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Developing technological capabilities for Industry 4.0 adoption: An analysis of the role of inbound open innovation in small and medium-sized enterprises

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To keep up with rapid technological change, firms are pushed to acquire new competencies and resources, often leveraging the external networks in which they are involved. The paper examines how firms' engagement in inbound open innovation (OI) enables the adoption of Industry 4.0 (I4.0) technologies in small and medium-sized enterprises (SMEs) through the deployment of technological capabilities. We combine the OI and dynamic capabilities frameworks to assess how the absorption of knowledge from different actors impacts the necessary technological capabilities for adopting I4.0 technologies. The capabilities are categorized in technological sensing, seizing and reconfiguring. The study is based on in-depth case studies of two selected SMEs from the footwear industry. The cases show that engaging in external collaborations, particularly with universities, pushes SMEs to renew the bundle of competencies underlying their technological capabilities. However, this effect is influenced by the OI modalities adopted by both companies. While in Company A OI takes place through a broader array of formal and informal linkages that contribute to the exploration of distant knowledge bases and the experimentation of more diverse technologies, such as the Internet of Things, Company B relies on informal networking concentrated in its own field of specialization for the adoption of manufacturing-specific I4.0 solutions, such as automated robots and 3D printing.

KEYWORDS
dynamic capabilities, Industry 4.0, knowledge, open innovation, small and medium-sized enterprises

1 | INTRODUCTION

To keep up with rapid technological change, firms are increasingly pushed to acquire new technologies, competencies and resources, often leveraging their external networks. In this context, open innovation (OI) has been widely acknowledged as a key driver of technological opportunities and particularly because it enables risk and cost sharing, while also providing access to a wider range of inputs, such as knowledge and technology, for more successful ideation and commercialization of innovations (Chesbrough, 2003; Lee et al., 2010; Nambisan et al., 2018). Importantly, the knowledge acquired through an open network can also potentially call for a

change within the existing 'organizational constructs' and support the adoption of disruptive technologies as well as the exploration of new markets (Ahn et al., 2015, p. 37). In line with this view, OI can become a springboard to the renewal of firms' capabilities, which are critical for them to seize new technological opportunities (Warner & Wäger, 2019).

This relation between OI and new technological opportunities can be particularly beneficial for small and medium-sized enterprises (SMEs) (Crupi et al., 2020; Marullo et al., 2020; Messeni Petruzzelli et al., 2021; Scuotto, Santoro, et al., 2017), given the difficulties they are facing in accessing and integrating advanced new technologies, mainly due to the lack of tangible and intangible resources and formal knowledge management procedures (Santoro et al., 2018). It is envisaged that due to their characteristics and differences compared with large firms (in terms of financial and organizational resources), cooperation with other actors, including both firm and non-firm organizations (e.g., universities, government agencies and research institutes), can be crucial for SMEs to tap into the ongoing technological transformation (Benitez et al., 2020; Bonfanti et al., 2018).

Against this background, the aim of our research is to investigate the role of OI in Industry 4.0 (I4.0) adoption by SMEs. Specifically, we look at inbound OI as a key driver of strategic change within the firm (Hervas-Oliver et al., 2021). Inbound OI can be defined as the sourcing of 'external knowledge for technology development and technology exploitation' (Parida et al., 2012, p. 288). Through inbound OI, companies are expected to develop internal capabilities that underpin the adoption and integration of new technology within the organization (Saebi & Foss, 2015). In so doing, we build on the extensive literature discussing OI as a source of technological opportunities for the firm (Lee et al., 2010), while also emphasizing its role in enabling the development of new competencies, routines and organizational structures to cope with new digital technologies (Hanelt et al., 2021). We explore this relation, by examining the impact of different approaches to inbound OI on the transformations undergone by the organization and the type of technologies that were eventually adopted. This is based on the assumption that the participation in a broader array of external collaborations enables the exploration of more distant knowledge bases (Laursen & Salter, 2006) and thus the experimentation of radically new I4.0 solutions.

The paper addresses three important gaps in the literature. First, it explores how SMEs can benefit from the external environment by engaging in various forms of collaborative relationships that help them leverage external knowledge and enhance their innovativeness (Bianchi et al., 2010; Lee et al., 2010). Indeed, prior studies have mostly focused on large firms as OI adopters and have not provided extensive evidence of the opportunities for technological innovation accruing to SMEs through external collaboration (Hossain & Kauranen, 2016; Remneland & Styhre, 2017). Second, by analysing the effects of inbound OI on SMEs' technological capabilities, we propose a different perspective from the existing literature, which is largely focused on investigating the opposite relationship, that is, the role of dynamic capabilities in implementing OI (Grimaldi et al., 2013). In this regard, while the literature has largely focused on the relationship between inbound OI and product development, we emphasize that SMEs may also pursue broader strategic change through OI (Hervas-Oliver et al., 2021). This is enabled by the integration of internal and external knowledge, contributing to new competencies, routines and organizational structures within the firm (Henderson, 1994; Teece et al., 1997; Tripsas, 1997). Third, the paper contributes to a better understanding of how I4.0 can be implemented within low-tech manufacturing sectors, and especially within SMEs, whereas existing literature tends to mostly focus on a relatively small minority of high-tech sectors (Faller & Feldmüller, 2015).

To explore these issues, we combine the paradigm of OI (Chesbrough, 2003) with the dynamic capabilities framework (Teece, 2007). Drawing on this theoretical background, we present an analysis of two leading SMEs in the Marche Region, Italy, and particularly located in the footwear district of Fermo-Macerata. This is a typical example of a mature regional ecosystem largely dominated by SMEs, most of which are struggling to integrate I4.0 within the organization (Bellandi et al., 2020; Bonfanti et al., 2018). The case studies offer a unique insight into the recent challenges and opportunities faced by a typical backbone of the Italian economy, corresponding to SMEs concentrated in areas with high specialization in traditional manufacturing sectors, the so-called *Made-in-Italy* sectors (e.g., textile, food and beverage and furniture), accounting for about 40% of manufacturing employment at the national level (ISTAT, 2015). The findings of this exploratory study are discussed in light of the following research questions: How do SMEs engage in inbound OI for I4.0 adoption? How does inbound OI for I4.0 adoption in turn affect SMEs' technological capabilities?

The paper is structured as follows. Section 2 begins with a literature review on OI and technological capabilities. In Section 3, we describe the methodology, before discussing the findings of our research in Sections 4 and 5. Conclusions and implications for future research are presented in Section 6.

2 | THEORETICAL BACKGROUND

2.1 | Open innovation as enabler for Industry 4.0 adoption in SMEs

External collaboration is widely acknowledged as a vehicle to acquire resources, that is, financial, managerial and knowledge-related, reduce research costs and share risks with other participants in open networks (Nambisan et al., 2018). In this context, the open innovation (OI) paradigm has been proposed to emphasize the benefits for businesses to engage in external collaboration with other entities (Chesbrough, 2003; Nambisan et al., 2018). OI is indeed referred to as one of the multiple ways through which organizations can combine internal and external ideas, technology and R&D, to speed up their innovation processes and access new markets, as they attempt to commercialize and advance their technologies (Chesbrough, 2003). Adopting OI strategies can thus benefit all partners and create a space

for the development of competitive business advantages (Wank et al., 2016).

The literature has widely examined the approach of SMEs to OI (Bianchi et al., 2010; Crupi et al., 2020; Lee et al., 2010; Marullo et al., 2020). On the one hand, smaller firms are typically found to have less resources to build and maintain collaborative networks and to create and enforce intellectual property rights (Huizingh, 2011). Furthermore, the adoption of OI among SMEs encounters additional barriers with respect to large firms, including difficulty in finding the right partner, lack of managerial skills for establishing an effective collaboration, potential loss of know-how and opportunistic behaviour by partners (Bigliardi & Galati, 2016).

On the other hand, the adoption of OI strategies gives SMEs the opportunity to overcome their structural limitations and become more adaptive to the increasing level of complexity in products and processes (Brettel et al., 2014; Lee et al., 2010; Scuotto, Santoro, et al., 2017). The tendency of SMEs to be involved in dense external networks has been discussed by an extensive amount of research, which has shown the importance for these firms to establish relationships based on trust, so as to enable the exchange of more implicit and tacit forms of knowledge (Bellandi et al., 2020; Brunswicker & Vanhaverbeke, 2015). This is especially visible in systems of co-located stakeholders, where SMEs can take advantage of knowledge flows across inter-organizational boundaries to sustain their learning and innovation process (Radziwon & Bogers, 2019).

Building on this approach, OI can be determinant for the successful adoption of I4.0 technologies by SMEs, as these firms are typically burdened with financial, managerial and market size barriers (Bonfanti et al., 2018; Weking et al., 2020), causing a slower technological uptake in the field of I4.0 compared to large companies (Matt & Rauch, 2020; Sommer, 2015). For example, recent evidence shows that SME managers tend to be less aware of the opportunities offered by new digital technologies (Horváth & Szabó, 2019). Furthermore, I4.0 projects in SMEs appear to remain cost-driven initiatives, and there is still no evidence of real business model transformation (Moeuf et al., 2018). As underlined in the German report 'The Challenges of Industry 4.0 for Small and Medium-sized Enterprises' (Schröder, 2016), SMEs generally lack the competencies to define a strategy able to generate value from the technologies offered by I4.0.

In this regard, the emerging literature connecting OI and I4.0 has largely focused on examining the role of I4.0 as enabler of OI. Specifically, these studies underline how I4.0 can support greater horizontal integration across the supply chain, driven by information flows, interconnection and integration of IT systems between different entities (i.e. businesses, customers, suppliers and external partners) (Camarinha-Matos et al., 2017; Kagermann et al., 2013). To this end, SMEs' technological orientation is found to be key to prepare the ground for adopting I4.0.

Another stream of literature provides a different perspective emphasizing the importance of looking at the organizational implications of OI for I4.0 adoption (Wikhamn & Styhre, 2017). In line with this approach, the next sections aim to discuss how OI practices can indeed enable I4.0 adoption by affecting the technological capabilities of SMEs. This means that the entire organization is called to be dynamic and acquire new competences and capabilities in a rapidly changing environment.

2.2 | Differences among SMEs' open innovation strategies

The literature has extensively discussed OI activities as falling into two different categories. Inbound OI refers to the exploration and absorption of external knowledge to complement and advance internal innovation processes. Outbound OI corresponds to controlled outflows of knowledge and technology to seek market opportunities, for example, through out-licensing (Chesbrough, 2003; Lichtenthaler, 2009). In this paper, we focus on inbound OI more specifically, representing the most common approach to OI among firms (Chesbrough & Crowther, 2006; West et al., 2014), and SMEs in particular (Hervas-Oliver et al., 2021; Parida et al., 2012). Inbound OI appears to be especially popular among firms, when they are in a position to adopt technology rather than create it internally (West et al., 2014). In line with this view, SMEs can leverage inbound OI to tap into external resources and improve their innovative performance (Bianchi et al., 2010; Hossain & Kauranen, 2016; van der Vrande et al., 2009).

Brunswicker and Vanhaverbeke (2015) argue that SMEs engage in different forms of external knowledge sourcing with a variety of actors, from IP experts to universities, customers and other firms. These relationships can take the form of formal collaborations, for example, through joint R&D and alliances, and informal networking activities (Scuotto, Del Giudice, et al., 2017; van der Vrande et al., 2009), which are typically assumed to convey different types of knowledge and for this reason they tend to be associated with different outcomes in terms of innovation. Indeed, formal ties require a higher degree of codifiability of knowledge, whereas informal ties are often described as conduits of more implicit and tacit knowledge. This has paved the way to studies demonstrating the relationship between formal ties and incremental innovation on one hand and informal ties and radical innovation on the other hand (Zhang & Groen, 2021). However, the literature is still divided on this outcome, as we also find evidence that both formal and informal interactions may contribute to incremental and radical innovation, with the innovation type being largely driven by the degree of network openness (Hemphälä & Magnusson, 2012).

In this regard, the OI literature has explored different degrees and types of openness among firms, suggesting the importance of adopting a multifaceted approach to OI depending on the nature and context of innovation (Dahlander & Gann, 2010; Manzini et al., 2017). Prior studies find that a broader engagement in OI strategies can open up opportunities for knowledge exploration that extend outside familiar knowledge bases (March, 1991), thereby conveying complementary resources and knowledge for the implementation of new (and more radical) technology solutions (Messeni Petruzzelli et al., 2021). Laursen and Salter (2006) propose a definition of openness based on

the breadth (i.e., number of external sources used) and depth (i.e., how intensively the firm draws on each source) of external relations. Similarly, Lazzarotti and Manzini (2009) combine two dimensions of openness, namely, the number and type of partners, and the number and type of phases of the innovation process opened to external collaborations. However, recent evidence also shows that a more closed approach to product and process innovation is sometimes suited, and especially when the company relies on strong internal competencies and know-how that can hardly be protected through formal intellectual property protection mechanisms (Manzini et al., 2017).

As the discussion above suggests, SMEs develop their capabilities for technological innovation by participating in external networks, providing a sufficient degree of cognitive proximity between internal and external knowledge and adequate internal structures that allow for the effective absorption and integration of external knowledge (Bel Hadj & Ghodbane, 2019; Cohen & Levinthal, 1990; Rothwell & Dodgson, 1991). In the following section, we focus on internal capabilities more specifically and discuss how OI can act as a driver of competence development within firms. This is expected to be key for successful I4.0 adoption.

2.3 | Effect of open innovation on technological capabilities

Prior studies have pointed out the importance of taking advantage of external knowledge to renew the firm's business processes and achieve competitive advantage (Ahn et al., 2015; Dodgson et al., 2006; Ferraris et al., 2017). Indeed, the integration of internal and external knowledge encourages firms to re-examine their current behaviours, strategies and processes, potentially leading them to establish new ways, customs and norms of doing things, that is, to adopt new organizational routines (Zollo & Winter, 2002).

In this context, dynamic capabilities are used by an extensive literature to understand how firms achieve competitive advantage in rapidly changing environments (Collis, 1994; Teece et al., 1997; Zollo & Winter, 2002). At the bottom of the dynamic capabilities construct is the idea that to gain a sustained competitive advantage, firms are called 'to integrate, build, and reconfigure internal and external competences' (Teece et al., 1997, p. 516), so as to achieve greater alignment with the changing business environment (Helfat & Peteraf, 2009). Being the process of competence development cumulative and path dependent, the ability of the firm to explore, acquire and integrate external knowledge is expected to be bound by its pre-existing competencies, skills and organizational practices (Cohen & Levinthal, 1990; Gebauer et al., 2012). Therefore, at any point in time, the firm's adaptability to the new requirements of a changing business environment depends on its prior commitment to certain domains of competence, following a firm-specific trajectory of competence development (Teece et al., 1997).

A growing body of literature has recently emphasized the need for firms to develop dynamic capabilities for digital transformation (Ellström et al., 2022; Warner & Wäger, 2019; Yeow et al., 2018). When faced with radical, competence-destroying technological change, firms can see those resources and competencies that contributed to their competitive advantage in an earlier era lose their value, and this is especially true for established firms with entrenched organizational practices, routines and capabilities (Tripsas, 1997). In this case, the ability to identify and integrate internal and external knowledge is widely considered as a key condition for established firms to be able to defend their competitive advantage over new entrants in times of rapid technological change (Henderson, 1994).

In line with this literature, the recent advancement of digital technologies for I4.0—such as the Internet of Things, cloud computing, big data and analytics (Li et al., 2020)—appears to be a potential source of disruption within industries, posing a serious threat to the advantages of established firms (Li, 2020; Warner & Wäger, 2019). Yoo et al. (2012) argue that a defining characteristic of digital innovation is the expansion of physical materiality through the incorporation of software-based digital capabilities into physical objects. The wider affordances enabled by digital technology open up a spectrum of innovation opportunities by *convergence* (bringing previously separated user experiences and even industries together) and *generativity* (being digital technology subject to continuous improvements thanks to its reprogrammability). These characteristics call for the reshaping of existing business models, as they require new business strategies, value creation processes and firm capabilities to match the requirements of pervasive digital technology (Ellström et al., 2022; Li, 2020).

Tripsas (1997) provides three broad reasons why established firms may fail to implement these transformations: (1) They may not have the incentive to invest if the innovation is radical and replaces the existing technology; (2) even if they invest, they may not be able to adapt their cumulated organizational structures, routines and procedures in response to the new technology; (3) even if they invest and adapt the organization to the new technology, they may not have access to the complementary assets required to bring the new products to market. Dynamic capabilities are thus pivotal for established firms to successfully change those routines and competencies that have become obsolete through the integration of internal and external knowledge, so as to enable digital transformation and protect their competitive advantage.

Based on Teece's dynamic capability framework, we refer to those capabilities required for I4.0 adoption as technological capabilities. *Technological sensing* describes the ability of the firm to anticipate unexpected changes in the business environment that could undermine the firm's competitive advantage (Teece, 2007). To do so, firms require embedded routines acquired through investment in research and related activities, allowing them to detect threats and opportunities from their ecosystem (Ellström et al., 2022; Teece, 2007). With the fast pace of digital transformation and a growing level of unpredictability, recognizing emerging opportunities requires even more porous organizational walls, where employees at all levels are involved in the exploration of new ideas (Warner & Wäger, 2019). This vision is in line with the new role of humans in I4.0 companies presented by Nelles et al. (2016). According to the authors, rather than being

involved in routine work activities, humans should be put in positions where they can quickly make the right decisions in production planning and control, thereby allowing them to evolve to 'knowledge workers' (Engelmann & Schwabe, 2018).

Technological seizing involves discarding unviable ideas and avoiding threats, and it is implemented through the decision of the firm to invest resources for pursuing the selected technological opportunities (Teece, 2007). This is accompanied by a sequence of actions in which the firm first designs its new business model, and then moves to the selection of the opportunity and the commitment of resources (Yeow et al., 2018). Access to external knowledge through the participation in open networks is crucial to enrich the firm's cumulated experience, providing additional resources to support technological seizing capabilities (Inigo et al., 2017). In the context of rapid technological change, experimenting opportunities could be particularly costly as not all investments are successful (Teece, 2007). For this reason, Day and Schoemaker (2016) argue that a gradual 'probe-and-learn' approach combined with flexible investing solutions, such as real options, reduces the risk of failure while maintaining high rewards.

Lastly, the selection of opportunities and the commitment to design new business models and to invest resources in the pursuit of such ideas may lead the firm to wider transformations across the organization, primarily following the growth of assets and profitability (Helfat & Peteraf, 2009; Teece, 2007). In this context, *technological reconfiguring* capabilities define the ability of the firm to be responsive and quickly adjust its resource base in a fast and rapidly changing environment in order to fully *deploy* the technologies introduced and develop their capabilities for the future exploration of opportunities (Ambrosini et al., 2009; Day & Schoemaker, 2016).

The diffusion of I4.0 technologies is bringing about new challenges for firms in terms of recombining old and new competencies to support digital transformation (Warner & Wäger, 2019). While incremental learning dynamics facilitate a gradual adoption of new competencies as they involve knowledge being strongly related to the existing configuration of capabilities, I4.0 technologies require internalizing a more disruptive type of knowledge emerging from cutting-edge scientific and engineering achievements. This calls for radical change within the organization based on the extensive reconfiguration of business assets to overcome inertia and avoid path dependencies (Lavie, 2006; Teece, 2007).

3 | RESEARCH METHOD

This exploratory study aims to understand how the integration of external knowledge through inbound OI can drive the adaptation of SMEs' technological capabilities for I4.0 adoption. As discussed in the introduction, this goal can be further unpacked in the following research questions. RQ1: How do SMEs engage in inbound OI for I4.0 adoption? RQ2: How does inbound OI for I4.0 adoption in turn affect SMEs' technological capabilities?

To address these research questions, a multiple case study methodology was adopted, allowing us to compare and contrast the findings obtained from different cases for deeper theoretical reflection (Bell et al., 2022; Eisenhardt & Graebner, 2007). Despite the well-known limitations of this approach, especially in terms of reliability and validity (Yin, 2003), case study appears to be most suited method for two main reasons. First, it allows an in-depth investigation of new or emerging fields of study (Edmondson & McManus, 2007; Oesterreich & Teuteberg, 2016), as is the investigation of the role of inbound OI in driving strategic change in SMEs (Hervas-Oliver et al., 2021). Second, the methodology is appropriate to study complex phenomena where several elements and multiple dimensions may simultaneously intervene (Eisenhardt & Graebner, 2007). In this regard, case study allows us to gain a deeper understanding of the richness of contextual conditions that are relevant to the phenomenon under analysis (Yin, 2003), particularly in relation to the multiple organizational determinants that can drive I4.0 adoption in SMEs. To mitigate the limitations of a case study approach, a research protocol was designed, carefully documenting all the procedures undertaken for case selection, as well as for data collection, elaboration and analysis.

3.1 | Definition of the theoretical constructs

Building on the theory of OI and dynamic capabilities discussed in the previous sections, we develop a reference theoretical framework presenting the key constructs and the relationships among them that will be used to inform the analysis of the cases and answer the two research questions.

OI modalities are based on previous studies looking at the various approaches of firms to openness (Laursen & Salter, 2006; Manzini et al., 2017; van der Vrande et al., 2009; Zhang & Groen, 2021). This classification is used to inform RQ1 more specifically, as it allows us to describe the type of OI strategy pursued by each company in the field of I4.0 adoption, including the level of formality/informality of external collaborations and the overall degree of openness. Then, to explore the impact of inbound OI on technological capabilities for I4.0 adoption in line with RQ2, we use the concept of 'microfoundations', defined by Teece (2007, p. 1319) as the 'distinct skills, processes, procedures, organizational structures, decision rules, and disciplines', that form the basis of dynamic capabilities. Based on this definition, we identify the patterns of technological capabilities renewal in the data, by looking into the microfoundations for I4.0 adoption and how these have been affected by the integration of internal and external knowledge through inbound OI (Henderson, 1994; Tripsas, 1997). Further information on the coding strategy is provided below.

3.2 | Case selection

To select our cases, a two-step purposive sampling strategy was followed. In the first step, we established four criteria for case selection. First, a firm size of less than 250 employees and a turnover up to

50 million is required to identify SMEs, in accordance with the definition adopted by the European Commission. Second, firms were expected to have adopted at least one I4.0 technology, so as to allow the analysis of relevant transformations in the organization. In this way, we aim to shed light on the transformations incurred by I4.0 adopters and the role of inbound OI in enabling the renewal of technological capabilities. Third, firms were sought out of those belonging to a traditional, low-tech manufacturing sector, that is, footwear manufacturing. This approach was considered particularly suited to study our research questions and generate valuable insights for practitioners and policymakers, in that low-tech manufacturing is largely populated by SMEs for which resorting to external resources is critical to enable I4.0 adoption. Furthermore, the same sectoral specialization of firms helps reduce any sectoral bias in the analysis of the findings. At the same time, footwear SMEs present comparable challenges to other traditional manufacturing sectors, including textiles, clothing, furniture and toys. These sectors are indeed populated by SMEs relying strongly on product customization and short manufacturing cycles, with limited capabilities to invest in I4.0 (Jimeno-Morenilla et al., 2021). Based on these considerations, we selected the Fermo-Macerata district, which is the main regional ecosystem specialized in footwear manufacturing (Bellandi et al., 2020; Cutrini, 2011). Fourth, we aimed at selecting cases that vary from each other in terms of their open innovation strategy in line with the heterogeneity sampling's approach, as this allows us to reach a more holistic understanding of the phenomenon through the identification of common features and variable features between cases (Patton, 1990).

In the second step of case selection, a screening of regional SMEs was carried out based on the four criteria described above. A list of companies with these characteristics was provided and discussed with experts from the regional school for advanced business studies, ISTAO. The screening led to identify two representative SMEs from the footwear sector in the Marche region, Italy, showing different approaches to open innovation for I4.0 adoption. The first company, that is, Company A, is operating upstream as an intermediate producer of accessories for shoes, especially soles. Company A relies on a mix of formal and informal external collaborations in the field of digital platforms and I4.0 adoption, with three joint projects admitted for public funding since 2015 counting for over €10mln funding and about 30 partnerships established within and outside the footwear sector. The second company, that is, Company B, is a final producer of shoes (i.e., downstream). Company B has also received public funding to support the implementation of I4.0 technology, although this appears to have come mostly from individual project submissions, suggesting a more limited use of formal external collaborations as part of their open innovation strategy. Nonetheless, informal collaborations are valuable to Company B and especially with institutional entities, as demonstrated by its ongoing dialogue with universities and technical schools for talent and skill building in the field of I4.0 for footwear manufacturing. Therefore, while being both committed to I4.0 adoption, the two companies show remarkably different OI strategies to serve this goal.

3.3 | Data collection

Data collection was organized over a 2-year period (2018-2020) and included several primary and secondary sources. As for primary sources, direct interviews were carried out with the general manager, innovation and plant manager of the companies. Interviewees were assured of anonymity and confidentiality, to reduce bias and increase the reliability of the results.

A semi-structured questionnaire was set up in keeping with the theoretical framework discussed in the previous sections (Appendix A). Semi-structured interviews are used since these allow greater flexibility for the respondent to enrich the description of the underlying context, thereby providing a wider picture of the phenomenon under investigation (Seidman, 2006). The questionnaire consists of two main parts. The first part focuses on questions related to the specific I4.0 technologies adopted by the company. In the second part, we examine the relationship of each company with external knowledge sources (i.e., regional institutions, academia and firms) in the context of I4.0. This has allowed us to collect information on both the approach of the companies to inbound OI, as well as on patterns of competence development for I4.0 adoption that led to renewed technological sensing, seizing and reconfiguring capabilities. The questionnaire was further developed and crossed checked with the ISTAO experts, who helped integrate the questions based on their knowledge of the challenges faced by local SMEs in accessing and adopting I4.0 technologies, as well as of collaborative initiatives in the regional ecosystem. More specific questions emerged naturally during the interview and further integrated the theoretical constructs identified in our reference framework. Each interview lasted about an hour, and was recorded and transcribed afterwards. The interviews were also integrated with a round of follow-up emails and calls during the stages of data categorization and analysis to further clarify ambiguous findings and gain a deeper understanding of emerging concepts.

To ensure reliability in our methodological approach and augment construct validity (Eisenhardt & Graebner, 2007; Golafshani, 2003; Yin, 2009), we complemented our primary sources with other secondary sources of internal and external evidence for data triangulation. The use of multiple authoritative third-party sources ensures trustworthiness of data quality and reduces both source and researcher bias (Calantone & Vickery, 2010). Internal secondary sources include (1) annual reports and governance documents, providing information on the organizational ethos, values and leading motivations for I4.0 adoption; (2) company websites and social media, revealing the external communication strategy of the companies; (3) balance sheets, allowing us to document financial performance. External secondary sources comprise institutional websites and reports, press articles, and official data released by the Italian National Institute of Statistics (ISTAT). Institutional websites were used to gather information on public calls for funding opportunities in the field of I4.0. We examined the documentation related to public calls since 2015 to understand the level of participation of the companies (e.g., how many applications did they submit?) and the type of

commitment in each funded project (e.g., did they submit their applications jointly or individually? What were the key objectives of the projects?). Press articles and ISTAT data provided additional information on the broader context where the two companies operate and particularly in relation to the pace of digital transformation in the footwear sector and the economic structure of the Marche region. Press articles were also used to evidence specific events and news relating to the companies.

3.4 | Data categorization and analysis

All the data collected from primary and secondary sources were further elaborated to build categories echoing the main theoretical constructs examined in our reference theoretical framework. To this end, we adopt a coding strategy that takes into consideration our research questions and key variables (Miles & Huberman, 1994), giving evidence of the definitions of OI modalities along the two dimensions under consideration—that is, level of formality/informality and degree of openness—and of the microfoundations for I4.0 adoption, as reported in Table 1. To handle and codify data, we took inspiration from the Ünlü-Qureshi instrument as a way to understand, interpret and organize the data. Thus, we implemented a four step-process involving the identification of codes, concepts and categories till reaching the highest level of abstraction through themes (Qureshi & Ünlü, 2020). An example is provided in Appendix B. The final stage was aimed at discovering relations by comparing, assessing and interpreting the information within the different context of the selected cases (Chad & Jensen, 2001; Skytte, 1992).

4 | RESEARCH SETTING

Considering the number of active firms over inhabitants, the Marche region is the second highest in Italy, with a density of 97.5 firms every 10,000 inhabitants (Regione Marche, 2019). The technological uptake of the region in the advanced manufacturing field is still strongly related to the growth and competitiveness of its Made in Italy sectors such as fashion (including footwear), wood products and furniture and mechanics. Here, the adoption of new technologies is supported by two main motives. The first one is the ambition to move towards a sustainable manufacturing model, whereas the second one corresponds to the development of new systems for a 'Smart Factory'. The interplay of these two motives is expected to facilitate the transition

TABLE 1 Coding strategy.

OI modalities		Microfoundations for Industry 4.0 adoption	
Degree of openness: • Number of projects for I4.0 adoption carried out with external organizations • Type of organizations with which the company is carrying out OI projects for I4.0 adoption, that is, firm (e.g., technology providers, other suppliers) and non-firm (e.g., Universities, government agencies) • Type of activities and business processes affected by OI projects for I4.0 adoption • Involvement of various levels of the company (managerial and non-managerial figures) in the implementation of OI projects for I4.0 adoption	Laursen and Salter (2006); Lazzarotti and Manzini (2009); Manzini et al. (2017)	*Technological sensing:* • Routines adopted for screening and assessing I4.0 opportunities from the external environment • Involvement of various levels of the company (managerial and non-managerial figures) in the screening of I4.0 opportunities *Technological seizing:* • Selection of the I4.0 opportunities to pursue • Commitment of resources to pursue the opportunity • Adaptation of the product mix, business processes and digital infrastructure *Technological reconfiguring:* • Definition of a long-term strategy for I4.0 adoption • Adaptation of internal structures (e.g., department configuration, managerial structures, workforce digital maturity) • Adaptation of the company's position and role in its business ecosystem	Teece (2007); Warner and Wäger (2019); Ellström et al. (2022); Yeow et al. (2018)
Level of formality/informality: • Use of contractual mechanisms to regulate joint R&D and other alliances • Use of informal agreements (e.g., arising from informal communication with suppliers and/or customers)	Scuotto, Del Giudice, et al. (2017); van der Vrande et al. (2009); Zhang and Groen (2021); Hemphälä and Magnusson (2012); Tripsas (1997)		

Source: Authors' elaboration.

towards an eco-sustainable and intelligent factory, where automation and digital technologies enable greater efficiency and lower environmental impact of products and materials (EC Regional Innovation Monitor, n.d., accessed 29 April 2020).

The Marche region is known for the presence of specialized productive districts in traditional sectors, such as wood in the northern part of the region, mechanic, domestic appliances and precision instruments in the centre and food and footwear in the southern area (Il Sole24Ore, n.d., accessed 29 April 2020). The region has a smaller percentage of firms undertaking innovation activities (46.3%) compared with the Italian average of 48.7% in 2016. At the same time, they register a performance above the national average in terms of process and product innovation (39.6% compared with 38.1%) and share of firms with agreements on innovation (18.7% compared with 13.6%).[1] This confirms the difficulties for SMEs usually populating traditional district areas to implement forms of innovation, such as organizational or marketing, involving high fixed costs, while benefiting from the geographical proximity with other firms for innovation based on the creative recombination of ideas within local networks (Bellandi et al., 2020).

In the Marche region, there are 3858 footwear firms, which represent 3.2% on the total number of firms registered in the region (Camera di Commercio delle Marche, 2018). This value is particularly high considering that the national incidence of footwear firms in Italy is 0.2%. Taking into account the manufacturing sector only, footwear manufacturing holds the lead representing 19% of the active enterprises in the sector, followed by metallurgical production (14%), wood (12%), fashion (12%), food and tobacco (9%) and paper (4%) (Regione Marche, 2019). Footwear firms are mainly microenterprises with 0–9 employees (79.4%), followed by small firms with 10–49 (18.9%) and medium with 50–249 employees (1.6%). On the other hand, big firms in footwear with over 250 employees are just 0.1% of the total (Camera di Commercio delle Marche, 2018). Above all, the Italian footwear sector has strong economic value in Europe. In 2019, 9 out of the top 15 world exporters were European, with Italy at the third position accounting for 21% of global leather footwear exports with France and Portugal.[2]

5 | RESULTS

5.1 | The state of implementation of Industry 4.0

The assessment of I4.0 technologies has shown differences between the two companies in terms of both the type of technologies and the motivations driving I4.0 adoption (Table 2).

Company A shows a broader scope for I4.0 adoption, as it applies it to achieve higher levels of sustainability and enhance the wellbeing of employees, while also increasing its productivity, as underlined in its sustainability reports.

The main I4.0 technologies introduced by Company A are related to collaborative robots, interconnected machines and IoT. These technologies allow exchanging continuous data and integrating information from the supplier to the final client using barcodes. Internal and simplified software are used to manage all the data flows and support decision making. The software builds *what–if* scenarios that allow filtering data under a set of criteria. The company is planning to integrate RFID technologies to monitor and trace all resources and stages of the supply chain in real time across all its production lines of soles. The company has also invested in automatic guided vehicle (AGV), which are vehicles able to move without the need of the operator. Financial support came from the innovation plan of the Italian Government for I4.0, called *Piano Nazionale Industria 4.0*,[3] to transform the production line towards a Smart Factory.

On the other hand, Company B is looking to optimize the entire supply chain to enhance the design and development of new high-quality products and increase the offering. For example, in designing its product lines, the firm has invested in advanced 3D technologies connected with digital software, which are helping to reduce the time of prototyping of a shoe from 10 to 2 days. In relation to the production of shoes, collaborative robots have also been introduced and adapted to the specific features of the product, leading to automatize certain working tasks, while keeping a high level of quality, even in the production of small quantities. The company has benefitted from the national innovation plan and also from regional funded programmes. The next technologies that will be introduced are related to

TABLE 2 Description of the two SMEs.

	Company A	Company B
SME information	Intermediate producer of accessories for shoes, especially soles	Final producer of shoes
Position in the supply chain	Upstream	Downstream
Technologies introduced	Collaborative robots Interconnected machines Internet of Things (*future*) RFID and AGV technologies	Collaborative robots 3D technologies *(future)* to PDM (product data management).
Industry 4.0 objectives	Sustainability Wellbeing of employees Productivity	High-quality design Productivity
Communication of I4.0	Website, sustainability report, social media	Website, social media

PDM (product data management), which will allow managing data related to the product during the design, quality control, marketing, distribution and promotion stages.

I4.0 developments are integrated in the companies' communication strategy, such as in their websites and social media. Moreover, Company A also publishes a yearly sustainability report including information on current I4.0 projects.

5.2 | Company A: the 'sustainable' innovator

5.2.1 | Open innovation

As declared in its sustainability reports, the research and development unit of Company A is regularly involved in formalized partnerships with universities, technology providers and firms, to carry out joint projects for the development and adoption of technological innovations.

One key example of collaboration with universities was the 'Social Sustainability in Manufacturing Project', which took place in 2017. The objective of the project was to identify a methodology for the sustainable development of the factory where industry I4.0 is emerging. The project refers to 'Social Sustainability' and is aimed to offer improvements in the field of employees' health and safety, as well as to increase productivity. The company worked on this project with a team of researchers from the regional university. The test has taken place in the factory, with the contribution of two employees of the company. The research team captured workers' behaviours while performing working tasks through wearable smart objects based on IoT to monitor vital parameters (heart rate; breath rate) and posture. Data were available in real time on a smart tablet and a dashboard presented variables and relevant threshold. The results of the test gave the chance to understand the importance of a dynamic working condition assessment to improve jobs, which creates a win-win situation for both operators and the company. The optimization of job design and workers' capability allowed the matching with a socially sustainable manufacturing experience. On the other hand, the research team had the opportunity to test and validate its method of monitoring workers in the workplace, which they consider crucial to develop a systematic approach to worker protection and business efficiency. Thanks to the positive results of the research, several studies are currently underway to develop the IoT framework for other companies with other sustainability drivers.

Inbound OI takes place also through partnerships with other firms and with technology providers to develop eco-friendly innovation technology based on I4.0 principles, as demonstrated by the numerous applications for regional funding in the area of research and innovation. In one of these projects, Company A was involved in the development of technological solutions to reduce the environmental impact of the footwear supply chain. The project brought together the competencies and resources of firms from the footwear, mechanics and ICT sectors, with the support of Università Politecnica delle Marche, demonstrating the importance for Company A of recombining knowledge in the own field of specialization (footwear) with the exploration of less related knowledge from other sectors (mechanics and ICT) to generate technological innovation (March, 1991).

The company is also benefitting from more informal external relationships, although these seem to be largely focused on the promotion of awareness and knowledge sharing among firms, rather than on the actual development and implementation of ad hoc technology solutions, as in the case of formalized partnerships. For example, the company is a member of the innovation cluster of the Marche region, representing a benchmark on Smart Factory. The participation in these initiatives enables the company to both collect and share its knowledge of Smart Factory with other firms in different sectors.

5.2.2 | Technological capabilities

The OI modalities described above are reshaping the microfoundations for I4.0 adoption in Company A. In terms of sensing I4.0 opportunities, the company acknowledges a key role of universities, which are appointed as 'consultants' of the firm. In this regard, regular dialogue and the participation in joint projects enable the company to be up to date with current technological trends combining productivity and sustainability. Furthermore, the company's openness to collaborations with actors from the same and other sectors supports knowledge sharing for the integration of new eco-friendly manufacturing processes with a long-term mindset that is attentive to the potential consequences on present and future generations. These results suggest that inbound OI modalities characterized by a pluridimensional combination of formal and informal relationships, coupled with the openness to collaborations within and outside the sector, are strengthening the Company's capabilities of testing I4.0 technologies to integrate them effectively in their smart factory.

To seize these opportunities, Company A relies on the involvement of all levels within the Company, which help select and integrate I4.0 opportunities with their different competences. In fact, as specified by the plant manager: 'There is a regular dialogue with the operational level, which is strongly involved in the definition and introduction of I4.0 technologies'. The company is also showing strong commitment to human resource reallocation from traditional tasks to the implementation of I4.0 projects, as it recognizes that a smart factory, from a social point of view, has positive effects on the operators and in general, on the development of the human factor, which is at the heart of their business model. This 'smart factory' vision is embedded in the external communication of the company, as underlined in its sustainability reports and press articles.

In terms of technological reconfiguring, Company A has adopted well-structured projects, as underlined by the plant manager: 'technologies are the results of a project based on the company's needs, which must be linked to the strategic drivers of the company'. Based on this long-term vision, Company A is reshaping and strengthening existing networks by sharing knowledge with regional and extra-regional firms that can prepare them for I4.0 and, ultimately, optimize their

productive systems. Furthermore, I4.0 technologies laid the basis for a continuous improvement of the working environment, enhancing the level of quality for workers. New technologies empowered individuals to acquire more advanced skills, while also contributing to the reduction of simple and more dangerous tasks. In this way, employees can supervise the entire process in a safer environment. Moreover, since not all the stages of production can be automatized, the operator had to learn how to collaborate with new machines. Training was offered to all employees in their different functions.

5.3 | Company B: the 'high-speed-for-quality' innovator

5.3.1 | Open innovation

Company B recognizes that collaborations based on a fruitful exchange of knowledge with private, public and institutional actors are all necessary to nurture the company's technological capabilities. However, looking into the company's relationships with external actors, we observe that these are mainly informal in nature and are aimed at understanding the I4.0 technological developments, while no joint projects are taking place to design and implement new technology solutions. There is also a regular exchange of knowledge with business and technical schools which are supporting the company in understanding the necessary skills to develop, in order to fully embrace the technological revolution.

From the institutional point of view, there is a constant relationship with the regional administration and with the Ministry of Labour, which picked the company as a pilot case for experimenting with the introduction of I4.0 technologies. The company also takes part in workshops and conferences organized by the regional administration to exchange knowledge with other local firms of the footwear sector on I4.0 opportunities and challenges. As pointed out by the innovation manager: 'our company is always open to collaborations with regional institutions by participating in workshops, programs, seminars that are fostering sharing of knowledge. We are also a benchmark to understand the current needs on Industry 4.0'. Nevertheless, the exchange of knowledge with other firms of the same sectors is limited. Indeed, as underlined by the innovation manager: 'footwear is still a conservative sector not prone to innovation. The sector looks at change as a risk instead of an opportunity'.

5.3.2 | Technological capabilities

With regard to the screening and selection of I4.0 opportunities, Company B is mostly driven by the ambition of optimizing design and production processes, while also keeping a high standard of quality even in the case of small quantities. Screening and assessment routines mainly rely on informal relationships with academia and business schools, while no structured activities and practices are identified for the identification of I4.0 opportunities. For example, the abstention from joint OI projects suggests limited commitment to long-term and systematic investment in I4.0 capabilities, constraining future competence development in the area (Teece, 2007).

I4.0 opportunities are typically selected by the strategic level of the Company (managers and external consultants), before being explained to the operational level in their different sectors of competence, including design, production, quality control, selling and marketing. The innovation manager of Company B specified that: 'the introduction of new technologies was gradual (…)'. This is partly due to the fact that: 'The introduction of new technologies continued to uncover new needs that we were not able to address before and for which a new technical solution was required'. As further underlined by the general manager, the I4.0 technologies introduced were adapted to the needs of the downstream supply chain, which requires field-specific technologies that consider the needs of the market and the features of the product.

Company B has expressed its commitment to the adoption of structured plans that respond to the Company's needs, manifesting an attempt to reconfigure existing competencies and organizational practices for I4.0 adoption. As declared by the innovation manager: 'After an initial phase of ''experimenting'' the company has become aware of the need to develop a structured Industry 4.0 plan balancing the financial incentives of the national plan for Industry 4.0 together with the real needs of the company'. Reconfiguration endeavours are also visible in the adaptation of the Company's internal structures. In this regard, the process of reconfiguring has seen the company extend its management structures and review internal procedures to better assess business opportunities, including the involvement of new executive and consultancy roles. A great effort has also been placed in making employees aware of the need to change their working tasks. In relation to the empowerment of employees, the company recognizes three main motivations for change, namely technological, organizational and cultural. In the first place, training current employees and employing new professional roles is one of the key priorities of the company to allow employees to become 'knowledge employees', who can share their knowledge in a transversal way through different departments and promote quicker adoption of new technology. As specified by the innovation manager: 'Even if there was initial scepticism on the introduction of new technologies, the sharing of knowledge and training activities among employees has helped embrace change'. In this function, the role of business schools is considered essential. Second, the company acknowledges that it is important to motivate employees to help them contribute to organizational learning and to the overall innovation process. In line with this view, innovation must become part of the wider organizational culture and particularly of the routine of all employees, supported by long-term capabilities based on innovative work behaviour.

6 | DISCUSSION

In the first part of the analysis, the case studies show the different approaches of the two companies to OI for the integration of I4.0

technology solutions, allowing us to answer research question 1: 'How do SMEs engage in inbound OI for I4.0 adoption?'

Our findings suggest that inbound OI plays a crucial role in incentivizing and supporting the adoption of I4.0 in SMEs and particularly when it is based on a broader set of formal and informal cross-sectoral relationships. An in-depth analysis of both companies reveals important differences between them in terms of the nature and type of OI strategy adopted, as exemplified by the two dimensions of our reference theoretical framework, that is, the level of formality/informality of external collaborations and the overall degree of openness.

With regard to relationships with external actors, such as universities, technology providers and other firms, inbound OI takes place through a broader set of formal and informal interactions in Company A as compared with Company B. It appears that formalized collaborations with actors from the same and other sectors are especially beneficial to the experimentation of I4.0 technologies that tend to be more widely adopted and less specific for the manufacturing knowledge base, such as the IoT (Corradini et al., 2021). Through the development and implementation of joint projects, Company A seems to be more prone to exploring knowledge from a variety of knowledge bases, paving the way to the adoption of technologies that require more radical adaptation of existing routines and competencies (Messeni Petruzzelli et al., 2021). On the other hand, Company B is largely involved in informal relationships with universities and business schools, which are being leveraged to explore emerging I4.0 opportunities in the company's own field of specialization. This result combined with the openness of the company by and large towards institutional stakeholders leads to a refinement, rather than reconfiguration of the existing business model (Isobe et al., 2008), to support the adoption of specific process technologies being especially linked to manufacturing, such as automated robots (Corradini et al., 2021). Therefore, while in general OI informal modalities are more frequently observed in SMEs (Scuotto, Del Giudice, et al., 2017), the two cases reveal that a level of formality is needed to support wider exploration and integration of external knowledge (Tripsas, 1997), contributing to competence development for the adoption of a broader spectrum of I4.0 technologies (Teece et al., 1997).

The second part of the analysis focuses on the role of knowledge sharing with external actors, especially universities, providing unique resources and capabilities, such as knowledge, qualified skills and networking opportunities, that promote the development of technological capabilities. Based on these findings, we address our second research question: 'How does inbound OI for I4.0 adoption in turn affect SMEs' technological capabilities?'

Our findings reveal that the adoption of varying types of inbound OI is pushing the two companies to adapt their competencies, routines and organizational structures for I4.0 adoption. For example, as a result of their active participation in local networks, the two Companies have reconfigured their role in the regional ecosystem. In this regard, the regional administration has increasingly involved them in initiatives to promote mutual knowledge sharing with firms, universities and other public and private institutions. This approach is in line with Kiel et al. (2017), who argue that I4.0 requires an extension of the triple bottom line (TBL) of sustainable value creation (that includes economic, ecological and social aspects) by other three dimensions: technical integration, data and information and public context. In line with this view, it becomes necessary to communicate and demonstrate the benefits of technological advancements, by promoting examples of best practices and offering training and workshops addressed specifically to SMEs (Wank et al., 2016).

Nevertheless, we also observe that the approach of each company to inbound OI is driving the adaptation of technological capabilities in different ways. A clear example is the different contribution of employees to the reconfiguration of the organization.

In both cases, great effort has been placed in making employees aware of the need to change their working tasks. Training was offered to employees in their different functions to help them become actively engaged in the change, accelerating the innovation process within the organization (Grant, 2013). This practice is used to foster the capabilities of individuals and teams encouraging them to discover opportunities and establishing a culture of innovation and growth since coaching promotes the change of individual behaviours through enhanced self-awareness and self-efficiency (Nelles et al., 2016).

However, in Company A, the involvement of employees is highly relevant in all of the three technological capabilities examined. This is deemed necessary to sense and seize the opportunities that can better meet the goal of the company to improve wellbeing, and to reconfigure the organization accordingly. On the other hand, in Company B, the involvement of employees is less present in the technological sensing and technological seizing stage, while being recognized as an important driver of wider reconfiguration of the organization to effectively optimize production processes. This approach caused greater resistance of employees in the initial implementation of I4.0 technology (Remneland & Styhre, 2017).

In Figure 1, we present a dynamic model of technological capabilities evolution for I4.0 adoption, building on the results of our analysis.

The model is based on the assumption that the integration of internal and external knowledge through inbound OI transforms the microfoundations for technological sensing, technological seizing and technological reconfiguring (Henderson, 1994; Saebi & Foss, 2015; Tripsas, 1997), within the boundaries of the firm's existing trajectory of competence development (Cohen & Levinthal, 1990; Teece et al., 1997). Indeed, by opening up new opportunities for external knowledge absorption, OI can trigger new learning dynamics within the firm, proposing new alternatives to existing routines and thus affecting the configuration of technological capabilities (Lavie, 2006; Warner & Wäger, 2019). This can eventually support technology adoption and create future learning and innovation opportunities along the firm's competence development path (Gebauer et al., 2012; Teece et al., 1997; Woiceshyn & Daellenbach, 2005).

As demonstrated in this study, OI modalities affect the evolution of technological capabilities, and ultimately, the adoption of I4.0 technology. On the one hand, external relationships *within* sectors are linked to the investigation of technology solutions in the same field of

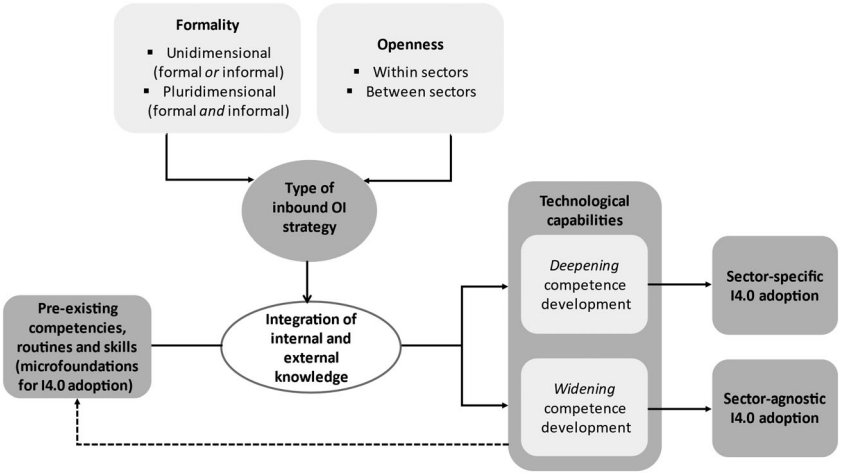

FIGURE 1 Dynamic model of technological capabilities for Industry 4.0 adoption.

specialization, showing a *deepening* approach to competence development for I4.0 adoption that builds on the existing microfoundations of technological capabilities and aims to optimize processes without changing the interdependencies between them (Corradini et al., 2021). On the other hand, external relationships *between* sectors provide access to more distant resources and knowledge bases, enabling radical changes in the organization that support a *widening* approach to competence development for I4.0 adoption. This is also facilitated by a greater involvement in both formal and informal relationships, which contribute to internal strategic change by conveying knowledge through both strong ties and weak ties (Messeni Petruzzelli et al., 2021; Scuotto, Del Giudice, et al. 2017; Zhang & Groen, 2021).

7 | CONCLUSIONS

Management and applied economics scholars have long debated the ability of SMEs to keep up with new technology given their inherent technical, organizational and financial barriers. More recently, the attention of scholars towards the participation of SMEs into the Fourth Industrial Revolution has revamped. Yet, limited empirical evidence has been produced so far, to understand how SMEs can undertake the necessary organizational steps to adopt I4.0 technologies.

Drawing on a multiple case study methodology, our analysis has shown that SMEs can overcome their structural limitations for I4.0 adoption by engaging in collaborative relationships with external stakeholders. Indeed, inbound OI enables SMEs to integrate internal and external knowledge required for renewing competencies, routines and organizational structures (Henderson, 1994; Teece et al., 1997; Tripsas, 1997), triggering a dynamic process of technological capabilities development that helps them sense and seize emerging opportunities from the internal and external environment.

More specifically, our findings show that engaging with external knowledge sources, and especially with universities, is crucial to help firms enhance their capabilities for technological sensing and technological seizing, even if differences in terms of nature and type of inbound OI modalities are found to moderate the impact of these collaborations. Interestingly, we find that exploring distant knowledge through a broader set of formal and informal relationships enables more radical adaptation of technological capabilities for the adoption of I4.0 technologies characterized by wider and more general applicability, such as the IoT (Corradini et al., 2021; Messeni Petruzzelli et al., 2021). On the other hand, the use of only one type of external relations (in our case, informal) combined with relatively more limited openness, tends to be associated with knowledge search in the company's own field of specialization, contributing to the adoption of sector and process-specific I4.0 solutions, such as automated robots, that largely build on existing organizational structures. Therefore, our study adds to the current understanding of I4.0 adoption in SMEs, by emphasizing the importance of considering differences between technologies in future research.

A lower involvement in external collaborations is found in the phase of reconfiguration of the firm and deployment of the new I4.0 technology. In this regard, we observe that technological reconfiguring is largely driven by the motivation of the company for adopting I4.0 technologies. Different purposes drive the management of internal resources and particularly employees as a key driver of strategic change within the organization. Based on our findings, we argue that employees play a key role in the adaptation of competencies for I4.0 adoption, when they are at the heart of the company's strategic goals, as we observed in the case of Company A. On the other hand, product-driven and efficiency-driven motivations for I4.0 adoption led to a more limited involvement of employees in such processes, mainly driven by the aim of effectively reconfiguring operations and procedures, as demonstrated by Company B.

7.1 | Theoretical implications

The analysis provides useful insights into the rapidly emerging topic of I4.0 by combining the paradigm of OI (Chesbrough, 2003) with the

dynamic capabilities' framework (Teece, 2007). We use these frameworks to unpack the effects of inbound OI modalities on the type of competence development that SMEs can implement for more successful adaptation to the challenges of I4.0. Thus, we propose a different perspective from the existing literature, which is largely focused on exploring I4.0 as enabler of OI, as well as discussing the role of dynamic capabilities in implementing OI (Grimaldi et al., 2013). Based on our results, we posit inbound OI can be a key driver of strategic change, in addition to sustaining product development as discussed by extensive literature (Hervas-Oliver et al., 2021). Drawing on the idea that the integration of internal and external knowledge is necessary for the renewal of competencies, routines and organizational structures (Henderson, 1994; Teece et al., 1997; Tripsas, 1997), we further contribute to this debate by showing that the type of engagement in external knowledge exploration and integration through various OI modalities paves the way to different trajectories of competence development, i.e. *widening*, when exploration endeavours involve more distant knowledge bases (e.g. knowledge from other sectors), and *deepening*, when knowledge exploration largely occurs within the same field of specialization. We observe these trajectories have an impact on I4.0 adoption, with the former enabling the adoption of a broader spectrum of I4.0 technologies, and the latter contributing to the adoption of more sector-specific I4.0 technologies. As for teaching avenues, the cases can be presented to students as examples to discuss barriers faced by SMEs in the Fourth Industrial revolution and how OI can help reduce them by acting on firms' technological capabilities.

7.2 | Practical implications

As for managerial implications, the study first shows that focusing on external collaboration combining both formal and informal ties, supports the development of capabilities for I4.0 adoption. In particular, the results suggest that firms can follow different types of inbound OI strategies, choosing different levels of formality/informality of external collaborations and degrees of openness. In this regard, formal partnerships prove to be useful to exploit the potential of cross-sectoral collaboration as a win-win solution for the stakeholders involved. Second, activities of knowledge sharing within the company can be pivotal to raise awareness and employees' skills and thus to enable the integration of internal and external knowledge, enhancing pre-existing competences, routines and skills as microfoundations for I4.0 adoption. In this way, companies might develop their capabilities to sense and seize opportunities from the external and internal environment.

As for policy implications, our cases shows the role that inbound OI has in supporting technological developments and transformations, especially for SMEs (Matulova et al., 2018; Travaglioni et al., 2020), for which new industrial policies are being called (Bellandi et al., 2019). In this regard, industry-university partnerships appear to play a key role in experimenting and introducing I4.0 technologies based on firms' microfoundations for I4.0 adoption. This is especially true for those firms that require I4.0 technologies to be adjusted to the product and market needs. These projects may possibly specify the advantages of such collaboration from both a research and industrial perspective. In this sense, policy awareness and training events tailored to the different levels of technological capabilities might be considered. For instance, the study proposes the role of 'knowledge propagators' that is, firms with exceptional connections and exposure within the supply chain allowing them to convey knowledge among different actors to strengthen relationships along the supply chain and leverage them as conduits of technological opportunities. In this sense, open days to visit firms are suggested in presence and in remote mode to give the opportunity to understand how technologies are used in the company. These events may possibly stress the potential of I4.0 as a means to introduce sustainable processes and products.

7.3 | Limits and future research perspectives

Even if the two SMEs represent exemplary cases in their regional ecosystem, the lessons learned from their experience can provide useful insights to optimize regional programmes that support SMEs in their path towards I4.0. As for the limited generalizability of case study analysis, it should be taken into account that SMEs in traditional sectors face similar challenges in integrating I4.0. Building on the findings of this study, future research should examine the evolution of I4.0 in SMEs from other industries, including other manufacturing sectors and services. This analysis based on a broader sample would shed light on the various approaches and motivations that drive strategic change in smaller firms for the adoption of new technology. Comparative analysis with other regions at the national and international level could also enable to capture the role of environmental conditions, such as the presence of 'thick' or 'thin' local networks from which companies can draw upon, in incentivizing OI practices for the absorption of external resources and capabilities. Lastly, the case studies were only discussed from the perspective of SMEs. Thus, it would be of interest to also capture the views of the other stakeholders who are involved in OI.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable as no new data was generated or the article describes entirely theoretical research.

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ENDNOTES

[1] Analysis based on Community Innovation Survey (CIS) data extracted from the Italian National Institute of Statistics (ISTAT)

[2] European Confederation of the Footwear Industry, http://cec-footwearindustry.eu/sector/key-facts-and-figures/

[3] Piano Nazionale Industria 4.0: https://www.mise.gov.it/index.php/it/industria4.0

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APPENDIX A: INTERVIEW STRUCTURE

1. Which I4.0 technologies have been introduced so far and why? (Please consider the list of I4.0 enabling technologies described in the I4.0 national plan).
2. Which other I4.0 technologies is the company thinking of adopting in the future?
3. How does the company research and evaluate which I4.0 to introduce?
4. Has the company adopted procedures to involve employees in deciding which technology to introduce and/or how to introduce them?
5. Which main changes did the introduction of I4.0 bring in the company?
6. Are there any training activities for employees regarding specifically I4.0?
7. Which are the main actors with who the company collaborates when considering I4.0 technologies (institution, academia, other firms, clients)?
8. How is this knowledge managed within these collaborations?

APPENDIX B: EXTRACT OF CODING

Code	Concept	Category	Theme
Listening to employees' suggestions for I4.0 adoption	*Engaging employees in I4.0 decision making*	*Empowering employees*	*Technological reconfiguring*
Involving strategic employees in I4.0 decision making			
Communicating I4.0 plans to employees	*Enhancing employees' knowledge of I4.0*		
Involving employees in knowledge sharing activities on I4.0			
Training employees on I4.0			
Engagement with external consultancy services on I4.0	Involvement in industry networking activities	*I4.0 knowledge sharing*	
Engagement with local firms to share insights on I4.0			
Engagement with regional administrations on I4.0 programs	Involvement in support activities for I4.0		
Engagement with universities to shape training programs			

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