMI rather blindly and because of they often lack business model innovation leadership (BMIL) skills (Lindgren, 2012). In addition, when comparatively looking at marginal effects of non-digital and digital SMEs, our findings offer some insights about different BMI paths adopted by the two types of firms: in particular, it could be reasonable to assume that non-digital SMEs favors the most traditional building blocks value proposition, target customers and value chains regardless of the actual market demand and context of BMI, in a context of incremental innovation adoption, respect to firms with higher digital orientation. These firms tend to invest more in experimentation and intensively use their

technology base to find new technical and technological solutions, irrespective of the BMIs that their market requires, thereby not perfectly balancing the associated risks (Andersen et al., 2022).

With respect to the engagement in OI2 practices, the results are mixed. For non-digital companies, the marginal effect suggests that their engagement in OI2 lead into an increased likelihood of having positive financial performance by 5.9 %, even if this effect is not significant. Conversely, digital firms experience a reduction of the likelihood of a positive financial performance by 32.3 %. Those findings support our Hypotheses 3a and partially (just for the sign) 3b. Managing external relationships guarantees access to external knowledge, technologies, and expertise, thus broadening firms' resources and competences base. For digital SMEs, findings corroborate Lee et al.'s (2010) thesis of increasing costs associated to the management of more research-intensive relations that could worsen financial performances. In addition, although digital SMEs usually are more research- and technology-intensive companies, they often lack in-house capacity to absorb the external knowledge and do not have the appropriate structure necessary to benefit from this kind of network, with higher associated risks exacerbated by the more tacit nature of technologies and knowledge exchanged. On the contrary, for non-digital SMEs, our results show that their engagement in managing more demand and market-based collaborations does not translate into statistically significant improvement in financial performances. This suggests that those kinds of companies may still lack organizational and managerial competencies required to provide them the strategic benefits they reasonable could expect from closer customers and supplier collaborations (Macpherson and Wilson, 2003).

Finally, Relatedness practices (OI3) have positive effects on the likelihood of positive financial performances: for non-digital firms, the impact is marginal and not significant (only account for 0.109 %), while for digital SMEs, marginal effect- significant at 5 % level- shows that their engagement into OI3 results in an increased likelihood of positive financial performance by 23 %. Thus, our findings support Hypothesis 4a. This is in line with previous studies (among others, Peters et al., 2017) and resource-based theory that consider internal innovation activities as "base competence" for success probability of innovation processes. Internal R&D activities, better balanced with external sources of knowledge, increase the likelihood of having positive financial performance (Hervas-Oliver et al., 2021). In addition, this result confirms that digital companies have in their own nature a proclivity toward OI, mostly originating from the complexity of digital solutions' architecture and their need for integration and modularity with multiple and different solutions (Hafkesbrink and Schroll, 2010). Conversely, Hypothesis 4b is not supported. This could be related to the differential response toward implementing ambidexterity in the non-digital industry compared to the digital sectors (Marín-Idárraga et al., 2022), mainly due to non-digital SMEs reduced availability of resources and capacities needed to develop better skills, either explorative or exploitative (Cao et al., 2009).

Finally, looking at other variables included in our study, results of Model I are confirmed, even if some differences emerged.

R&D intensity (lagged 1 period) is positively associated to perform success, even if the non-significance of both coefficients and marginal effects. For the second innovation output, given by the *log_wPAT*, the significant negative impact persists only for digital SMEs: its marginal effect- statistically significant at 10 % level- show that an increasing patent value results into a decreasing likelihood of a successful financial performance of 10.9 %. This result confirms either the defensive nature of patents' uses for those companies and their signaling effect concerning their own innovation capabilities, useful to gain power in the future relationships with larger and more technologically-intensive partners.

Differently from Model I, the corresponding impact for non-digital companies became positive, even if non statistically significant. When separately accounts for OI practices, our results seem to better align with theory highlighting that patents can provide substantial economic value to SMEs by offering them exclusive rights to their innovation, especially when the embedded knowledge and technologies are exploited mainly in the production processes and the development of new products (Hussinger, 2006) In addition, for non-digital companies, with lower propensity to invest in digital technologies, higher patent value could act as catalyst for potential external investors, thereby increasing their changes of establishing profitable collaborations (Hall et al., 2014).

Working capital management positively impacts the dependent variable only for digital companies, even if the magnitude is not significant, while the negative effect persists for non-digital ones. These conclusions are partially aligned with those of Model I (in which the likelihood of positive performance is negatively affected by increasing values of working current ratio for all companies), meaning that for digital SMEs, the engagement in one or more OI practices mitigate its impact on performance success probability so that there should be a particular configuration of those 4 practices more profitable for SMEs.

Finally, looking at the two control variables, we can conclude that, in general, bigger and older firms seem more profitable.

As a concluding remark, Fig. 2, plotting MEMs for both Openness and the main four OI practices, highlights that, overall, they have a more detrimental effect on the chance of having a positive financial performance for digital SMEs. Among the four different *DeMarkers* indicators, digital SMEs engagement in OI2 practices has the worst effect (32,9 %) on the likelihood of positive financial performances, while, on the other side, for non-digital companies, OI1 has the highest negative effect (26.9 %).

Table 4 summarizes the findings obtained according to the research hypotheses identified.

Furthermore, we conducted additional robustness checks, to ensure the validity of our results.

We checked for the presence of outliers and influential values, in the multivariate context, by using the two suggested thresholds of 0.05 and 0.15 (Weber, 2010). Since two observations were considered as potential multivariate outliers, we re-estimated Model I and Model II without them. Our results do not exhibit substantial changes, meaning that they are robust enough to outliers.

We additionally double-checked the robustness of results, by considering a different variable parametrization for Openness without passing through a rescale of the existing *DeMarkers* indicators (OI1, OI2, OI3 and OI4) but relying on structural equation model (SEM) approach. In this scenario, our findings are robust to different parametrizations of Openness when compared to Model I specification for both digital and non-digital SMEs). To further validate our results, we altered the functional form of the model specification, by re-estimating the model through the logit link. Again, our results aligned with the probit ones for each model specification (Model I and Model II) and for both kinds of companies. Due to space constraints, the detailed results of these robustness checks are not included in this paper but are available upon request.

5. Discussion and conclusion

This study focused on a sample of digital-and non-digital European SMEs to investigate OI economic impact on firms' financial performance in the short run. By relying on the framework proposed by De Marco et al. (2020), this study investigated whether OI affects SMEs' financial performances and, specifically, the impact of every single OI challenge. To answer our research question, we operationally measured OI by following the OI challenges identified by De Marco et al. (2020) and explore their impact on SMEs' financial performance. First, we calculated a single OI index according to the OI challenges faced by SMEs; second, we disentangled the impact of every single challenge on SMEs' financial performance, namely Internal Assets Protection, Management of External Relations, Relatedness, and Business Model Innovation. In doing so, we investigated such impact on two different types of SMEs, the digital- and the non-digital, to address the rising need for a more comprehensive view on the relationship between SMEs and digital

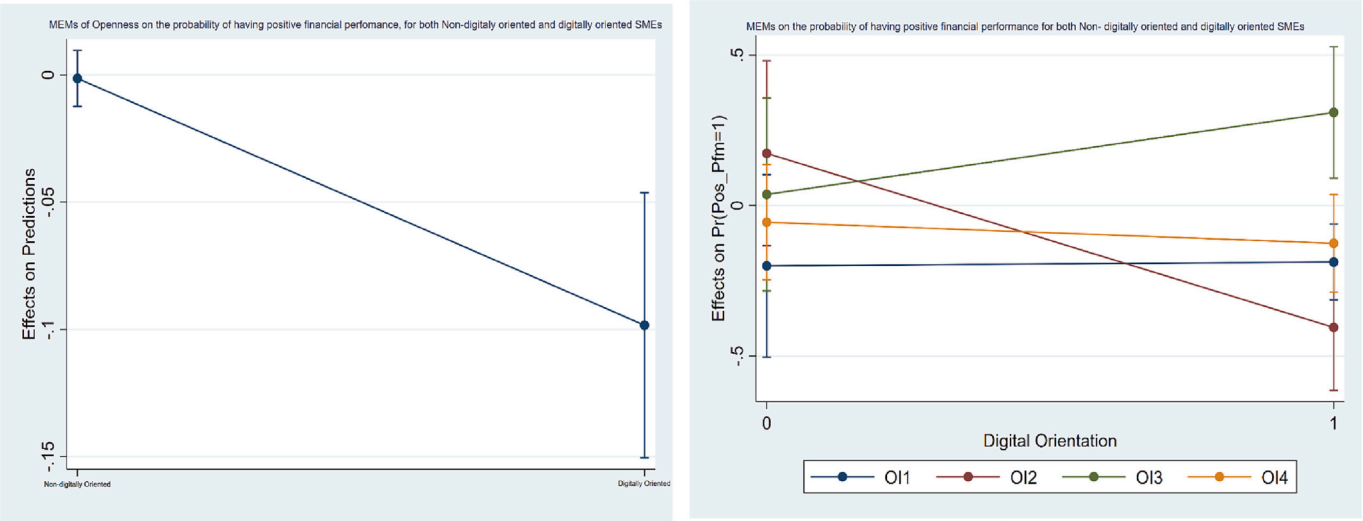

Fig. 2. MEMs for Openness (left) and OI practices (right) obtained from probit specification.

Table 4
Summary of the results.

# Hp	SMEs orientation	Description	Expected sign	Results
H1a	Digital	Open Innovation impact on financial performance	–	Supported
H1b	Non-digital		–	Non supported
H2a	Digital	Internal Assets Protection impact on financial performance	–	Supported
H2b	Non-digital		+	Non supported
H3a	Digital	Management of external relations impact on financial performance	–	Supported
H3b	Non-digital		+	Non supported
H4a	Digital	Relatedness impact on financial performance	+	Supported
H4b	Non-digital		+	Non supported
H5a	Digital	Business Model Innovation impact on financial performance	–	Non supported
H5b	Non-digital		–	Non supported

technologies (Obradović et al., 2021).

5.1. Theoretical contributions

Overall, our findings show that OI practices, in the short run, play a significant impact on SMEs' financial performances, and this is valid for both digital- and non-digital SMEs. However, by looking more in detail at the four OI challenges, results indicate interesting differences for digital- and non-digital SMEs. Indeed, non-digital SMEs are less impacted in the short run from the OI costs. In turn, digital SMEs are, in the short run, more exposed to OI costs. The first contribution of our findings is related with the OI literature. Our results align with previous studies that identify the risk of immediate financial drawbacks faced by firms while implementing OI due to the cost-increasing effect and the growing need for value appropriation (Bogers et al., 2017; Duran et al., 2016; Faems et al., 2010). However, they enhance the understanding of how OI affects firms' financial performances, especially for the digital SMEs that tend to be high on experimentation and use their technological competencies and expertise to leverage new tech-based solutions and knowledge exchange, thereby increasing their risk exposure.

This confirms that looking for external knowledge in volatile and uncertain environments (such as the digital one) obliges SMEs to an additional effort deriving from keeping the pace with the technological development that pushes them to look continuously for new knowledge, managing numerous and diverse partners, internally integrate such knowledge and protecting the existing one. Indeed, it clearly emerges that OI1 – Internal Assets Protection – and OI2 – Management External Relations – are the challenges that drain considerable resources, more than the other ones. Thus, if OI remains a vital choice for SMEs to compete in highly competitive environments, it represents a financial effort in the short run. The results of our study rest on the foundations of Audretsch and Belitski (2023), who individuated transaction costs, investment in internal knowledge and the ability to appropriate knowledge outputs as main factors that limit open innovation approaches, in knowledge-intensive sectors as well as in other sector, even if sectorial differences and geographical proximity are two boundary conditions that leverage knowledge collaborations. Additionally, our findings suggest that while collaboration is necessary to keep pace with technology development, it also has immediate costs that firms must be prepared to face, especially when SMEs are called to balance absorptive capacity and inbound open innovation (Kim et al., 2016) This also support the argument of knowledge value creation and network orchestration as factors that fuel the challenging dark side of open innovation (Hurmelinna-Laukkanen et al., 2023).

The second main contribution of the paper, in relation to the strategic management and OI literature, is related to the measurement of different collaboration activities and their impact on firms' performance. Our study extends the work of De Marco et al. (2020) by operationalizing a methodology for measuring OI performance, in contrast to many studies on OI and firm performance that are based on observations of broad dimensions or survey data. Additionally, we expand upon the work of Lu and Chesbrough (2022) by assessing the varying impact of OI practices on firms' financial performance. By looking at the single dimensions it emerges that the internal assets protection (OI1) negatively impacts financial performance for both digital and non-digital SMEs, even if it is significant only for the first. This finding goes into the direction of Lu and Chesbrough (2022), who found a different impact of IP protection on financial performance, depending on collaboration type: the author argued that more scientifically-based collaborations, as we supposed being for digital firms, might require more IP protection, while more market-based collaborations- as we supposed being for non-digital SMEs, by contrast focus more on whether and when to disclose information about pricing and availability instead of technical or scientific data, so that IP protection may become crucial if strongly related to firms' commercial success. According to our findings managing intellectual property represents a cost for SMEs, especially when engaged in collaborative experiences (Li et al., 2012; Wen et al., 2016). This is amplified in the digital environment where firms are more forced to

secure their internal assets for different reasons. Our finding suggests that first, dealing with rapidly evolving technologies, recurring to IP represents a necessary way to appropriate the internally generated knowledge. Second, the digital environment pushes SMEs to collaborate with external partners to gather more and new knowledge to progress in their technology development. In doing so, they must protect their internal assets to ensure technology ownership. Third, in line with the signaling theory (Mina et al., 2020), digital SMEs rely on protecting their internal assets to attract private investments and external growth strategies (Hall, 2019).

In line with what was expected, our findings show that digital SMEs suffer in the short term from the management of external relationships (OI2) in terms of financial impact. On the contrary non-digital SMEs' results, even if not significative, show a positive magnitude. Non-digital SMEs usually engage in relationships with partners on the demand side of the value chain, while digital SMEs engaged in more dynamic environments tend to collaborate with partners on the supply side for research-driven initiatives. Contrary to large firms, that adopt a "single search path" strategy for external knowledge acquisition, SMEs tend to activate multiple search paths, usually from one to four simultaneously (Chaochotechuang et al., 2019), meaning that some forms of coordination are required, and, in many cases, open innovation can entail what has been called orchestration (Hurmelinna-Laukkanen et al., 2023). This engagement in multiple search paths pushes SMEs to look for distant external knowledge to integrate to push forward their technology development (Afuah and Tucci, 2012; Jacobides et al., 2018; Bogers et al., 2019). These activities usually generate higher costs at increasing the number of partners engaged because of the more expensive effort required to identify, integrate, and exploit several types of different partners simultaneously (Dahlander and Gann, 2010). Similarly, managing different partnerships can imply the coincident exploitation of non-scale-free resources for the different partnerships (Hashai, 2015).

Interestingly from our findings emerges the positive effect on financial performances given by the engagement in OI3 – Relatedness, whose effect does not compensate for the overall negative impact derived from OI challenges. Noticeably, digital SME, even if challenged to look for broad and distant knowledge, are better able to stay focused on their core strategies, thus avoiding the risk of looking for too many external activities and benefitting in terms of financial performance. At the strategic level, especially digital SMEs should avoid centrifugal activities, that however could have detrimental effects for non-digital companies too. When embracing open innovation, pursuing more focused strategies, that do not entail inefficiencies in the resources' use could help SMEs to benefit also in financial terms, by leveraging their existing capabilities, resources and structures and by reinforcing their already trustworthy network of relations (Lado et al., 2008), thus reducing knowledge waste (Durst and Ferenhof, 2016; Temel and Vanhaverbeke, 2020).

5.2. Practical contributions

The results of the present study are eminently practical and providing valuable insights especially for managers of digital SMEs. Firstly, our findings suggest SMEs -both digital and non-digital- simultaneously consider benefits and pitfalls of open innovation. Secondly, there is an urgency for digital SMEs to harmonize their resources distribution on the diverse open innovation (OI) challenges, to contain short-term costs and improve chances of success. Our findings demonstrate that digital SMEs should be prepared to sustain immediate costs to engage in OI challenges. Managers of digital SMEs can use our results as a guide in the elaboration of new collaborative strategies, by assuming the necessary precautions.

In line with Hurmelinna-Laukkanen et al. (2023) our study alerts SMEs to carefully balance knowledge sharing with IP mechanisms. In open innovation context the use of varying appropriability mechanisms could help SMEs in creating and capturing value originated from their open innovation partners, in preventing unwanted knowledge spillovers and in addressing the risks of both misappropriation of innovation and imitation of ideas. However, increasing levels of IP protection could hinder SMEs' financial performance, not only because of the financial effort required but also because of the more concrete risk of a negative signaling effect to the external environment (Dahlander and Gann, 2010), that prevent the establishment of some productive collaborations with external partners.

Digital SMEs should pose attention in the management of external relationships with multiple (and changing) actors, trying to remain focused on their core business. Managing OI external relationship is a demeaning task and SMEs face notable organizational and cultural challenges when trying to deal with a large number of external partners (Marullo et al., 2020). In OI activities, SMEs are called to better balance that the inflows and outflows of knowledge, often limiting the number of the potential engaged partners, to reduce misallocation of scare resources and unnecessary risks related to intellectual property protection and external knowledge over search (Molina-Morales et al., 2011). This is particularly crucial for digital SMEs, since they operate in more knowledge-intensive sectors that are likely to be affected when performing knowledge sourcing across different partner types (Audretsch and Belitski, 2023). In network and OI practices every firm has its own goals, that can also differ in time depending on what type of OI activities the firm is engaged in and could be not perfectly aligned with those of external partners. For reducing the risks related to the external over search and to goals mismatching, our results suggest that the risk of losing one's focus is to be reckoned by those digital SMEs that are therefore called to invest effort only in those valuable relationships compatible with their own development trajectories.

Furthermore, digital SMEs in organizing, promoting, or implementing innovation strategies or collaborative actions should rely on the Resource-Based view and the transaction cost theory to harmonize internal knowledge and core assets sheltered with extremal partners' competencies. This approach can help SMEs to balance the costs and benefits of OI and to make better decisions about the allocation of resources.

In conclusion, our findings provide managers with valuable insights to harmonize the SMEs' resources distribution on the diverse OI challenges to contain short-term costs and improving chances of success. By applying these insights, digital SMEs can increase their chances of success in the OI process and achieve the desired results.

5.3. Limitations and future research

We recognize that this study suffers from some limitations. We acknowledge that our sample is limited in size and mainly relies on digital European SMEs. These two characteristics – the geographic origin and the sector – do not allow us to generalize our results. However, it represents a starting point to be tested on larger samples embracing multiple industry sectors to deliver broader generalizability of the findings. In addition, we recognize the methodology here proposed does not inspect the relationship between SMEs engagement in OI practices and financial performance from a mechanics perspective, as it does not consider mediating and/or moderating variables. Our study is, in fact, a first attempt to reveal the relations between OI and financial performance, by considering not only a general measure of Openness but also through four separate OI practices measures. At this stage of analysis, the current study does not pretend to individuate and explore causal mechanisms or to discover complex mediating processes or moderating variables in the nexus between SMEs engagement in open innovation practices and financial performances, but instead treated digital and non-digital SMEs as separate sample of analysis. Thus, future research should deepen the analysis by considering the complexity of these aforementioned relations, thus finally contributing to the generalizability of results (MacKinnon, 2011). Moreover, we acknowledge that *DeMarkers* indicators are not the only available measures for capturing

related OI dimensions, so that future studies should consider alternative valuable measures of both openness and open innovation practices. Furthermore, future studies should conduct longitudinal investigations to evaluate the relations between the OI challenges and the long-term effects on SMEs' financial performance.

CRediT authorship contribution statement

Alessandra Costa contributed to this work by designing the methodology, performing conceptualization and validation, carrying out formal analysis, and writing the original draft of the manuscript.

Antonio Crupi contributed by performing conceptualization, validation, writing the original draft of the manuscript, and participating in the writing, reviewing, and editing process.

Chiara Eleonora De Marco contributed to this work by conceiving the original idea, conducting the investigation, and providing critical feedback on the manuscript.

Alberto Di Minin contributed to this work by providing supervision and guidance throughout the research and validation process.

All authors have reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Data availability

The authors do not have permission to share data.

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Alessandra Costa is Assistant Professor at the University of Messina, Italy. She is also Research Affiliate with the I.E.M.E.S.T. She received a Ph.D. in Economics, Management and Statistics from the University of Messina. Her main research interest is in the field of green innovation, especially in low-tech sectors and agrifood industry, with a particular focus on sustainability, green innovation, traceability, digitalization and technological innovations, entrepreneurship and consumer behavior in the lens of green transitions as well as innovation and open innovation in SMEs, strategic use of intellectual property and technology transfer. Her studies have been published in journals and books and presented at national and international conferences.

Antonio Crupi is Assistant Professor at the University of Messina, Italy. He is also Research Affiliate with the Institute of Management of Sant'Anna School of Advanced Studies, Italy; and with the Strategic and Technology Innovation Management (STIM) at the Institute of Manufacturing of the University of Cambridge, UK. His research concerns innovation, entrepreneurship, and intellectual property. His current research focuses on intellectual property rights systems, strategic use of intellectual property, entrepreneurial dynamics, and university–industry interactions. His works have been published in high-quality peer-reviewed journals and presented at international conferences.

Chiara Eleonora De Marco is a versatile and passionate professional of innovation, with sound academic and professional experience in innovation management and policy. Developed open, logical, and thorough attitude in multicultural and cross-discipline environments. Interests and experiences focused on open innovation, digital transformation, R&D, knowledge management and knowledge transfer, innovation strategies and policies. 6 years of academic research, 4 years of consultancy activities for both public and private sectors, looking forward to applying expertise and create impact. Chiara is Research Affiliate with the Institute of Management of Sant'Anna School of Advanced Studies.

Alberto Di Minin is a Full Professor of Management at Sant'Anna School of Advanced Studies of Pisa and also Research Fellow with the Berkeley Round table on the International Economy (BRIE), University of California – Berkeley. Alberto teaches innovation management and innovation policy and he is the Co-Director of the Confucius Institute of Pisa, and the Director of the Galileo Galilei Italian Institute in Chongqing University. Alberto is Co-Editor in Chief of the "R&D Management" Journal, and on the International Advisory Board of "California Management Review". His research deals with Open Innovation, appropriation of innovation and science and technology policy. He also works on technology transfer, intellectual property and R&D management.