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Unveiling knowledge ecosystem dimensions for MSMEs' digital transformation, toward a location-based brokerage

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ABSTRACT

This study explores how knowledge ecosystems (KEs) led by a knowledge broker (KB) can support the digital transformation of Micro-, Small and Medium-sized Enterprises (MSMEs). By employing an exploratory research design and action research methodology, the paper proposes and applies an analytical framework to investigate the characteristics of KEs and the knowledge managed by the KB as the innovation intermediary acting as leader of the KE The case study selected uncovers the dimensions of a regional KE guided by a digital innovation hub (DIH) supporting MSMEs towards the adoption of the "Digital Artisan platform" deriving from an Industry 4.0 project.

The findings highlight the importance of trust, strategic alignment, and dynamic capabilities of KBs in enhancing MSMEs' digital journey and emphasize the location dimension of the regional KE as a means for providing tailored support. This research contributes to the theoretical and practical understanding of regional KEs enabling the digital transformation through KBs who are the innovation intermediaries covering the role of leaders of the ecosystem.

1. Introduction

Digital technologies are acknowledged as an imperative that is redefining firms' competitive advantage (Urbinati et al., 2018). These technologies support the redesign of business processes and customer experiences to match the changing needs of businesses and markets (Acciarini et al., 2022; Scuotto et al., 2020; Fitzgerald et al., 2014). However, Micro-, Small and Medium-sized Enterprises (MSMEs) are often reluctant to start digital transformation processes due to their limited financial and organizational resources (OECD, 2019; Schröder, 2016). In this scenario, a knowledge ecosystem (KE), can facilitate both knowledge interactions between different actors (Borgh et al., 2012; Clarysse et al., 2014) and knowledge application (Thomson, 2007). As for many ecosystems, a central actor often selects members and establishes objectives and rules (Teece, 2016). Considering the case of KEs, this central role is likely to be covered by a knowledge broker (KB). This kind of innovation intermediary can support these firms in external knowledge search (Franzò et al., 2023). The presence of a KB may also support MSMEs in overcoming their financial and organizational challenges through the selection, exchange, integration, and appropriation of knowledge sources that are relevant for accessing and adopting digital technologies (Crupi et al., 2020).

KEs including KBs can represent a critical area of study, particularly in addressing the digital transformation needs of MSMEs. In fact, MSMEs face significant technical and financial challenges in adopting digital technologies, which they cannot surmount alone (Costa et al., 2023; Heberle et al., 2017; Kesting and Günzel-Jensen, 2015; Brunswicker and Ehrenmann, 2013). KEs could facilitate knowledge interactions and applications across various actors, potentially enabling MSMEs to integrate digital technologies into their business processes and meet the needs of technology providers (Borgh et al., 2012; Clarysse et al., 2014; Thomson, 2007). Particularly, the role of KBs within KEs can become crucial, as they aid MSMEs in overcoming barriers through the selection, exchange, integration, and appropriation of relevant knowledge sources for accessing and adopting emerging digital technologies (Crupi et al., 2020). Despite the apparent relevance of KEs in this context, there

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remains a paucity of research on how KEs, particularly through the efforts of KBs, manage and organize knowledge flows to support MSMEs' digital transformation (Ritala et al., 2023; Järvi et al., 2018). Previous studies have often focused on technologies like social media as a tool for creating KEs rather than exploring how KEs support the broader adoption of digital technologies (Yu et al., 2022; Crammond et al., 2018). This study aims to address these gaps by exploring the dynamics within KEs that include KBs, especially in the case of e uncertain outcomes of collaboration in the still-emerging stages of digital technology development (Fawcett et al., 2012; Lee et al., 2010). In such contexts, enforcing collaboration may prove counterproductive, potentially fostering a climate of mistrust (Barge-Gil, 2010), and the negative effects of cooperation become more pronounced where financial resources are scarce (Lee et al., 2010), a common challenge for MSMEs.

The objective of this study is thereby to understand how a KE can incentivize MSMEs to adopt emerging digital technologies through a KB who is the innovation intermediary acting as the leader of the KE. The research question thus focuses on how a KB fosters the creation of a KE to support the digital transformation of MSMEs and their access to and investment in emerging digital technologies.

To this aim, the research is grounded in the collective intelligence framework (Malone et al., 2010), which offers a novel approach to analyzing the characteristics of KEs.

In doing so, we first proposed a preliminary framework integrating the collective intelligence framework with the literature related to KBs and dynamic capabilities. Dynamic capabilities intended as those of the KB, the innovation intermediary acting as leader of the KE (Foss et al., 2023), were considered to uncover the knowledge selected, exchanged, integrated and appropriated.

Precisely, we used an exploratory action research approach to match theory with empirical data, discussing their consistency in terms of a new conceptual model (Goldkuhl et al., 2020). We conducted action research (Ollila and Yström, 2020; Ripamonti et al., 2016) in light of the direct experience of the first author. This research approach is becoming widely used in innovation management (e.g. Lepore et al., 2023; Bartoloni et al., 2022) to conceptualize what happens in practice, with implications for theory generation (Huxham, 2003). Indeed, the researcher was heavily involved in supporting the KB, namely the local digital innovation hub (DIH), in the process of building connections between the different actors within the KE.

The action research was based on observations from 2017 to 2023 of the Digital Artisan (DA) platform resulting from the I4IoT Advanced Cloud Solution for Industry 4.0 project. The project was launched in 2016 with the aim of developing a cloud-based platform for monitoring production processes for the industrial automation sector. The project was managed by a spin-off of the Faculty of Engineering at the Polytechnic University of Mache (Italy), with a special focus on MSMEs. The case study was marked by the involvement of a KB, which was embodied by the regional DIH, and featured technologies that were in their developmental or pilot phases.

The findings show the genesis and evolution of a regional KE centered around a digital artisan project, underscoring the intermediary role e of the DIH as a KB leading the ecosystem. The study emphasizes the importance of trust, strategic alignment, and the dynamic capabilities of KBs in enhancing MSMEs' digital transformation journey. Moreover, it underscores the significance of the "location" dimension as a foundational element for tailoring regional KE support to MSMEs' specific digital transformation needs (Gifford et al., 2021). Also, this paper contributes to the theoretical and practical understanding of regional KEs in the digital transformation context, highlighting the intermediary role of KBs as leaders of the ecosystem and the application of its dynamic capabilities (Ritala et al., 2023). Thus, in terms of theoretical contribution, first we enrich the emerging literature on KEs (Gupta et al., 2019), connecting and advancing the literatures on knowledge brokerage (Crupi et al., 2020) and ecosystem leadership (Foss et al., 2023). We contribute and integrate this literature by considering the role of an innovation intermediary, namely KB, that through its dynamic capabilities acts as the leader of the KE (Foss et al., 2023). Second, we design and apply a framework for studying the creation and evolution of regional KEs led by KBs, shedding light on how the dimension "location" can impact the digital transformation of MSMEs, thereby fostering recognition of location-based KEs.

As for practical implications, findings can help managers involved in digital transformation processes understand the relevance of the external environment and the importance of relying on trusted innovation intermediaries. Moreover, the findings can address policymakers in supporting KBs in creating and managing regional KEs, ensuring a synergetic activity of knowledge brokerage and enabling. The proposed conceptual model can guide the collection of information to support KBs foster collaboration and participation mechanisms in a regional KE.

The rest of the paper is structured as follows. Section 2 discusses the theoretical background that supported our observations. Section 3 explains the methodology, and Section 4 highlights the results obtained from the observations and data analysis. Finally, Section 5 discusses the results, and Section 6 presents the conclusions.

2. Theoretical background

2.1. Knowledge ecosystem perspective in the case of digital transformation

The concept of ecosystems is gaining momentum among scholars and policymakers as a way to foster the digital transition of companies and societies. The ecosystem metaphor refers to networks of organizations and individuals interacting through collaboration mechanisms to achieve a shared objective. Within management and economics studies, concepts often overlap, including those of innovation, business, and entrepreneurial ecosystems. In general, innovation ecosystems prioritize the invention-to-commercialization process (Rohrbeck et al., 2009) and joint value creation endeavors (Pushpananthan and Elmquist, 2022). In contrast, business ecosystems focus on customer value creation through the production of goods and services (Moore, 1996), while entrepreneurial ecosystems concentrate on entrepreneurs and startups (Nicotra et al., 2017). The term "digital entrepreneurial ecosystem" has emerged recently, highlighting the role of digital technologies in creating value for product development and organizational change (Elia et al., 2020). Among the different ecosystems codified in the literature, the concept of KE (Gupta et al., 2019) may be seen as a prerequisite for other types of ecosystems, potentially becoming the building blocks of innovation-based economies. Unlike the well-known ecosystems, KEs focus on the early stages of knowledge creation (Clarysse et al., 2014; Valkokari, 2015). Thomson (2007) defined a KE as a complex system comprising individuals, institutions, organizations, and technologies for knowledge creation, interpretation, dissemination, and application. In a KE, actors with different interests engage in a joint search for new knowledge to achieve goals unattainable by a single independent player (Järvi et al., 2018). Borgh et al. (2012) identified two key sources of value creation in a KE from a business perspective: facilitating the innovation process for individual companies and creating an innovation community.

Although relatively unexplored, a KE could present great opportunities for MSMEs in their digital transformation. MSMEs who are often hesitant to adopt advanced digital solutions (Lanzolla and Frankort, 2015), stand to benefit from the tailored knowledge provided by a KE to confidently advance in their digital journey. Despite the growing interest in digital transformation among practitioners and scholars in recent years, the literature has not yet formulated a common definition of this phenomenon (Morakanyane et al., 2017). According to Verhoef et al. (2021, p. 889), digital transformation is the way in which "a firm employs digital technologies to develop a new digital business model that helps create and appropriate more value for the firm." Kane (2017) highlighted that digital transformation involves the adoption of business processes and practices to help organizations compete effectively in an

increasingly digital world. In this context, when addressing the phenomenon from a company perspective, it is necessary to distinguish different issues. Above all, scholars, managers, and policymakers are now aware of the gaps that exist between large enterprises and MSMEs. Due to their limited financial and organizational resources compared to large enterprises, MSMEs often struggle to access digital technologies (OECD, 2019). Nevertheless, the role of these companies is important for both the economy and society. Based on this premise, the most urgent need for MSMEs is not whether to introduce digital technologies, such as those enabling Industry 4.0, but rather how to do so quickly enough to survive in the market and gain a competitive advantage (Matt et al., 2020).

However, MSMEs are unlikely to overcome the technical and financial challenges of digital transformation independently (Costa et al., 2023; Heberle et al., 2017; Kesting and Günzel-Jensen, 2015; Brunswicker and Ehrenmann, 2013). Even digitally native startups face significant barriers in securing financing and accessing markets, highlighting the importance of embedding within an ecosystem to mitigate these challenges and enhance their growth potential (van Rijnsoever, 2022). This is why the KE concept is valuable for MSMEs as it offers diverse knowledge sources essential for initiating their digital transformation journey. In this field, scholars have begun to consider the creation of KEs as a consequence of technologies, such as social media. For example, Yu et al. (2022) discuss how MSMEs can leverage mass collaboration to build social media-based KEs for managing stakeholder interactions for knowledge creation and innovation. Crammond et al. (2018) propose a model to improve entrepreneurial SMEs' KEs through social media. However, despite its potential, there is a gap in understanding how KEs can enable the digital transformation of MSMEs, especially concerning their role in helping MSMEs overcome financial and organizational challenges in accessing and investing in emerging digital technologies.

However, to be effective an ecosystem like a KE requires the presence of a central actor, namely KB, who sets goals, appoints members, and establishes rules (Teece, 2016), as the next paragraph will address.

2.2. Understanding the role of KBs within KEs: a dynamic capability perspective

To be effective an ecosystem perspective requires an innovation intermediary capable of managing the network, developing collaborations among multiple stakeholders, and driving knowledge flow.

The role of innovation intermediaries is crucial for innovation integration in complex environments such as ecosystems, where the complexities and uncertainties arising from interdependencies and co-specialization coexist simultaneously, presenting particular challenges. These challenges lead to significant coordination and cooperation issues (Dattée et al., 2018; Kapoor, 2018; Teece, 1984). The critical role of management, often assumed by leading firms, is essential in this context (Altman et al., 2022; Gulati et al., 2012). These firms, variably referred to as "orchestrators" (Dhanaraj and Parkhe, 2006), "platform leaders" (Gawer and Cusumano, 2002), "captains" (Teece, 2016), or "keystones" (Iansiti and Levien, 2004), navigate these complexities. According to Williamson (1991), ecosystem leadership effectively resolves coordination and cooperation problems, ensuring alignment among participants without complete rules or common ownership. Ecosystem leaders exert influence through control of essential assets, such as central platforms (Baldwin and Woodard, 2009) or bottleneck resources (Jacobides et al., 2006), combining hierarchical authority with market efficiencies (Williamson, 1996).

In this light, there remains much to explore regarding the role of innovation intermediaries in mitigating such risks and costs.

Wthin this context, we argue that KEs may play a focal role in providing MSMEs the necessary knowledge to access advanced digital technologies, even at their experimental stage, through collaboration mechanisms of an innovation intermediary namely the KB.

KB might play a key role in building and managing a successful KE aimed at supporting the digital transformation of MSMEs. Intermediaries generally connect companies to external sources, including academia, enterprises, and governmental institutions, and mediate relationships between these actors (Nambisan, 2012). This type of innovation intermediary can support MSMEs in external knowledge search by reducing costs and uncertainty (Franzò et al., 2023). Not only can KBs identify external knowledge sources, but they also make knowledge accessible through activities like knowledge selection, exchange, integration, and appropriation (Crupi et al., 2020). Indeed, KBs are often involved in both the transfer of knowledge and its conversion into value, which in turn facilitates knowledge diffusion (Haas, 2015). In this way, KBs can impact local entrepreneurs' projects, taking into account the unique social, environmental, or technological challenges faced in their territories (Owen-Smith and Powell, 2006). The presence of a KB may be invaluable for local MSMEs, which often struggle to initiate digital transformations. In this context, a KB may help MSMEs access external knowledge and obtain the necessary assistance to overcome their limited financial and human resources (Klewitz et al., 2012). The knowledge-based practices managed by KBs can generate financial and non-financial value, especially when collaborative projects are launched (De Silva et al., 2018). Furthermore, to overcome the financial and organizational constraints of MSMEs, innovation intermediaries are often involved in policy actions and regional programs to gather additional support (Feldman and Lowe, 2017). Thus, understanding how KBs may capture benefits for the wider national or regional innovation systems, as well as for their clients, is relevant (De Silva et al., 2018). One of the main managerial challenges faced by KBs may be building trust between participants and coordinating relationships, especially when the outputs of the collaboration are uncertain (Fawcett et al., 2012). Barge-Gil (2010) found that forcing firms to collaborate can be counterproductive and create a climate of mistrust, whereas Lee et al. (2010) recognized the negative effects of cooperation in the context of MSMEs when financial resources are lacking. Among potential KBs, digital innovation hubs (DIHs) are emerging as an effective option capable of supporting the digital transformation of MSMEs in a European context (Crupi et al., 2020). DIHs are structures recognized by the European Commission for supporting the digital transformation of MSMEs by connecting these firms to external stakeholders, such as governmental bodies, academic institutes and other firms (Macias Aragonés et al., 2020; Vakirayi and Belle, 2020).

Within this context, this study explores KBs as innovation intermediaries acting as leaders of the ecosystem by building on the framework of dynamic capabilities, which emerges as particularly pertinent, offering insights into the nature of the knowledge being brokered. Prior research has linked dynamic capabilities with ecosystem dynamics in contexts such as leadership (Foss et al., 2023), and notably, knowledge brokerage (Fait et al., 2023). Central to the concept of dynamic capabilities is the proposition that sustained competitive advantage requires firms to "integrate, build, and reconfigure internal and external competences" (Teece et al., 1997, p. 516). Teece's framework of sensing, seizing, and reconfiguring capabilities offers a vital approach to managing ecosystem leadership challenges. Foss et al. (2023) state that sensing involves creating a unified vision, essential for overcoming uncertainty and fostering trust among participants through strategic communication (Adner, 2012; Brusoni et al., 2001; Witt, 1998). Seizing is about convincing participants to make ecosystem-specific investments and agree to shared rules, necessitating consensus and mutual agreement. Reconfiguring addresses unforeseen issues, requiring ecosystem-wide problem-solving and a deep understanding of various factors. The agility required in adjusting a firm's internal resources is crucial in a rapidly evolving environment, especially in those encompassing the implementation of new technologies and the development of future-oriented capabilities for opportunity exploration (Ambrosini et al., 2009). Indeed, recent studies highlight the importance of using dynamic capabilities for digital transformation (e.g., Ellström et al.,

2021).

Therefore, by considering the case of DIHs as KBs, our paper seeks to answer the following research question:

How does a KB foster the creation of a KE to support the digital transformation of MSMEs and their access to and investment in emerging digital technologies?

3. Methodology

3.1. Research design

Because we know so little about how a e KE can enable the digital transformation of MSMEs, we relied on an exploratory research approach to grasp the various dynamics in terms of actors and activities taking place in the ecosystem. First of all, it is crucial to emphasize that the type of ecosystem under study can indeed be regarded as a knowledge ecosystem. This is because the focal element upon which it is formed is not technological innovation (as in an innovation ecosystem) nor entrepreneurial initiative (as in an entrepreneurial ecosystem), but rather the flow and the application of knowledge which, in its various forms, is generated and disseminated among the actors. To this end, we selected a qualitative action research methodology that enabled us to observe a particular context while performing the analysis. The research questions justified an exploratory study because they were "what" and "how" questions (Meredith, 1998; Yin, 1994). Similar questions have underpinned previous models analyzing ecosystems' mechanisms, such as that of Elia et al. (2020), who developed a framework based on the collective intelligence approach (Malone et al., 2010). Collective intelligence is a form of aggregation of several independent actors with different competences, whose collaboration can produce better outputs than those that the single actors would have performed individually. Since collective intelligence has already been applied to ecosystems (Elia et al., 2020) by assuming ecosystems as a form of collective intelligence, we decided to map the characteristics of the KE under study according to the following four building blocks, or "genes" (Malone et al., 2010), that characterize a collective intelligence system:

- What is being done? The whole goal of the collective intelligence system.
- Who is doing it? The actors involved.
- Why are they doing it? The set of individual motivations of each actor involved.
- How is it being done? The set of activities carried out within the collective intelligence system to achieve the objective, as well as their organization.

Within this analytical framework, we considered the dynamic capabilities of the KB pictured as an innovation intermediary acting as a leader of the ecosystem, as suggested by Foss et al. (2023). This framework enabled uncovering the knowledge selected, exchanged, integrated and appropriated. This is possible by focusing on sensing, seizing and reconfiguring capabilities.

The action research contributes to supporting theory development (Huxham, 2003; Ripamonti et al., 2016), in particular within innovation management (e.g. Lepore et al., 2023; Bartoloni et al., 2022), and can be particularly useful in still-emerging KE and KB fields, especially regarding the digital transformation of MSMEs.

Action research can lead to a thorough conceptualization of what happens in practice, with implications for theory generation (Huxham, 2003). Friedman and Rogers (2009) recommended action research for explicit theory building and testing.

As in any action research, the selected case mixed scientific inquiry with social action to create knowledge relevant to the research partners (Lingard et al., 2008). The extensive collaboration between the researchers and partners was evident across all stages of the research, from identifying the problem to disseminating the results. Above all, the action research enabled us to collect and analyze multiple sources of data, including observations, direct participation, document analysis, and interviews. The direct involvement of a researcher in a study context enhanced knowledge acquisition through practical involvement.

Above all, the action research facilitated a multigrounding process (Goldkuhl et al., 2020), based on empirical, theoretical, and internal foundations. The first stage was data driven and inductive, the second was based on comparing the empirical results with the existing literature, and the last evaluated the theoretical coherence of the research by matching concepts to relationships. The multigrounding process fits well with action research, which "generates emergent theory, in which the theory develops from a synthesis of that which emerges from the data and that which emerges from the use in practice of the body of theory which informed the intervention and research intent" (Eden and Huxham 1996, p. 80).

As stated above, by following the collective intelligence's building blocks, we mapped the characteristics of the KE based on a preliminary analytical framework (Fig. 1) designed to link the ecosystem literature to studies regarding KBs through the three dynamic capabilities: sensing, seizing, and reconfiguring (Teece, 2007).

Following exploratory logic, we mapped the "what" and "how" facets of the context, considering the goal, the activities and the organization taking place within it and linking them to actors ("who") and motivations ("why"). We linked this model to the KB literature (Crupi et al., 2020), considering the necessary presence of central actors in the ecosystem (Teece, 2016) that possess dynamic capabilities as the leader of the ecosystem (Foss et al., 2023). To this end, we formulated the following definitions to underpin the preliminary framework:

- Knowledge ecosystem actors (who) were defined as KBs, MSMEs, and external knowledge sources (e.g., academia, firms, institutions, etc.) with particular roles and responsibilities.
- Knowledge ecosystem motivations (why) were defined as the reasons for which each actor enters and remains in a KE.
- Knowledge ecosystem goal (what) was defined as the incentives and control mechanisms used by KBs to coordinate and adjust actors, motivations, and activities.
- Knowledge ecosystem organization and activities (how) were defined according to the KB activities presented by Crupi et al. (2020): 1) Knowledge selection refers to the activities conducted by a KB to make MSMEs aware of digital transformation and match them with external knowledge sources. 2) Knowledge exchange and integration are defined as the management of knowledge flows between MSMEs and external knowledge sources that favor the successful exchange and integration of knowledge. 3) Knowledge appropriation concerns follow-up activities to integrate knowledge into MSMEs, support their market potential, and coordinate the new partnerships established between them and technology providers.

Fig. 1 reflects the relationships and processes described in the theoretical framework of this paper. The framework shows how dynamic capabilities influence the leadership abilities of the KB (specifically DIHs) in creating and governing an emerging KE to support MSMEs in their digital transformation.

3.1.1. The case study

For the case study, we selected an emerging regional KE in an exemplary context involving MSMEs in the Marche region of Italy (Yin, 2009). According to the European Commission (2005), micro-enterprises are included in the definition of SMEs, which includes three different categories of enterprises, namely, micro-enterprises, small enterprises, and medium-sized enterprises. To classify firms, the definition of SMEs considers three different factors: level of

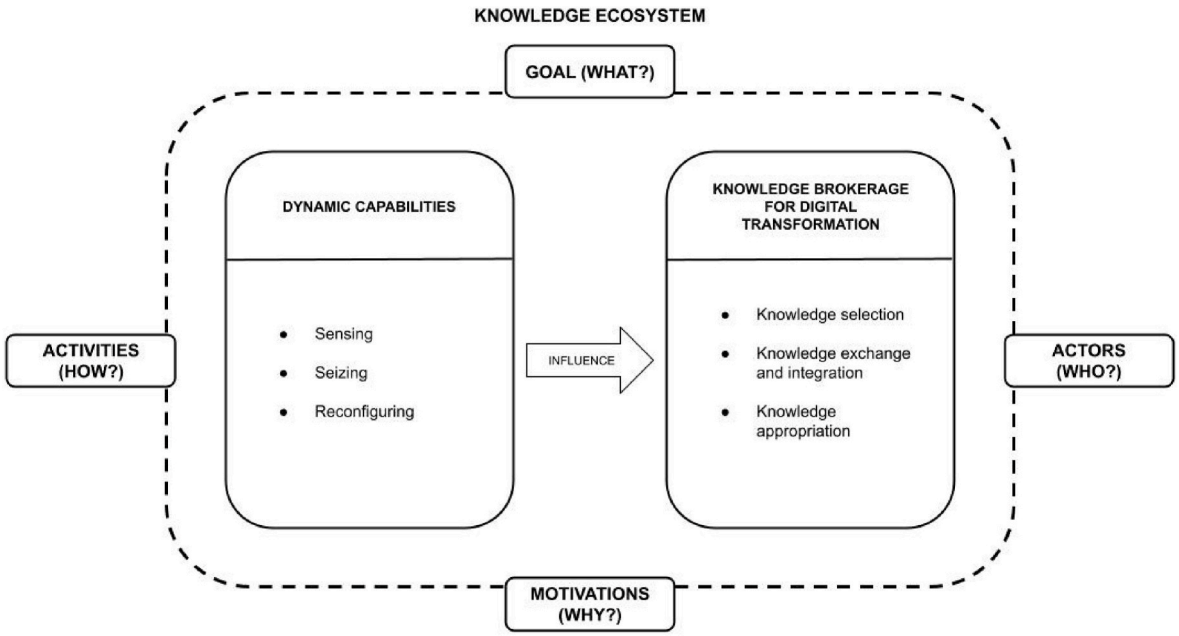

Fig. 1. Preliminary analytical framework.
Source: Authors' elaboration based on Malone et al. (2010) and Crupi et al. (2020).

employment, level of turnover, and size of balance sheet.[1] SMEs are very different in business models, size, age, and entrepreneurs' profiles. They range from liberal professions and microenterprises in the services sector to middle-range industrial companies, including traditional crafts to high-tech ones (European Commission, 2020). Europe has about 25 million SMEs, including a large share of MSMEs, and these organizations employ around 100 million people, contributing to more than 50% of the European GDP. The 2019 Italian SMEs generated 66.9% of overall value added in the Italian non-financial business economy, exceeding the EU average of 56.4%. The share of employment generated by SMEs was even larger, at 78.1%, compared to the EU average of 66.6%. Microfirms were particularly important, providing 44.9% of employment in comparison to the EU average of 29.7% (European Commission, 2019).

The Marche's economy is characterized by a prevalence of SMEs, organized in cluster,[2] specialized in traditional manufacturing sectors, including typical Made in Italy products such as shoes, clothing, machinery and furniture. The selected KE emerged around a cloud-based solution, named DA, aimed at monitoring the production processes of industrial firms.

3.2. Data collection

Overall, the entire period of participation and direct observation lasted 65 months, from 2017 to 2023. During this period, the professional researcher acted as a facilitator for networking activities, driving interactions in the KE (e.g., with local entrepreneurs, innovation brokers, research centers, and professional associations). The researcher also collaborated directly on the definition of the DA project with other stakeholders in order to apply to a financial tender.

Primary and secondary data were employed in our research. Primary data was collected through nine semi-structured interviews, which were administered at three critical stages of the knowledge ecosystem creation and development: initial stages, post-launch of the DA solution, and maintenance phase. Semi-structured interviews were considered necessary to allow greater flexibility and provide a wider description of the phenomenon (Seidman, 2006). The interviews encompassed all key actors of the knowledge ecosystem, namely the o DIH director and manager, the entrepreneurs, the spin-off offering the technical solution and the sales manager.

Interviews directed to the DIH aimed at understanding its mission, activities relating to SMEs, and specific involvement in the DA project. These interviews further sought to comprehend how knowledge was selected, exchanged and appropriated in the KE. In addition, the DIH's perception of the motivation of other participating actors were considered.

Then, interviews with entrepreneurs seeked to grasp their motivations for participating in the KE, and their feedback on the activities organized by the DIH. Primary data was also gathered from the spin-off and sales manager to understand not only the solution proposed but also why they contacted the DIH and needed the support of entrepreneurs to succeed. Follow-up interviews were instrumental in tracking ongoing interests and involvement throughout the DA launch and maintenance stage, supplemented by subsequent email correspondence for additional clarity and confirmation of the findings.

Secondary data was obtained from a variety of documents, including informative materials, project proposal and tender application. The combination of primary and secondary sources enabled triangulation to support the reliability of our study (Gibbert et al., 2008).

The list of sources used is presented in Table 1.

The knowledge actors that were interviewed are described in more detail in Table 2.

The three companies involved are regional MSMEs belonging to three different sectors and markets. More specifically, Company 1 has been active for 24 years and has an annual turnover of about 1 million euros. Its reference market is national and is mainly aimed at armed forces (Carabinieri, Aeronautics) and public bodies. Over the years the company has included some numerically controlled machines such as UV plotters, pantographs, laser engravers and 3D printing. Each operator was related to the central office through paper-based records, so it was impossible to check the processing phases in real-time. Company 1 needed to manage orders and control the workflows of the aforementioned machines by monitoring them from the office (or remotely) and

[1] https://ec.europa.eu/growth/smes/sme-definition_en.
[2] Regional Innovation Monitor, https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/marche.

Table 1
Summary of data sources.

Data Source	Volume	Details
Face-to-face interviews	12 interviews, ranging from 30 to 90 min; approximately 12 h of interviews in total.	Three interviews with DIH members, three with entrepreneurs, and three with the manager of CTF Automazioni and the founder of the Syncode spin-off.
Email correspondence	32 email exchanges with 6 different people	Communication exchanges between the actors involved.
DA documents	65 pages	Three PowerPoint presentations and two description papers, providing informative material.
Project proposal	11 pages	Official project proposal submitted to tender.
Other documents	58 pages	Tender documentation; National Plan Industry 4.0.

Table 2
Knowledge actors interviewed.

Profile	Role	Organization	Description
Sales manager	DA and business idea developer.	**CTF Automazioni**	*Industry:* a first-tier manufacturer of both automated areas and production lines. *No. of employees*: 57.
Spin-off founder	DA project manager	**Emmezero & Syncode**	Spin-offs of the Faculty of Engineering at Polytechnic University of Marche. *Industry*: Internet of Things solutions. *Number of members*: 6
DIH director	DA project leader, managing relationships with other actors.	**DIH established by The Artisan Association Confartigianato of Ancona, Pesaro and Urbino (Italy)**	*Industry*: helping businesses (mainly MSMEs) to choose the most suitable opportunities among those offered by Industry 4.0, through information, training, networking, intermediation, and the dissemination of innovative digital technologies. *Number of employees*: 2
DIH manager	Managing relationships with other actors.		
Entrepreneur 1	DA early adopter	**Company 1**	*Industry*: production of small leather goods, accessories, and technical/ classic/leisure clothing. Product customization (embroidery, engraving, four-color printing, etc.) *Number of employees*: 8
Entrepreneur 2	DA early adopter	**Company 2**	*Industry*: cable harness and wiring assembly *Number of employees*: 11
Entrepreneur 3	DA early adopter	**Company 3**	*Industry*: sheet metal stamping (stainless steel, iron, etc.) and bending iron, steel, and other alloys. Producer of filters for extractor hoods and industrial kitchens. *Number of employees*: 6

integrating them into the active order cycle in real-time.

Company 2 has been in business for 43 years and generates an annual turnover of approximately 1.7 million euros. Its reference market is national, including in particular companies producing machines and household appliances, which are mainly exported to the US. The level of digitization was rather low before joining the project. In fact, the main assembly activity consisted of work islands that were not interconnected with each other. The only computerized data were those related to the inventories of the warehouse.

Company 3 also has 43 years of activity, its annual turnover is around 500,000 euros and its clients are companies in the household appliances sector. Before entering the project, the technological equipment used was limited to an accounting software and a cutting machine. Therefore, the company needed to interface and interconnect multiple machines to automate and digitize processes.

The development of the study followed an iterative approach (Lofland et al., 2005) and covered three main steps used to develop a narrative: identifying digital needs to be addressed in performing an action, finding the right intermediaries to build the ecosystem and involve the DIH as the KB, and developing the core digital activities underpinning the creation of the DA project. The steps are illustrated considering the origins, the creation of the KE, and the launch of the DA platform (Fig. 2).

Accordingly, we discuss the narrative according to the four dimensions represented in Fig. 1: knowledge actors (who), knowledge motivations (why), knowledge activities (what), and knowledge organization (how) matched with the KB activities.

As the figure shows, while the solution was already designed at the end of 2016, only in 2018 the DA solution was developed and became known to entrepreneurs in the KE through a set of activities organized by the DIH. In mid-2019, the solution was launched and the maintenance stage was considered throughout the last year of observation. In this final phase, various follow-ups and updates were conducted, and the platform continued to evolve based on the feedback from entrepreneurs.

3.3. Data analysis

For the data analysis we followed an iterative approach, which, in line with the action research methodology, was based on a continuous comparison between theory-driven concepts and data-driven evidence. This approach has therefore allowed us to identify the theoretical dimensions connected to the data (Table 3). Data-driven observations based on the triangulation of primary and secondary sources were discussed internally and linked with the aggregated theoretical dimensions relating to KEs and KBs. Table 3 shows how data and theory dimensions were linked.

The data collected enabled us to discern the needs and motivations of the actors involved. This included the mission of the DIH, the drive for digital transformation for the MSMEs, and the necessity for the providers to establish use cases and gain trust among entrepreneurs.

Moreover, our data analysis revealed how knowledge was managed by the DIH, with specific regard to knowledge selection, exchange, integration, and appropriation. The activities conducted by the DIH enabled us to appreciate how the KE was organized, in line with our preliminary model. Furthermore, our data yield an additional

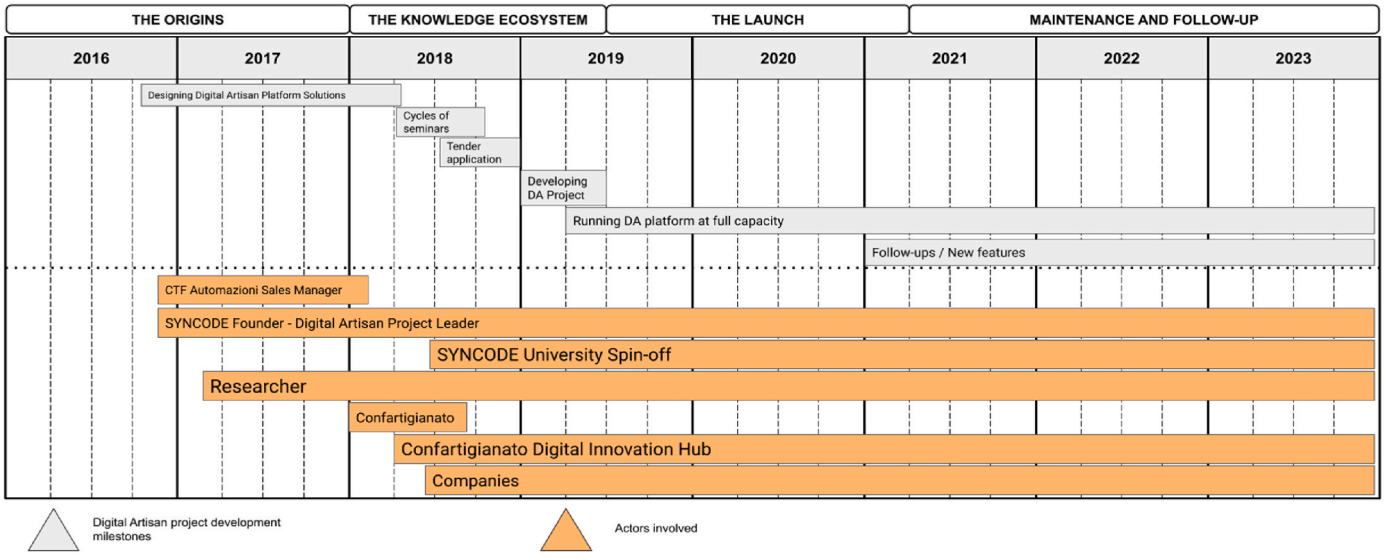

Fig. 2. Process phases and digital actors involved.

Table 3
The theoretical aggregated dimensions.

Data-Driven observations	Theory-Driven	Aggregating Theoretical Dimensions
● DIH mission ● MSMEs' need for digital transformation ● Providers' need for use cases	Actors enter an ecosystem with different interests (Järvi et al., 2018)	Knowledge actors and motivations
Awareness seminars organization	The KB aims at creating a unified vision, essential for overcoming uncertainty and fostering trust among participants - sensing (Foss et., 2023)	Knowledge activities
Involvement in DA	The KB acts in convincing participants to make ecosystem-specific investments - seizing (Foss et al., 2023)	Knowledge activities
DIH seeks financial resources	The KB addresses unforeseen issues - reconfiguring (Foss et al., 2023)	Knowledge activities
All the actors were from the same regional territory.	The main challenge is to build trust between participants, especially when the outcomes of collaboration are uncertain (Fawcett et al., 2012).	Knowledge location

dimension: the knowledge location. In the following paragraphs, the findings are discussed.

All the data collected was used to build categories reflecting the main theoretical dimensions of our framework. Precisely, the Ünlü-Qureshi instrument was adopted to understand, interpret and organize the data. Following this approach, we adopted a sequential four-stage method, starting with the identification of specific codes, then moving to the formation of concepts and categories, and finally achieving a broader understanding through the development of overarching themes, as outlined in the work of Qureshi and Ünlü (2020).

4. Findings

This section presents our findings and is structured as follows. In Section 4.1, we analyze the origins of the KE, considering the initial interests involved and focusing on the motivation behind the creation of the DA platform. In Section 4.2, the KE is described according to our preliminary framework based on the specified four dimensions: the KE goal (what), the KE actors involved (who), the KE motivations (why), and the KE activities and organization (how). Section 4.3 presents the final phase of KE activities, namely knowledge appropriation.

4.1. Origins

According to the first interview conducted with the sales manager and the spin-off, it is noted that the concept of the DA platform emerged from the particularly positive outcomes achieved in a prior project experience named "I4IoT—Advanced Cloud Solution for Industry 4.0, The latter was aimed at creating a cloud-based platform for monitoring the production processes of large companies. The I4IoT project, established in 2016, was managed by the founder of a spin-off of the Faculty of Engineering at the Università Politecnica delle Marche (Italy) that, for over five years, has dealt with software development for the automated manufacturing sector. The platform was developed in collaboration with CTF Automazioni, an Italian company specializing in the planning and construction of special machinery and full plant and automated assembly units. In particular, the founder was supported by the CTF Automazioni sales manager, who managed the business relationship with a large multinational company to which the DA platform was applied.

In light of the positive results obtained, the spin-off team foresaw that I4IoT technologies, if organized into individual customizable modules, could also be useful for MSMEs. As stated by the sales manager in one of the first interviews: *"The intention was to create a tailored solution for a market segment that today seems to be excluded from digital transformation processes, but that plays a significant role in the economic landscape of the Country."*

Thus, the very first aim in terms of knowledge motivation for the technical provider was to increase MSMEs' access to I4.0-enabling technologies, introducing entrepreneurs to a new managerial "data-driven" culture. The organization therefore decided to design and develop a new dedicated DA platform.

The business idea behind the DA platform was to provide micro-small and medium-sized manufacturing companies with production measurement and monitoring systems installed on their machines. Both the sales manager and the founder were convinced that the adoption of this type of technology would allow companies to take advantage of new data to monitor processes, production times, and costs and to provide their customers with analytical information on production progress. Moreover, if the entrepreneurs were part of a supply chain network, the systems would enable the main client to digitally monitor them,

resulting in greater transparency that would appeal to the market. The involvement of the first author as a researcher and an expert on MSMEs' digital transformation began in February 2017, when he was contacted by the sales manager of CTF Automazioni and asked to support both the sales manager and the founder in defining the business model for the DA platform.

During the first quarter of 2017, the founder, the sales manager, and their collaborators worked to develop the technology underlying the services facilitated by DA. From a technical point of view, DA was conceived of as a cloud-based software infrastructure that would facilitate real-time interactions between all the entities of a production plant and allow them to acquire, control, and analyze data regarding entire manufacturing processes. The data visualization would be processed and made available to entrepreneurs on both mobile devices and a Web-based dashboard. When they were ready to test the first version of the DA platform on the market, one of their first issues was to identify a valid way to engage entrepreneurs and demonstrate the opportunities provided by the DA solutions. At that stage of the project, the DA team members believed it would be difficult to establish trustful relationships with local entrepreneurs who would be asked to consider investing in a developing platform with as-yet-unknown outputs. Additionally, they were aware that the MSMEs context was fragmented and that entrepreneurs were typically characterized by low levels of technology adoption and limited financial resources; therefore, the creation of a regional KE led by a trusted KB was required.

4.2. The knowledge ecosystem

Given the absence of structured communication channels between the DA team and the target companies, in December 2017, the researcher suggested demonstrating the project to representatives of the Italian association for artisans and small business (Confartigianato). Contextually, Confartigianato was developing a DIH that was officially launched in February 2018. This involvement of the researcher in the DIH was facilitated by a previous collaboration between the researcher and Confartigianato in supporting MSMEs' challenges, mainly regarding digital transformation. The goal of the preliminary engagement with Confartigianato was to explore the involvement of its DIH in developing the DA platform. After the first meeting, held in January 2018, Confartigianato agreed to actively support project dissemination by making this activity a high priority for the DIH. Based on the first interview with the DIH director, the reasons for the engagement can be summarized in the following statement:

> *We immediately decided to support the project, primarily because we were aware that this type of technological solution was barely accessible to small companies, and second, because of the actors involved—a university spin-off, a company with long experience in the automation industry, and the university researcher with whom we have been collaborating for some time.*

In a nutshell, the value proposition that pushed the DIH to enter the project was to create the conditions to allow the digitization of manufacturing MSMEs by providing them ad-hoc technological solutions, matching their production process, entrepreneurs' and staff capabilities, as well as the companies' financial resources.

In this vein, as stated in the first follow-up interview with both the DIH director and manager, the DIH's support in terms of innovation intermediary, namely KB, for the DA project was twofold: First, the DIH explored effective ways of involving entrepreneurs, making them aware of the state-of-the-art in digital transformation opportunities, and explaining the characteristics and potential benefits of the solutions offered by DA. This initial approach would have allowed everyone to align on a common vision of the phenomenon, as well as on the goals that entrepreneurs should have achieved. Second, it helped entrepreneurs scout for sustainable economic investments to support the integration of DA. Therefore, the DIH positioned itself as a neutral actor in support of all stakeholders.

These activities were performed in the launch phase. The first task in 2018 was to organize several operational meetings and workshops to facilitate the integration between technology providers and MSMEs. As a matter of fact, by organizing a series of seminars and workshops, the DIH effectively raised awareness about the digital transformation landscape and the DA platform's potential benefits by selecting relevant knowledge for the MSMEs. The knowledge selected regarded the latest digital transformation trends, including emerging technologies and potential impacts across industries. Moreover, the collaborative effort between the DA developers and the DIH exemplified a fine-tuned response to the articulated needs of entrepreneurs, ensuring the platform's features were precisely aligned with their operational realities and concerns. In this context, the DIH managed the knowledge exchanged among the parties involved ensuring an effective integration among the MSMEs. This knowledge referred mainly to the current situation of MSMEs in terms of organisational and financial challenges, including their doubts regarding the platform's implementations and outcomes, and the expectations of the technology provider.

Through the knowledge exchanged, the DIH members and the researcher supported DA developers in implementing graphic user interface (GUI) features by considering the needs and critical concerns of entrepreneurs regarding their production processes.

The goals of the seminars were to introduce and list the main structural changes and challenges prompted by digital technologies and to provide a brief presentation of DA solutions, thus encouraging entrepreneurs to consider adopting the DA platform. These seminars served as a platform for exchanging insights and experiences, enabling participants to learn from one another and from the experts.

The most important achievement in terms of knowledge appropriation was to involve entrepreneurs in an experimental project since the DA platform was in its preliminary development stage. The engagement with entrepreneurs was successfully achieved by considering them not as mere customers, but rather as co-development partners with the right ability to test and further improve the DA platform. To ease the entrepreneurs' economic burden, the DA team provided the first movers with a considerable discount. However, as stated by one of the entrepreneurs who attended the seminars:

> *Although we understood the need to adopt this type of technology in our businesses, the DA platform developers had no suitable use case to show us as an example. It was difficult to see the benefits of investing in something unknown, for which there was no evidence at the time.*

Another important event that took place in June 2018 was the foundation of Syncode, a new university spin-off, established by the engineering faculty of the Polytechnical University of Marche. Syncode[3] was formed to develop and sell IoT solutions, including the DA platform, and to help match demand and supply in the digitization service market.

4.3. The launch of the digital artisan platform

Despite the presence of a reduced cost, the investment for adopting

[3] The SYNCODE offer is presented in two different ways: the first is a dedicated custom software service that starts from the physical interconnection of the machines up to the personalization of the views, as well as the data analysis algorithms, while the second is a monthly subscription that can be purchased on the dedicated website, where each company can create its own account, customize their views and decide how much and what data to send to the Cloud. Through a standardization of the communication protocol from the machines to the Cloud, the company can independently decide which data to send and to refer to them with correct logical meaning. The possibility of choosing the graphic widgets to display the quantities of interest as well as the most suitable data analysis algorithms, allows companies to customize the views without the help of an external consultant.

DA solutions still appeared to be quite high for MSMEs. The DIH was indeed realizing that the lack of adequate financial resources available to entrepreneurs was representing a significant barrier that was undermining the continuation of the DA project.

In order to address this issue encountered during the course of the project, in those months, the DIH started scouting for financial support to facilitate MSMEs' adoption of the DA platform.In September 2018, after systematically seeking financing sources, the DIH identified an invitation to tender issued by the local Chamber of Commerce (in the city of Ancona in Italy). The tender initiative, entitled Call for Digital Voucher Enterprise 4.0, aimed to stimulate companies' "demand for services for the transfer of technological solutions" by offering each company a grant of 50% of the total approved expenses. As specified in the programme of the call, organizations were expected to tender services that would support MSMEs and boost collaboration between different actors, such as incubators, technology transfer centers, national or regional technological clusters, and DIHs.

Combining, on the one hand, the task of scouting for investment support for MSMEs and, on the other hand, responding to the tender requirement to aggregate the different actors of an ecosystem, the DIH both performed the aggregation activities and facilitated access to financial tools. As stated by the DIH manager in the second set of interviews, *"We were not merely an aggregator; we mainly acted as a guarantor, trying to immediately establish a climate of trust between the various actors involved." Their role was also confirmed in the project proposal.*

Thereafter, the DIH carried out a series of consultancy activities tailored to the needs of entrepreneurs who were interested in adopting digital technologies. Accordingly, the DIH's support in identifying financial tools for MSMEs positively influenced the attitude of entrepreneurs toward digital investment and boosted their digitization, providing constant follow-up on knowledge selection, exchange, and integration activities. As stated by the DIH director, *"The companies contacted, and their technical requirements, were very heterogeneous, and the fact that the proposed project was a 'pilot project' increased their levels of uncertainty."*

Thereafter, three of the companies that decided to apply for the tender emphasized the key role played by the DIH throughout the whole process in increasing their willingness to invest, as stated by one of the entrepreneurs: *"Without the continuous* support *of the DIH in initially training us and guiding us during the tender application process, I would not have invested in the DA solutions. The trust placed in the representatives of the DIH was maximum, they deserve the credit for having been the guarantors of the whole project."*

On December 20, 2018, the DA platform received an official grant from the Chambers of Commerce, following a successful tender, and Syncode started to inspect the three companies and proceed with the subsequent installation of the hardware components. The entire workflow was carried out under the continuous supervision of the DIH, which always maintained contact with the relevant digital actors. As specified in the last set of interviews during the maintenance stage of the solution, the DIH director also visited each entrepreneur personally and regularly.

The DA platform has been operational since May 2019. The technology installed in the three companies' manufacturing plants produces data for decision-making purposes regarding the state and status of their machinery and production processes. The entrepreneurs and their employees now are able to access the platform and use the interface correctly. Notably, one of them has decided to increase the investment by extending the DA monitoring to additional machineries.

It is therefore possible to state that the use cases have been successfully completed and this has allowed the DA developers to gain more experience in this emerging business segment, and thus identify new opportunities for improvement. At the same time, the DIH is also enhancing the results obtained from these first use cases during its continuous dissemination activities.

4.4. Digital artisan follow-up

The maintenance phase was characterized by periodic exchanges of feedback obtained through follow-up sessions organized by the DIH. This interaction between entrepreneurs and the DA developers facilitated the implementation of additional functionalities for the DA platform. Specifically, one entrepreneur expressed the need to extend monitoring to order management. Consequently, a dedicated interface was developed to connect production with customer orders, which are often fragmented and consist of relatively low quantities. The entrepreneur reported that following the release of the interface, the design of the website's customer area was developed following the same layout. In another instance, a mobile version of the DA dashboard interface was developed to allow the entire staff to monitor production status at any time. In conclusion, all entrepreneurs continued their digital transformation processes, also considering the significant changes brought about by COVID-19. The DIH has worked to create conditions for continuous dialogue among stakeholders, while the DA developers used the platform to foster the development of additional applications.

5. Discussion

The following section explains how the empirical evidence gathered from the exploratory action research enabled us to develop a final model conceptualizing the dynamics taking place in the KE. It therefore presents the internal evidence, following the dimensions of the preliminary framework and illustrating the match between the theory and the empirical evidence (Section 5.1). The internal evidence led to a final model that incorporated a fifth dimension—location (where)—relating to the presence of a regional knowledge ecosystem led by a KB who is the innovation intermediary covering the role of leader of the KE (Section 5.2).

5.1. Connecting the knowledge ecosystem dimensions

The DA platform case, on the one hand, showed that a KE focuses on the early stages of knowledge creation (Clarysse et al., 2014; Valkokari, 2015) and provides a preliminary stage for building other types of ecosystems. On the other hand, the case KE demonstrated that innovation intermediaries (in this case, KBs) are necessary knowledge actors for the creation and development of successful ecosystems (Teece, 2016).

The importance of clarity in the early stages of KE development is emphasized in this context, aligning with existing research on ecosystem leadership (Foss et al., 2023). This emphasizes that an ecosystem's formation is more efficient when its key participants possess a shared, coherent vision. This collective vision acts as a mechanism for coordination, allowing different members to align their complementary investments (Richardson, 1997). It forms a fundamental cognitive framework, as described by Adner (2017), encompassing a multilateral alignment structure. This includes an understanding of the potential combined offerings, the dependencies between them, the governance structure, and each participant's role and contribution to the broader ecosystem. While this vision may initially be broad and adaptable (referred to by Dattée et al. (2018) as a "protovision"), it must encompass enough mutual comprehension of the anticipated coordination and cooperation challenges. This understanding is crucial for participants to commit to jointly developing the ecosystem, make necessary ecosystem-specific investments, and agree to common regulations and agreements.

In our case, the mission of the KB, as represented by the regional DIH, was to support the digital transformation of MSMEs. This was achieved by connecting these firms to external knowledge sources, including technical providers, academia, and regional institutions. In so doing, the DIH as a KB is the innovation intermediary acting as leader of the KE by managing the diffusion of knowledge related to digital transformation. Specifically, The DIH assumes the role of a KB acting as a leader that,

thanks to its dynamic capabilities of sensing, seizing and reconfiguring (Foss et al., 2023), is able to provide a multifaceted knowledge, able to interface with MSME entrepreneurs, technology suppliers, and various external stakeholders. This represents an element of novelty as the KB was not limited to a traditional brokerage between supply and demand of a solution, but, in this specific case in which the MSMEs are involved, before the pure intermediation, the KB has had to create the conditions to trigger a demand for technology. As a matter of fact, if on the one hand this demand did not yet exist, on the other hand the offer of technology was not ready due to the lack of knowledge of the MSMEs context by the providers. These relevant lacks have been filled by the actions put in place by the KB. Moreover, this actor benefits from a high reputation and recognition among the local actors and by an in-depth awareness of KE actors' needs and capabilities. These two characteristics, reputation and awareness, enable the DIH to recognize organizational needs, match the right partner with the right technological solution, and shape the knowledge diffusion among participants for boosting awareness on digital transformation.

Also, the DIH exhibits the capacity, particularly in the initial stages of ecosystem development, to guide its members towards a collective and harmonious comprehension of the overall value proposition related to the spread of digital transformation and knowledge for MSMEs. This includes an initial mutual recognition of both the advantages and challenges in realizing this comprehensive value proposition. Indeed, under significant uncertainty, individual leadership can be profoundly influential in directing the collective journey of ecosystem participants (David, 1992). With the rise of the regional KE, a key function of the DIH is to sway other members towards a common vision. This instance solidifies the insights derived from research on ecosystem leadership (Foss et al., 2023). Furthermore, it underscores the concept of cognitive leadership or what Foss (2007) describes as "strategic belief management." This approach enables the DIH to shape others' beliefs to foster highly cooperative, coordinated states through the "provision and enforcement of cognitive frames" (Witt, 1998: 166). Lastly, the DIH's role as a KB also aligns with the findings of Macias Aragonés et al. (2020) and Vakirayi and Belle (2020), who investigated exemplary instances of DIHs serving as pivotal links.

By following this stream, our findings advance those of Järvi et al. (2018), showing that each actor participates in a KE with different interests that require a shared search for new knowledge that would not be possible to obtain independently. From the three sets of interviews, it was noticeable that these motivations were shaped by the KB who matched the multiple interests involved: the initial motivation of the technology provider was to test its solutions and build use cases to disseminate its business model, whereas the initial motivation of the MSMEs was to gain knowledge of digital transformation in order to address this process. The KB is in fact the actor who was able to manage the knowledge flow on the basis of a clear value proposition that has been defined at the ecosystem level. This ecosystem value proposition, which can be summarized as the creation of a favorable environment for the digital transformation of MSMEs, has guided the whole process up to the launch of the DA platform.

Using a set of knowledge organizational activities typical of KEs and KBs (Haas, 2015; Crupi et al., 2020), the DIH acted on the aforementioned motivations to empower the created regional KE. The knowledge selection, exchange, and integration activities were organized as means to create awareness of digital transformation among MSMEs by involving local knowledge sources in explaining the need to engage in this process. These activities ensured knowledge exchange and integration between MSMEs and technical providers regarding the proposed DA solution. In face-to-face meetings, the DIH mediated the potential of the DA platform for SMEs, explaining its practical benefits for their businesses.

At this stage of development, the knowledge organization, characterized by regular follow-up meetings organized by the DIH, led to the shaping of initial motivations based on new knowledge. The technology provider understood that it was necessary to involve MSMEs as partners in the technical solution, while MSMEs became aware of the need to invest in digital technologies, as the proposed DA. As the case showed, the knowledge-based practices managed by innovation intermediaries generated financial and non-financial value by fostering a collaborative project (De Silva et al., 2018). At this stage, the DIH began a process of knowledge appropriation through financial scouting to ensure that the new motivations were satisfied, leading to the launch of DA and its adoption by MSMEs. Securing a grant through a targeted tender demonstrated the DIH's reconfiguration capability, as well as a significant effort to mitigate the financial barriers to digital adoption. This endeavor not only eased the economic challenges but also cemented the DIH's role as a trusted innovation intermediary among the ecosystem's participants.

However, as the literature has confirmed, one of the main managerial challenges of an innovation intermediary is building trust between participants, especially when the output of collaboration is uncertain (Fawcett et al., 2012), as in the case presented here, with the DA solution was still at an experimental stage of development. In this regard, results show that use cases, which are the real setting and application of technologies on the production processes of companies, played a particularly important role as they represent a first tangible outcome of the joint efforts carried out at the ecosystem level.

However, the four proposed dimensions proved inadequate for explaining how innovation intermediaries in their role of KBs foster trust between MSMEs, persuading them to invest in digital technologies; hence, as illustrated in the next section, it was necessary to consider a fifth dimension revealed by the interviews—"where?"

5.2. Toward a location-based knowledge ecosystem through knowledge brokerage and knowledge enabling

As the interviews with the DIHs, entrepreneurs, sales manager and spin-off revealed trust emerged as the main factor enabling the creation and evolution of the regional KE. On the one hand, the trust dimension was found to be the factor motivating MSMEs to enter the regional KE and participate in the initial knowledge activities. Later, trust became crucial for partners to remain in the KE and contribute actively to the knowledge appropriation phase by investing some of their financial resources in the adoption and development of the DA platform. MSMEs' trust was also required by the technology provider in the KE, who was proposing an innovative solution that was still in its experimental stage of development.

The action research methodology made it possible to analyze the mechanisms that fostered trust among entrepreneurs (Roundy and Fayard, 2019). As highlighted by the interviews, trustful relationships were ensured by the KB (in this case, the DIH), which was responsible for the knowledge activities from the beginning, linking the knowledge actors and processes into an effective organizational model and influencing their initial motivations.

The activities organized by the DIH aimed to encourage informal discussion between MSMEs and technology providers, mainly through face-to-face meetings. Above all, the knowledge actors were all located in the same regional territory. This feature supports Scaringella and Radziwon's (2018) argument, according to which a KE covers key aspects of collaboration and knowledge exchange that are strongly connected to a territorial perspective.

This study, as anticipated by Bianchi and Bertini (2016), suggests that creating an effective KE depends on appropriate regional development policies. By recognizing the location (where) dimension, KBs as innovation intermediaries covering the role of leaders of the regional KE can influence local entrepreneurs' projects and support the launch of products that reflect the unique social, environmental, or technological challenges residents face in their region (Owen-Smith and Powell, 2006); thus, the case revealed how KBs may be used to capture benefits for wider national or regional innovation systems (De Silva et al., 2018;

Feldman and Lowe, 2017). The role of the territory was introduced by Crupi et al. (2020) in their discussion of the digital imprinting of KBs, according to which the activities facilitated by KBs in DIHs are linked to their territories of reference. This dimension explains a fundamental difference between KEs and other types of ecosystems, such as business ecosystems: as suggested by Clarysse et al. (2014), whereas a KE revolves around a set of central local actors, business ecosystems are not recognizable at the local level.

Thus, the case enabled us to position the "where" dimension as the pillar of regional KE. On the one hand, this dimension allowed the KB to obtain detailed information about the needs of local MSMEs; win their trust, which is a precondition for participating in a KE; and interact with other knowledge actors. On the other hand, MSMEs' lack of knowledge about digital transformation required a location-based approach that could gradually help them understand and participate in digital transformation. In this context, the KB selected relevant knowledge for making MSMEs aware of the role of digital technologies. In other words, the "where"dimension reduced uncertainty among MSMEs and facilitated knowledge actors' participation in the KE, not only through the brokerage of knowledge but also enabling it.

These findings are consistent with the theory of knowledge proximity relationships found in the economic geography literature, which highlights the impact of geographical proximity on innovation. According to this literature, proximity, defined as the spatial and physical distance between economic actors, reduces uncertainty and minimizes coordination problems. As the case showed, short distances favor the exchange of tacit knowledge (Boschma, 2005), and a key reason for this is that proximity fosters mutual trust. Through activities limited to a specific area, KBs can reduce distances (Villani et al., 2017).

However, as pointed out by Boschma (2005), geographical proximity alone is neither necessary nor sufficient for successful knowledge transfer, despite being a key enabler. Indeed, as our case indicated, prior to the involvement of the KB, the KE did not exist. Furthermore, as asserted by Nilsson (2019), a place cannot have a boundary-confined territory but depends on continuous fields in which linkages are created and exchanges take place; thus, to create a KE that can support the digital transformation of MSMEs, we argue that it is necessary to identify a KB that is rooted in the "where" dimension of the knowledge actors.

Based on the five dimensions, Fig. 3 conceptualizes the KE by incorporating the "where" dimension, represented by the regional KE in which the DIH was placed, as the fundamental factor enabling the KB to create and develop what can be called a Location-Based Knowledge Ecosystem. As shown in Fig. 3, the characteristics and dynamics of the KE, described by five dimensions, are defined through a process of knowledge brokerage and knowledge enabling. This process is led by the KB who manages the knowledge selection, exchange, and appropriation phases through its dynamic capabilities.

More specifically, this new form of regional KE is characterized by two major classes of activities implemented by the KB thanks to its dynamic capabilities of sensing, seizing, and reconfiguring, that mutually reinforce each other, namely knowledge brokerage and knowledge enabling. It is through the action of brokerage (knowledge brokerage) that KB are able to trigger dynamics within the ecosystem, which gradually gains traction through a process of knowledge enabling among the various actors present within it.

It is within this context that the succession of these two macro-activities allows for the occurrence of Knowledge Selection, Knowledge Exchange, and Knowledge Appropriation.

As a matter of fact, the DIH's networks ensured the effectiveness of brokerage by aligning the motivations of the knowledge actors with a common mission of promoting the digital transformation of MSMEs. The opportunity to impact the motivations of the knowledge actors was provided by the consistent mentoring approach of the DIH toward the MSMEs. The DIH played a proactive role in taking charge of the organization of the KE by fostering partnerships and identifying financial resources.

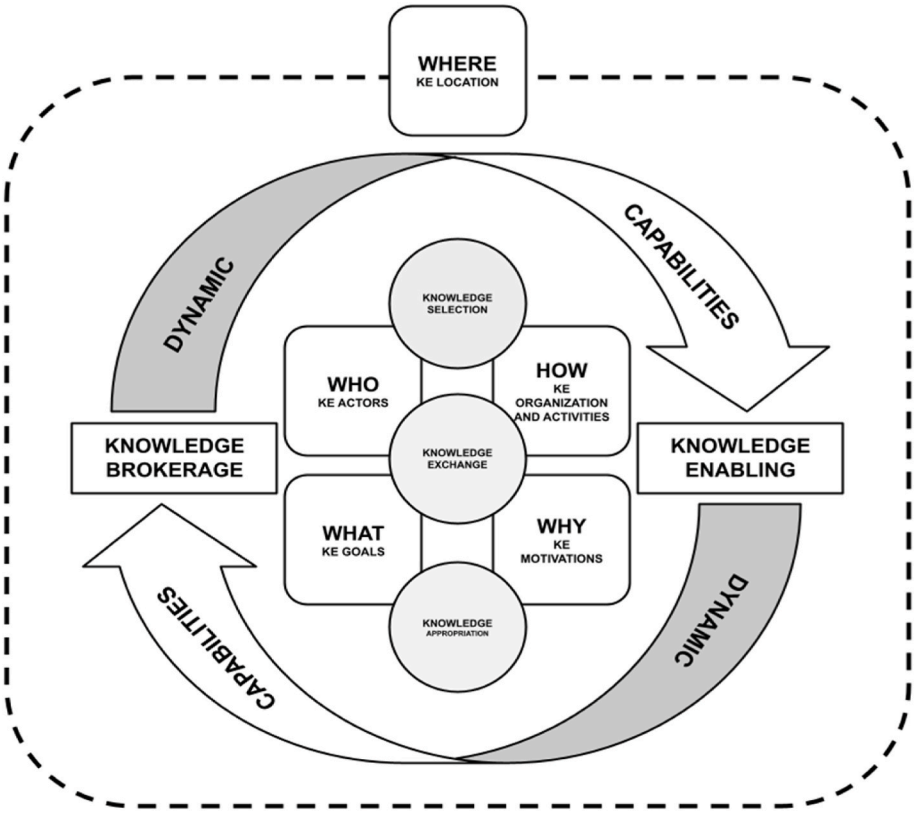

Fig. 3. The location-based knowledge ecosystem.

6. Conclusions

This paper, based on exploratory action research, explains how a KE led by a KB as the innovation intermediary of the ecosystem can facilitate the digital transformation of MSMEs, motivating them to invest in digital technologies, even at an experimental stage of technology development. Notably, the case showed how the intervention of a trustworthy innovation intermediary can support MSMEs, even when the outcomes of collaboration are uncertain. The action research underpinned a multi-grounded process that demonstrated how the location dimension allowed the KB to ensure that the MSMEs entered and remained in the regional KE through a synergetic activity of knowledge brokerage and enabling.

6.1. Theoretical contributions

In terms of its theoretical contribution, our study proposes the following implications. First, the main contribution of our study lies in disentangling the crucial role played by regional KEs in fostering digital transformation for MSMEs through innovation intermediaries, namely KBs leading the ecosystem. As clearly emerged from the theory, even if digital transformation is crucial for MSMEs to maintain a competitive advantage, these firms struggle to find the resources and the right environment to implement digital transformation strategies and cannot address this challenge alone. In this sense, our findings enhance and connect the literature on KEs (Gupta et al., 2019), knowledge brokerage (Crupi et al., 2020) and ecosystem leadership (Foss et al., 2023) by examining the internal dynamics of KEs, emphasizing the leadership role of KBs as the innovation intermediary facilitating the development of a regional KE. This is possible by creating a shared vision through the KB's dynamic capabilities. This vision is centered on disseminating knowledge of digital transformation among MSMEs and connecting them with resources to assist in overcoming the challenges they encounter in accessing and investing in digital technologies (Bollweg et al., 2020).

Second, the five identified dimensions provide a model for studying the creation and evolution of regional KEs, shedding light on how the dimension "location" can impact the digital transformation of MSMEs, thereby fostering recognition of location-based KEs. Our study highlights a new perspective on the digital transformation mechanisms in organized environments, and illustrates how KEs might foster entrepreneurship based on digital technologies solutions. From this perspective, our findings reveal the importance of the location and the knowledge of the actors involved in the regional KEs. KBs that possess a clear understanding of the technologies and the territories' needs play a crucial role in fostering collaborations based on technical solutions. Within this vein, our paper answers the call for new empirical investigations on the impact of digital technologies on innovation management and the definition of entrepreneurship in the digital age (Crupi et al., 2020), with specific attention to the ecosystem perspective (Elia et al., 2020).

The proposed conceptual model can guide the collection of information to support an understanding of the role of KBs as innovation intermediaries shaping collaboration and participation mechanisms in a regional KE. In particular, our study highlights what are the dynamics that are activated within a KE to support the digitization of SMEs and how the various actors involved are decisive, in their own way, to facilitate this transformation. Accordingly, such an aspect is strongly debated in modern literature which has increasingly studied what the barriers and drivers can be in the digitization of businesses (Pelletier and Cloutier, 2019). Thereby, with our study we contribute to this burgeoning literature.

6.2. Managerial implications

As for managerial implications, the findings can help managers involved in digital transformation processes or in the implementation of digital solutions by highlighting the relevance of the external environment, the importance of partners and trusted innovation intermediaries. Managers and firms should develop open innovation initiatives in collaboration with complementary counterparts (such as KBs, universities, and other firms) since partners' closeness enables them to use and integrate locally embedded knowledge and reinforce mutual trust, which are crucial in collaborative projects with high levels of uncertainty. The findings allowed us to consider an ecosystem approach as a suitable strategy for overcoming the lack of financial and organizational resources that are limiting MSMEs' digital transformations. Moreover, one of the aspects on which we want to focus is the brokerage method which goes beyond the mere matching between supply and demand. The method was effective as the broker first created the conditions for this to happen. This was possible by aligning on the one hand the MSMEs on the opportunities of digital transformation and, on the other hand, by supervising both the design steps of the technology providers and the entire R&D projects. The illustrated case therefore shows a type of regional KE management approach that seems to be successful in contexts where technological solutions are still non-existent and where the initial level of trust is low.

6.3. Policy implications

Findings provide two main policy implications linked to the role of KBs in creating and defining KEs. First, the case highlights the positive impact that KBs, namely DIHs, may have in supporting regional innovation in a European context characterized by high numbers of MSMEs. Thus, based on the insights provided, policymakers should valorise the brokering role played by DIHs by providing tailored incentives and resources to help them build and manage KEs. Second, by unveiling the extensive knowledge that DIHs hold of their respective territories, it is suggested that DIHs can provide support to regional administrators in defining new policies for incentivizing digital transformation in those territories, working to raise awareness of digital transformation and appropriate knowledge sources by considering the motivations of local actors.

6.4. Limitations and future research directions

Nevertheless, based on a single case, the results of this study cannot be generalized; thus, further research should include other cases of regional KEs in which intermediaries, such as DIHs or similar organizations, support the digital transformation of MSMEs and micro-enterprises. Furthermore, it would be of interest to analyze the evolution and ultimate development of KEs in other types of ecosystems. Quantitative studies could also contribute further to the emerging KE literature by mapping various KEs in different regions, comparing their performance using proxy variables and taking into account the actors and their motivation, activity, organization, and location dimensions. Lastly, given knowledge flows across regional borders, it would also be of interest to investigate cases that exemplify the interactions between different KEs at the national and international levels.

Declarations of interest

None.

CRediT authorship contribution statement

Luca Marinelli: Investigation, Conceptualization. **Antonio Crupi:** Writing – original draft, Validation. **Nicola Del Sarto:** Writing – review & editing, Supervision. **Dominique Lepore:** Methodology, Formal analysis.

Data availability

The data that has been used is confidential.

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