The digital transformation of SMEs – a new knowledge broker called the digital innovation hub

The Digital Transformation of SMEs –
A New Knowledge Broker Called the Digital Innovation Hub

ABSTRACT

Purpose: The study aims to understand if and how European Digital Innovation Hubs (DIHs) filling the role of knowledge brokers (KBs) can support the digital transformation (DX) of small and medium-sized enterprises (SMEs) by triggering open innovation (OI) practices.

Design/methodology/approach: After presenting a conceptual model of reference, a survey and a subsequent in-depth interview were conducted to capture evidence from Italian DIHs. These structures were selected for their growing importance, as confirmed by the National Plan for Industry 4.0.

Findings: The findings highlight that Italian DIHs act not only as KBs but also as knowledge sources that give rise to a digital imprinting process that is able to shape the DX of SMEs.

Originality/value: Research on knowledge sharing and OI has mainly focused on large firms. The study covers the gaps identified in the literature by considering the role of KBs in enabling SMEs to embrace DX.

Keywords: digital transformation, SMEs, knowledge sharing, knowledge brokers, Digital Innovation Hubs

1. Introduction

The sum of the knowledge acquired by firms (Voelpel et al., 2005) represents a key resource for the achievement of a sustainable competitive advantage (Caloghirou et al., 2004; Miller and Shamsie, 1996). By leveraging external knowledge sources, firms may expand their knowledge base (Gronum *et al*., 2012) and increase their innovative performance (Laursen and Salter, 2006). For this reason, firms must adopt a knowledge-driven approach, as this is considered one of the strongest determinants of innovation (Scuotto, Del Giudice, Bresciani, et al., 2017).

Within the stream of knowledge management (KM) literature (Nonaka and Takeuchi, 1995), knowledge sharing (KS) is defined as the process through which firms or individuals exchange knowledge informally, without specific compensation (Tallman et al., 2004). According to Allameh (2018), KS practices can enhance organizational innovation capabilities as they may increase innovation through a positive effect on social capital dimensions. Moreover, KS practices have been

analyzed by Bogers (2012) within the open innovation (OI) paradigm, as scholars consider such practices to be a way of accessing external knowledge for achieving collaborative innovation (Bogers, 2011; Zhou and Li, 2012). Openness to external knowledge becomes even more relevant in the context of the digital transformation (DX), which is recognized as a new strategic imperative that is changing the basis of firms' competitive advantage (Fitzgerald et al., 2014).

DX is defined as the process of using digital technologies to create new business processes and customer experiences that can meet the changing business and market requirements. DX processes can provide access and means to share the knowledge that is created and transferred (Urbinati et al., 2018). Although digital technologies may play a pivotal role in the development of small and medium-sized enterprises (SMEs) (EC, 2015), such firms remain cautious in adopting the solutions offered by these emerging technologies (Schröder, 2016). Considering that SMEs are the cornerstones of the economic growth of national economies (OECD, 2017), how SMEs may adopt digital technologies is an interesting topic to investigate. Extant research on the ways that SMEs can effectively participate in DX is limited (Barann et al., 2019). At the same time, as underlined by Simao and Franco (2018), there is still a lack of attention on how relations with external partners can deliver knowledge that can be exploited by firms, especially SMEs. We attempt to fill this gap by exploring the following research questions: Can DIHs be considered knowledge brokers? If so, how are DIHs supporting the DX processes of SMEs?

To answer these questions, we explore the role of knowledge brokers (KBs) in supporting the sharing of knowledge for the DX of SMEs. Indeed, KBs, defined as individuals or organizations that mediate interactions between a pair of unconnected actors (Burt, 2007), may help SMEs in their DX. The study is based on the case of Digital Innovation Hubs (DIHs), defined as one-stop shops that can help companies become more competitive with regard to their business/production processes, products, or services by using digital technologies. The study aims to understand if and how DIHs can be conceived as KBs to facilitate the introduction of digital technologies in SMEs by triggering OI practices. The research draws upon the Italian case due to the importance of these DIHs in driving the DX of SMEs as a result of the Industry 4.0 National Plan, "Piano Nazionale Industria 4.0," implemented by the Italian government in 2017.

Our findings show that Italian DIHs act not only as KBs but also as knowledge sources that support the exchange and integration of knowledge between SMEs and the DIHs partners, who are chosen as digital technology providers for the SMEs. Overall, the Italian sample of DIHs provides evidence of a process that, according to our findings, we name digital imprinting. This is a process by which the inner characteristics of a KB impact the DX process of SMEs.

The article is structured as follows. In sections 1 and 2, the literature on KS and KBs is reviewed and links with the OI paradigm are considered. Then, in section 3, after presenting the conceptual model, the methodology and context of the study are explained. In sections 4 and 5, the findings are discussed, and then conclusions are drawn and suggestions for future research are presented.

2. Understanding the relationship between knowledge management and innovation

Knowledge management (KM) has become a crucial function for business organizations (Xu and Bernard, 2011) that helps to identify critical assets to focus on to pursue competitive advantages (Sharkie, 2003). KM is defined as a process established to capture and use knowledge for the purpose of improving organizational performance and capabilities (Khalfan et al., 2010). The integration of knowledge into management decisions and practices can depend on the extent to which the organizational culture supports or impedes knowledge processes (Interazi et al. 2017). KM practices are often considered together with innovation since the two are logically linked (Perry and Uys, 2010). There is increasing evidence that knowledge is a key driver that supports innovation processes and their management (Darroch and McNaughton, 2002). The integration of knowledge management and business model innovation can lead to a sustainable competitive advantage (Bashir and Farooq, 2019).

Biscotti et al. (2018) find that employee training and development programmes as knowledge management tools can encourage the firm's propensity towards innovation within the field of environmental protection. Similarly, Papa et al. (2018) based on a sample of Italian firms operating in different sectors argue that employee retention and human resource management practices can positively moderate the relationship between knowledge acquisition and innovation performance. Further, Usai et al. (2018) reveal that entrepreneurial knowledge combined with the attitude to innovate can even overcome typical "imperfections" of innovation processes (i.e. risk management, hold up problems and asymmetric information) generated by technological advancement in knowledge-intensive sectors. Then, considering the context of multinational corporations, Ferraris et al. (2017) show that subsidiaries with superior KM capabilities result more effective in using external Research and Development (R&D), enhancing the extent of their external sources of knowledge, and consequently improving their innovative performance. Further evidence is captured in the banking sector by Peruta et al. (2014) finding that investments in innovation can increase if the enterprise favours the exchange of information with the banking system.

These considerations lead to consider KS as a crucial part of KM programs (Donnelly, 2019; Oyemomi et al., 2019). According to Van Den Hooff and De Ridder (2004), KS is a process in which individuals mutually exchange their implicit (tacit) and explicit knowledge to create new knowledge.

While explicit knowledge is codified and expressed in formal language (Nonaka and Takeuchi, 1995), tacit knowledge is intuitive and unarticulated, and it cannot be verbalized (Li and Gao, 2003). As underlined by Voelpel et al. (2005), knowledge is represented by the sum of the knowledge that is acquired and, thus, shared externally and internally. This process constitutes a resource for achieving a sustainable competitive advantage and may prove beneficial as it may promote firm innovativeness through external linkages (Caloghirou et al., 2004). Different knowledge sources can enable the flexible transfer of specific and commercially sensitive information about new product designs, new production processes, and market developments (Bönte and Keilbach, 2005).

Easterby-Smith and Prieto (2008) argue that learning processes can moderate the relationships between knowledge exploration and exploitation considering the firms' KM ability within the framework of dynamic capabilities. Mariano and Awazu (2016) discuss instead the role of artifacts and their benefits when designing KM processes and infrastructures, aware of the linkages between KM systems, KS and digital archives. Further, Santoro et al. (2017) show through a quantitative approach on a sample of Italian firms in the food industry, that firms' market-based sources are usually associated with income from incremental innovation and time to market, whereas science-based sources are linked with income from radical innovation.

Above all, these studies confirm the need to integrate new knowledge with existing knowledge (Cohen and Levinthal, 1990) leading to consider a knowledge search strategy to select new and valuable ideas among a large set of external sources of knowledge (Laursen and Salter, 2006), including customers, suppliers, competitors, universities, and other public and private institutions. Previous studies identified two dimensions of this search strategy: search breadth and search depth (Chiang and Hung, 2010). Search breadth is based on the diversity of the sources and thus calls for an extensive search strategy, which is characterized by establishing relationships with a high number of organizations. Search depth is related to the degree of intensity in relationships with a limited number of external sources (Laursen and Salter, 2006). In this field, according to Swan et al. (1999), KM practices focusing on Information Technologies (IT) as a means to create a network structure may even limit its potential for promoting KS across social communities.

However, even if KM—and, in particular, KS with external sources—gives rise to competitive advantages, this is more commonly observed in large companies rather than in SMEs (Ferraris et al., 2017; Gomezelj Omerzel and Antončič, 2008). SMEs are less structured because of the lack of formal KM procedures and the lack of tangible and intangible resources (Baptista Nunes et al., 2006). However, SMEs have realized the necessity of establishing external relationships to share and exploit talented resources and knowledge (Srikantaiah et al., 2000), especially for supporting innovation processes. In this field, Dezi et al. (2019) show that KM can play a significant role in mediating the

effects of external embeddedness on firm ambidexterity for SMEs, which in turn increases their performance. In general, the creation and use of new technologies have led entrepreneurs to exploit external opportunities to generate new business ideas (Schumpeter, 1934), enhancing their alertness and ability to discover new opportunities (McCaffrey, 2014). Nevertheless, as specified by Simao and Franco (2018), little is known about the ways in which the involvement of external partners can deliver knowledge that can help firms implement a wide range of organizational practices.

2.1. Knowledge sharing in the open innovation paradigm

As KS practices can be considered a way to access external knowledge for achieving innovation (Bogers, 2012), they have been analyzed by previous scholars through the lens of OI (Bogers, 2011; Chesbrough and Di Minin, 2008; Zhou and Li, 2012). OI is one of the multiple ways that organizations can gain access to external knowledge to speed up their innovation processes, access new markets, and reach external knowledge sources (Chesbrough, 2003). OI practices enable firms to combine internal and external ideas, technology, and R&D and to use both internal and external paths to market their products (Chesbrough, 2003).

Following the definition presented by Chesbrough (2003, 2006), OI is an organization's purposive inflow and outflow of knowledge across its boundaries in order to accelerate innovation and expand market opportunities or strengthen its business model. Purposive outflow, also called exploitation, takes place through different processes, as specified by Van de Vrande et al. (2009). These processes are related to knowledge venturing, outward licensing of intellectual property (IP), and involvement of non-R&D workers in innovation activities. On the other hand, purposive inflow, or exploration, is mainly linked to customer involvement, external networking, and collaborative projects aimed at accelerating internal innovation (Van de Vrande et al., 2009). In their analysis of agri-food businesses, Cillo et al. (2019) find that knowledge exploration capabilities can positively mediate the relationship between IT-based knowledge exploitation capabilities and open innovation, which allows collecting partners, analyzing, and using knowledge coming from crowdfunding partners.

On this ground, previous studies classified the relationship between OI and KS according to the direction of the knowledge streams, differentiating between inbound OI, outbound OI, and coupled OI processes. The first is characterized by an exchange of knowledge from outside sources. Firms tend to exploit the knowledge generated by other organizations, such as suppliers, customers, competitors, universities, and research centers. Conversely, the outbound OI process involves the flow of internal knowledge moving to outbound organizations. The third process defined coupled OI is a combination of inbound and outbound processes. In this process, knowledge flows from a focal

firm toward the external environment as well as from the external environment to the focal firm (Enkel et al., 2009; Natalicchio et al., 2017).

Overall, the generation of innovative outputs is facilitated by greater openness towards external sources of knowledge. This openness encourages knowledge exchange between firms (Crescenzi et al., 2016; Scuotto et al., 2020). This link is particularly strong considering that KS is a driver of successful collaborative innovation in the context of OI (Bogers, 2012). In this field, Casprini et al. (2017) show that distinctive capabilities, labelled as imprinting and fraternization, can help overcome the barriers to acquiring and transferring internal and external knowledge flows in the framework of OI.

Prior studies have underlined that most OI adopters are large firms, leading scholars to focus less on SMEs (Hossain, 2013). This is linked to the fact that SMEs lack the internal resources to master the new determinants of production, innovation, and competitiveness, especially when searching for specific OI opportunities, unlike large firms (Bianchi et al., 2010; Van de Vrande et al., 2009). Nevertheless, some studies have demonstrated that SMEs can improve their overall innovation performance by adopting OI and KS approaches (Hossain and Kauranen, 2016; Scuotto, Santoro, et al., 2017). Moreover, studies have highlighted that KS is the result of the message transmission from an origin to a beneficiary in a particular setting (Del Giudice et al., 2015).

3. The need for open and integrated approaches to the digital transformation of small and medium-sized enterprises

Nowadays, companies, especially SMEs, are facing the new challenge of DX. This phenomenon, also known as digitalization, refers to a business model driven by "the changes associated with the application of digital technology in all aspects of human society" (Stolterman and Fors, 2004, p. 689). In a challenging and competitive environment, companies seek to exploit opportunities by using technologies (Del Giudice and Maggioni, 2014; Del Sarto et al., 2019; Scuotto, Del Giudice and Carayannis, 2017) to achieve changes and creative destruction (Chesbrough, 2003; Gemünden et al., 2007). Moreover, DX plays a key role in enhancing KM-based practices that involve the inflow and outflow of KS (Messeni Petruzzelli and Rotolo, 2015). Digital technologies, involved in DX, are acting as a disruptive force that is reshaping firms' operations and organizational structure (Di Minin et al., 2019).

At a strategic level, studies have been focusing on systematic approaches to define a DX strategy (Hess et al., 2016) and on the effects of DX on competition and external decisions for individual industries (Kretschmer and Claussen, 2016). At an organizational level, scholars have investigated the impact on the processes, routines, capabilities, and structures through which organizations adapt

and innovate (George and Lin, 2017). Specifically, they highlighted the need for higher levels of business model innovation (Baldwin and von Hippel, 2011) and underlined how new technologies are challenging companies' internal capabilities and skills (Teece, 2012; Zahra et al., 2009).

In addition, studies have explored how digital technologies affect the ability of SMEs to achieve and sustain a competitive advantage over time (Lanzolla and Frankort, 2016; Markides and Sosa, 2013). Digital technologies enable knowledge to be created and transferred (Urbinati et al., 2018), giving rise to open and distributed innovation processes (Remneland-Wikhamn et al., 2011). However, due to the characteristics and differences of SMEs with respect to large firms, as underlined in studies on both KM and OI, there is a need for tailored approaches based on integration strategies as well as cooperation with other firms along the value-added chain (Müller et al., 2018). Therefore, the DX of SMEs can take place only via the integration of internal and external enabling factors (Quinton et al., 2018). The main internal factors are the organization's and entrepreneur's degree of openness towards innovation (Bharadwaj et al., 2013). The entrepreneur is often the sole decision-maker and therefore has a relevant role in the adoption of digital technologies (Li et al., 2018; Quinton et al., 2018). On the other hand, external factors include so-called "environmental factors" (Bharadwaj et al., 2013; Quinton et al., 2018), such as third-party digital platforms (Banerjee and Ma, 2012) and digital service providers (Li et al., 2018). Combined with the involvement of other companies, customers, and institutions, they have a strong impact on the embracement of DX and foster the creation of digital ecosystems (Brohman and Negi, 2015). Both types of factors require a higher degree of openness in SMEs (Lee et al., 2010).

3.1. The role of knowledge brokers in supporting the digital transformation of small and medium-sized enterprises

Although KS practices should contribute towards increasing firms' competitiveness, SMEs face difficulties in implementing these practices effectively (Dayan et al., 2017). According to Ritala et al. (2018), KS with external sources may be risky if not handled properly. Even if knowledge is a critical asset for achieving competitive advantages (Bolisani and Bratianu, 2017; Del Giudice et al., 2017), the application of such knowledge may be costly and ineffective (Massingham, 2014). In this context, individual or organizational KBs can mediate interactions between a pair of unconnected actors (Burt, 2007) by moving knowledge around, creating connections between researchers, inventors, and receptors in the market, and by taking advantage of the way in which scientific knowledge is transported and translated across organizational boundaries (Meyer, 2010).

Furthermore, brokers can support innovation by covering structural holes and bridging gaps in the flow of information between different groups (Burt, 2004).

Specifically, KBs can facilitate the transfer of complex knowledge between their clients and external sources of knowledge that are not directly related and rarely interact (Abbate and Coppolino, 2011; Verona et al., 2006). By doing so, they can work with their clients to obtain innovative solutions from external sources (Hargadon, 2002). Knowledge brokerage involves gaining access to relevant external knowledge sources, establishing contact between their clients and these sources, learning about the client's problems, linking the client and external source for knowledge transfer, and, finally, building environments for innovation (Hargadon, 2002).

Often, KBs are involved not only in the transfer of knowledge but also its conversion, which entails localization, identification, redistribution, dissemination, re-scaling, and transformation of knowledge (Haas, 2015). For this reason, KBs have been described as invention factories (Hargadon, 1998), knowledge transformers (Harada, 2003), or gatekeepers (Ishiyama, 2016). Although KB definition often coincides with that of boundary spanners and gatekeepers, KB do not belong to either group that they span (Paraponaris et al., 2015). In addition, research on KB is more recent and less developed than research on boundary spanners and gatekeepers (Paraponaris et al., 2015). Looking into the context of public administration, KBs identify and target knowledge, assist knowledge creation, translate and adapt knowledge, negotiate and convince, outreach and network, promote capacity building, and use knowledge by integrating internal and external knowledge (Olejniczak et al., 2016).

However, to be effective, KBs ought to be fluent in both the language of research and the language of action and decision (Schlierf and Meyer, 2013). In other words, KBs must be aware of both the research process and users' decision-making processes and must have a solid understanding of the political and economic factors that influence decisions (Naylor et al., 2012). Researchers have observed the emergence of organizations that are adopting the role of "virtual knowledge brokers" which are defined as "actors who leverage the internet to support third parties' innovation activities" (Verona et al., 2006, p. 765). Virtual KB can act through Internet sites dedicated to gathering customer feedback in targeted industries (Verona et al., 2006). Moreover, KBs can facilitate knowledge collaboration by leveraging OI practices due to the interactive nature of knowledge exchange in multi-actor settings (Randhawa et al., 2017). Liu and Li (2017) suggest a model that can ensure a better matching between technological knowledge suppliers and users through KB in an open innovation setting by considering the stakeholders' psychological behaviours. Above all, intermediaries can be considered facilitators who support OI processes for SMEs (Lee et al., 2010). KBs, as intermediaries,

are essential for establishing ties with other players in order to access new information, turn that information into knowledge, and transform it into a marketable result (Chiaroni et al., 2011).

With these considerations in mind, the present study is based on two models that connect KM and OI. The first model, developed by Wallin and von Krogh (2010), outlines the steps for integrating knowledge in OI. This integration requires the identification of relevant knowledge, then the selection of appropriate integration mechanisms, followed by the creation of effective governance based on the definition of incentives and control. The second, developed by Fetterhoff and Voelkel (2006), describes five steps of OI: seeking opportunities, evaluating market potential, recruiting potential development partners, capturing value through commercialization, and extending innovation offerings. Drawing upon these models, we codified a unique pattern based on three steps—knowledge selection, exchange integration, and appropriation—as shown in Table 1.

[TABLE 1]

4. Methodology

The paper builds a case study (Siggelkow, 2007, Yin, 2009) using as research setting Italian DIHs, which are a European means of supporting businesses, mainly SMEs, under the Digitising European Industry (DEI) strategy launched in 2016. First, we choose DIHs to answer our research questions because they play a key role in supporting companies in introducing digital technologies in their business/production processes, products, or services. Second, they are based upon a technology infrastructure that provides access to the latest knowledge, expertise, and technology to support DIHs in facilitating the DX of SMEs. Finally, DIHs provide business support to implement these innovations. As proximity is crucial, they act as one of the first regional points of contact and as regional multi-partners (including organizations like universities, industry and artisan associations, chambers of commerce, incubators/accelerators, regional development agencies, and even governments) that have strong linkages with service providers outside their regions and support companies in accessing their services.[1]

Based on the literature review, which connects KM and OI, a conceptual model is presented (Figure 1) recognizing KBs as intermediate actors for connecting SMEs to external knowledge sources through the three categories of activities that have been identified and linked to the typical OI steps: selection, exchange-integration, and appropriation of knowledge. The linkages with the OI paradigm are included, not only specifying the activities from the three categories but also considering

[1] https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs

OI exploitation and exploration, as stated by Van de Vrande et al. (2009). Applying the concepts of OI exploitation, as the knowledge that is transferred from SMEs to external sources and OI exploration as knowledge transferred from external sources to SMEs, the model incorporates the multi-directional role of KBs.

[FIGURE 1]

The model has been tested with a qualitative research methodology on the Italian DIHs to understand whether and how DIHs fulfill KBs' role in supporting the DX of SMEs. Qualitative research is a suitable methodology when the researcher investigates a new field of study or intends to theorize about prominent issues (Corbin and Strauss, 2014; Creswell and Poth, 2016). In addition, this methodology is appropriate when the focus of the study is on answering "how" and "why" questions and the contextual conditions are relevant to the phenomenon under study (Yin, 2009), as is the case in this study, which focuses on DIHs in Europe, specifically Italy. Furthermore, by using a phenomenological approach, the study avoids generalization based on theories and models and instead captures the complexity of the phenomenon under examination (Siggelkow, 2007). Applying an inductive research strategy enhances the research's contribution to existing theory by identifying new trends and experiences that are not strictly described in existing theory.

Our data has been analyzed following an iterative qualitative research design which allows us to develop our research plan with five consecutive steps (Lofland et al., 2005; Salaiz and Vera, 2017; Williams et al., 2019).

i. Definition of the Digital Innovation Hub phenomenon. To define the DIH phenomenon, we relied on the action research methodology, which involved observations, direct participation, document analysis, and the researchers' direct involvement (Greenwood, 2018; Ripamonti et al., 2016). People on the research team at various levels have been representatives at the European level for several DIHs, are expert researchers specialized in DIHs or members of competence centers during the research period. We initiated our research by participating in DIHs' initiatives, analyzing documents, and studying the state of the art in the literature to create our preliminary research strategy.

ii. Definition of open innovation practices. According to our preliminary direct observations and based on the current literature, in the second semester of 2018, we collected the first wave of data through a survey (Annex 1) that was forwarded to all Italian DIHs to preliminarily explore which OI practices they perform. The survey was based on the OI activities indicated by Van de Vrande et al. (2009).

iii. Validity checks. To guarantee the validity of our preliminary observations, we collected and examined data from multiple sources, and we used respondent validation (Locke and Ramakrishna Velamuri, 2009). After analyzing the survey data, we conducted several meetings with participants who were actively involved in DIHs' activities to validate our preliminary observations and the list of questions for the in-depth interviews.

iv. Defining Digital Innovation Hubs' activities. During the first semester of 2019, we performed 11 semi-structured interviews to investigate the mechanisms and logic behind the knowledge-sharing activities and OI practices performed by DIHs. Phone interviews were addressed to the contact person of the DIH activities, as indicated in the European catalogue of DIHs[2] (duration: 60 minutes). Semi-structured interviews (annex 1) are used since these allow greater flexibility and thus provide a wider picture of the phenomenon under investigation (Seidman, 2006). After reviewing the general characteristic of the DIH, the interview focused on the OI and KM practices carried out by the DIH to support SMEs.

v. Coding. Using the manual coding technique, we iteratively conducted line-by-line coding of the interview data and used the codes to identify the different activities of the DIHs, based on the activities identified in Table 1.

4.1. The research setting

4.1.1. The European context of Digital Innovation Hubs

Fully operational DIHs are differentially distributed across Europe with the highest number in Spain (47 DIHs), followed by Italy (30 DIHs) (Figure 2). DIHs have different structures, including clusters of organizations (18%), specific programs or initiatives, which are usually publicly funded (12%), and RTO (12%). Less frequent structures include joint ventures and alliances and regional agencies. A great number of these are described as units of the coordinator (34%), which in turn are represented by RTOs (23%), universities (18%), and industrial and artisan associations (7%). The residual part includes governmental agencies and clusters. In contrast, 26% do not have a specific coordinator in their structure.

In 40% of DIHs, a focus on SMEs is expressed in their missions and activities, and in 9%, SMEs are described as the only clients of the DIHs. In addition, 19% outline an interest in SMEs mainly as a result of regional, national, or European projects.

[FIGURE 2]

[2] As indicated in the European Catalogue of DIHs: https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool

Regarding the services provided, 16 activities were investigated, as indicated in Figure 3.[3]

[FIGURE 3]

These activities were analyzed based on the previously presented conceptual model and were considered in regard to the three macro-categories: knowledge selection, exchange-integration, and appropriation.

[TABLE 2]

The main services offered by the DIHs are represented in the category of integration and exchange of knowledge, including ecosystem building (89%) and collaborative research (87%), which gives rise to an exchange of knowledge among knowledge sources of different categories, mainly universities, research centers, and large firms. According to a description of their activities, purposive inflows were captured mainly in concept validation and prototyping as well as testing and validation services. Referring to the validation services, networking is important for the current partners of DIHs. As for selection, digital maturity assessment (DMA) activities, which are offered by 42% of DIHs, is the initial step for identifying relevant knowledge and selecting suitable partners. DMA activities are aimed at analyzing the current situation of SMEs to provide new growth opportunities based on networking.

Capturing value through commercialization, which was linked to knowledge appropriation, revealed to be less common among DIHs (30%). Moreover, customer involvement (i.e., the voice of the customer) and production consortia were not as fully exploited as purposive inflow and were present in only 23% of DIHs.

4.2. Focusing on the Italian system of DIHs

The research investigates Italian DIHs' role as KBs that support the DX of SMEs for several reasons. First, Italian SMEs[4] represent 99.9% of firms, compared to 99.8% in the EU, and generate 67.1% of value and 78.5% of employment in the non-financial sector, compared to the EU averages of 56.8% and 66.4%, respectively (EU, 2018). Second, there is an urgent need to focus on the DX of Italian SMEs since, as underlined by Deloitte (2018), Italian SMEs require specific support to adopt

[3] The activities are ecosystem building, visionary and strategy development for businesses, collaborative research, concept, validation and prototyping, testing and validation, pre-competitive series production, commercial infrastructure, digital maturity assessment, incubator/accelerator support, voice of the customer and product consortia, market intelligence, access to funding and investor readiness services, mentoring, and education and skills, among others.

[4] The main classes used in Europe are micro enterprises (less than 10 employees), small enterprises (10–49 employees); medium-sized enterprises (50–249 employees); SMEs (1–249 employees) and large enterprises (250 or more employees) (Commission Recommendation of 6 May 2003)

digital technologies, unlike big enterprises, which are the main adopters. The same conclusions were drawn in a recent investigation of the Italian Ministry of Economic Development, which was conducted on 24,000 firms between October 2017 and February 2018. The results show that only 18.4% of small enterprises and 35.5% of medium enterprises are adopting new advanced technologies, compared to 47.1% of large ones (MET-MISE, 2018). Third, looking more closely at the DIH system, Italian DIHs are differentiated from European DIHs due to their uniform characteristics. According to the European catalogue of DIHs, in Italy, there are 30[5] fully operational DIHs which is the second highest number in Europe. Italian DIHs emerged mainly after the DEI initiative of 2016 and are characterized by the fact that industrial and artisan associations act as their coordinators, contributing to more than half of these cases identified in Europe (67%). As for services, all Italian DIHs offer services related to awareness creation, and except for one case, all offer ecosystem building and education. Fewer focus on knowledge appropriation in terms of commercial infrastructure, pre-competitive serious production, or the voice of the customer. At the European level, Italian DIHs represent 24% of the DIHs that offer knowledge selection as a DMA activity.[6] Lastly, all Italian DIHs must work towards the accomplishment of common objectives, which are defined in the Italian Governmental Plan of 2017 for Industry 4.0. Specifically, Italian DIHs are called to raise awareness in Industry 4.0 and support the introduction of the latest digital and manufacturing technologies from a collaborative perspective.

5. Results

The surveys and interviews were conducted between March 2019 and June 2019 from 11 DIHs represented by 1 university consortium, 2 regional clusters, and 8 industrial and artisan associations (Annex 4). The survey collected evidence regarding the presence of OI mechanisms in terms of exploitation and exploration, which were further investigated in an in-depth interview lasting 60 minutes. The interview focused especially on knowledge selection, exchange and integration, and appropriation.

5.1. Survey - exploring the mechanisms of open innovation

The results of the survey highlighted the role of the DIHs in supporting SMEs in designing innovative products and processes by involving their employees. Just 4 (36.4%) DIHs found ways to also involve the final customers of SMEs. The creation of new organizations and management of intellectual property are less frequent. These two activities were identified in less than 5 SMEs and

[5] In the total number of Italian DIHs it must be considered that one DIH covers seven different regions but has one unique coordinator.

[6] The results of the analysis are presented in Annex 3.

in 4 (36.4%) DIHs. Just 3 (27.3%) DIHs provided support for the marketing and selling of products, similar to most European DIHs.

All 11 (100%) DIHs selected potential partners for SMEs to develop and implement innovative products/processes, and the highest number of SMEs were involved in this activity. Mechanisms of control over created partnerships are defined by half of the DIHs, while finding ways to incentivize follow-ups on the partnership is considered important for 9 (81.8%) DIHs.

5.2. Interviews – Digital Innovation Hubs as knowledge brokers

Interviews were conducted according to the conceptual model suggested in Figure 1. As previously explained, the model links the actors involved in KS practices in an OI context (e.g., exploration and exploitation), such as KBs, SMEs, and external knowledge sources. Accordingly, the interviews mainly focused on exploring the activities carried out by these actors (e.g., knowledge selection, knowledge appropriation, and knowledge exchange and integration) and the relationships among them.

5.2.1. Knowledge brokers

In all the examined cases, only a few people were found to be directly involved in the activities of the DIHs. The DIH represented by the university consortium (DIH1) had the highest number of technical profiles, with 10 technology experts. In most cases, there were just one or two technical profiles supported by managerial roles specialized in marketing or firm internationalization.

The strong presence of industrial and artisan associations is justified by their role in the territory:

"The DIH is open; it does not require an entry fee but there is an implicit trust mechanism given the context of Confindustria." (DIH11)

"We have widespread knowledge of the territory and its realities." (DIH9)

DIHs show a solid understanding of the political and economic factors that influence decisions of SMEs, which is a necessary attribute of KB, as indicated by Naylor et al. (2012). Their role was also confirmed by the regional cluster and the university consortium, both of which collaborate with the industrial and artisan associations in the region of reference. Moreover, the two regional clusters and the university consortium considered themselves to be acting as DIHs before the DEI program of 2016. In contrast, all the DIHs coordinated by industrial and artisan associations reported that they were acting as DIHs after 2016, when they underwent a process of restructuring of their activities in line with the objectives defined for DIHs. One industrial association (DIH4) considered DIHs to be a powerful brand positioned in Europe to access a larger ecosystem of partners that are able to support their SMEs.

On the other hand, emerging technological specializations are recognized in artificial and big data, or, more generally, in Industry 4.0-related technologies. Regarding the stakeholders connected to the DIHs, there was a strong involvement of universities, regional governments, other SMEs, and large firms. The growing role of other industrial and artisan associations acting as DIHs in other Italian regions was recognized. Furthermore, the interest of SMEs in the activities of DIHs was found to be strongly linked to the Industry 4.0 National Plan and to the SMEs' growing need to be competitive in the market.

5.2.2. Open innovation

OI dynamics already captured from the survey, were further confirmed:

> "Our holistic approach to open innovation is to accompany SMEs on a journey towards digitalization." (DIH11)

OI processes take place in different ways, such as organizing matching events between potential partners and utilizing collaborative online platforms as a first meeting point. The case of start-up involvement programs (DIH7) designed to develop new digital solutions based on collaboration between startups and SMEs, who are recognized to be unlikely to innovate, is particularly interesting.

Some DIHs also organize awareness events related to the OI approach to enhancing trust in the benefits and values of OI. Soft skills are required for both SMEs and their partners to achieve OI. The role of the personal relationship is very important in OI processes as it allows for a sustainable DX path. Overall, the DIHs promote a collaborative environment and provide a physical space where human relationships are the central focus. In addition, the introduction of OI logics to SMEs is reported to impact their organizational culture, overcoming the typical individualistic mindset of SMEs entrepreneurs. Accordingly, DIHs act as facilitators supporting OI processes for SMEs (Lee et al., 2010).

Furthermore, all DIHs recognize the importance of involving the SMEs' employees to ensure an effective transaction process and move towards digitalization. However, the ways to involve employees are recognized as being strongly linked to a set of factors, such as employees' roles and functions and the size of the SME.

5.2.3. Knowledge selection, exchange-integration, and appropriation

When selecting knowledge for SMEs, the first step for DIHs is a DMA activity aimed at assessing the SMEs' degree of digital maturity. This activity represents the basis for selecting relevant knowledge from potential partners and matching the needs and objectives identified from the SME.

The step results in line with the conceptual model presented (Figure 1) by considering the selection of knowledge, as described by Wallin and von Krogh (2010).

Then, as a following step, partners are selected by first exploiting the internal network of DIHs, as strongly underlined by the sample of industrial and artisan associations, and when necessary, relying on other players outside their network of reference. The DIHs also participate in trade shows to find other contacts of interest for their SMEs (DIH11). The exchange of knowledge takes place mainly through round tables with a DIH connecting SMEs to partners by mediating the knowledge exchange. Overall, face-to-face meetings were reported to be the most important way to enable the exchange of knowledge. These meetings are organized at the partner's venue so that SMEs can directly view the available technologies.

Within this process, DIHs play a pivotal role. In particular, in the context of industrial and artisan associations, the DIH acts as a coordinator due to associations' embeddedness in the local dimension, in terms of credibility and trustworthiness. Moreover, DIHs' members share the knowledge that is internally created through KS activities based on their cultural background and professional experience (DIH1). One of the results of this imprinting process is the mentoring activity provided by DIH to SMEs' entrepreneurs (DIH3). Mentoring and training are recognized as a first step to guarantee the integration of knowledge, together with the organization of tailored seminars that involve only a few companies.

The integration of knowledge for SMEs is supported not only by the DIH through frequent meetings but also by so-called opinion leaders identified as entrepreneurs that are already using digital technologies and that are called to share their direct experience with SMEs (DIH5).

In other cases, the integration takes place by focusing on the results supported by feedback:

"We try to simplify these activities, placing emphasis on the business benefits that can be obtained." (DIH7)

Within this vein, DIHs act as a facilitator in smoothing the communication between researcher and entrepreneurs (Schlierf and Meyer, 2013). All DIHs reported a lack of focus on knowledge appropriation, which is mainly supported by the partners that collaborate with SMEs. Therefore, tight control mechanisms are not considered to be necessary, except for informal follow-ups. From the perspective of the DIH, successful case studies are created to support other SMEs (DIH1).

6. Discussion

This work examines the role of DIHs as KBs within the DX processes of SMEs. We started with a careful review of the relevant literature concerning the linkages between KM and innovation (Perry and Uys, 2010). Then, adopting the OI paradigm (Chesbrough, 2003), we focused on KS practices

(Bogers, 2011; van den Hooff and de Ridder, 2004; Zhou and Li, 2012), which are considered a way of accessing external knowledge to achieve innovation (Bogers, 2012). Finally, we looked at KBs (Chiaroni et al., 2011) as drivers of the DX of SMEs. The findings were obtained by following the proposed conceptual model (Figure. 1), which allowed us to answer our research questions. First, consistent with Burt (2007) and Jang et al. (2015), our results confirm that DIHs act as KBs and mediate interactions between unconnected actors. These interactions boost the sharing of knowledge among organizations. We found that DIHs mainly support SMEs by leveraging a series of partnerships with external actors, such as universities, research centers, service providers, and corporations.

Second, the results confirm the linkage between OI and KS (Bogers, 2011; Zhou and Li, 2012). We found that an OI approach is a core component of each DIH in terms of both exploration and exploitation activities (Van de Vrande et al., 2009). However, these two practices are not equally addressed within the complete set of activities performed by DIHs. Specifically, exploration practices are considered more relevant for KS between SMEs and external knowledge sources (Bharadwaj et al., 2013; Quinton et al., 2018). On the other hand, exploitation practices, such as establishing relationships with entrepreneurs and encouraging and supporting the involvement of all members within the SME for innovation processes, are less relevant.

The literature fails to strongly contribute to the definition of KBs' role in supporting the sharing of knowledge for the DX of SMEs. To fill this gap, considering the results of the Italian sample of DIHs, we provide the conceptual model shown in Figure 4. The model highlights that DIHs' patterns are acting in support of SMEs' digitization processes. Based on the conceptual model, we termed the whole process digital imprinting.

[FIGURE 4]

Digital imprinting is a process in which the inner characteristics (e.g., founding members' profiles, mission, staff, technological specialization, and credibility among local recipients) of KBs and the type of knowledge (e.g., technical, relational, or territorial) that is shared shape the nature of the activities performed to drive SMEs' DX.

Our findings show that DIHs' inner characteristics and the types of knowledge that are shared help to determine the sets of products, service providers, technologies, and know-how to which SMEs have access. In addition, DIHs perform digital imprinting, confirming their role as both KBs and knowledge sources. The paths towards DX undertaken by SMEs is strongly linked to the characteristics of DIHs and their relationships with their partners. The overall process is bi-directional since the partners and SMEs can impact and enrich the key knowledge of DIHs' employees and, in turn, redefine the DIHs' inner characteristics (Feedback 1 and 2 in Figure 4).

With these considerations in mind, our findings contribute to the KM literature and shed light on the role of KBs in the KS process. By integrating the models of Wallin and von Krogh (2010) and Fetterhoff and Voelkel (2006), a novel theoretical model is introduced for exploring the activities of KB towards SMEs' DX within the OI paradigm. The model allowed contributing to the literature on KB in different ways.

6.1 Theoretical implications

The present study shows four main theoretical contributions. First, by defining the digital imprinting process and exploring the internal dynamics of DIHs' KS activities, we contribute to the ongoing debate, pointing out that DIHs act both as KBs and as sources of knowledge. Although several scholars have already found that KBs do not merely transfer knowledge (Haas, 2015; Harada, 2003), our findings imply that DIHs, in addition to being intermediaries, are capable of generating knowledge themselves based on their inner characteristics. Moreover, focusing on the SMEs' Italian context, we found that KS practices start with a knowledge selection phase, which is often based on an assessment aimed at evaluating the SMEs' level of digitization and identifying gaps.

Second, we identify the role of KBs in overcoming the barriers in the relationship between KS and OI for SMEs. As previously noted, most OI adopters are large firms because of their abundant internal resources and their ability to influence the external environment (Hossain, 2013). By focusing on SMEs, which sometimes struggle when adopting OI practices due to a lack of internal resources (Bianchi et al., 2010), our study highlights the key role played by these actors in promoting the OI paradigm among SMEs. DIHs become not only a space in which to share knowledge but also a trigger to help SMEs reach higher levels of openness, which in turn encourages the exchange of knowledge between firms (Crescenzi et al., 2016).

Third, our findings suggest that DIHs, due to their nature and capabilities, are not only facilitators in the creation of relationships but also are active players in the definition of connections and selection of the best partner for SMEs according to the SMEs' initial DMA. These results are in contrast with previous literature, which states that KBs ease the transfer of complex knowledge between their clients and external actors without direct involvement or interaction (Abbate and Coppolino, 2011; Verona et al., 2006). However, less evidence is found in the area of knowledge appropriation, as in the commercialization of outputs and involvement of SMEs' customers.).

Fourth, previous studies have shown how DX impacts SMEs' ability to achieve and increase their competitive advantage over time (Lanzolla and Frankort, 2016; Markides and Sosa, 2013). SMEs require tailored solutions focused on integration (Müller et al., 2018) due to their specific characteristics. DIHs act as external enabling factors (Quinton et al., 2018) that foster connections with other companies and institutions mediating the interaction between unconnected actors. In this

sense, by supporting the DX of SMEs through collaborative approaches, DIHs can strongly contribute to the creation of a digital ecosystem that is able to address SMEs' digital needs and gaps.

6.2 Practical implications

Our research has some practical implications for policy makers, entrepreneurs and DIHs' managers. First, the study recognizes the importance of policy makers in defining the right strategies for implementing DIHs at the country level. Our results, in fact, highlight the need for more coordinated action at the European level to allow DIHs to act effectively as KBs and trigger OI mechanisms. This perspective is crucial for the DX of SMEs, which constitute a vital economic resource for the European economic system. Moreover, the study shows that DIHs might be able to help small companies face the challenge of DX and help them exploit the Industry 4.0 national plan. For these reasons, control mechanisms for assessing the performance of DIHs and their impact on regional growth are necessary.

Second, our results show that SMEs can benefit from a new type of player capable of supporting the DX process in different ways. In order to be successful, this process requires companies with a certain degree of openness and proactivity. On the one hand, openness is needed to allow companies to open their boundaries allowing DIHs to carry out a comprehensive assessment of their organizations. While on the other hand, proactivity is needed to enable companies decision makers to respond to the DIHs digital stimuli.

Finally, our study encourages DIHs' to recognize the importance of their internal skills, knowledge and intangible assets, which are crucial to help them in responding promptly to the SMEs needs. Within this vein, DIHs should consider the local dimension which is pivotal in drawing tailored strategies based on the embedded know-how, resources and partners of the territory..

7. Conclusions and future research perspectives

Our study investigated the role played by DIHs (i.e., KBs) in supporting the DX of SMEs, focusing on Italian DIHs. The study sheds light on the importance that KBs may have in promoting the adoption of digital technologies required by innovation demanders among suppliers in the context of the DX of SMEs. Specifically, we focus on the role of Italian DIHs in connecting SMEs to different knowledge sources. The Italian DIH system was selected because of the high number of industrial and artisan associations that act as coordinators. These actors are profoundly embedded in local territories and benefit from high levels of recipient trust. Trust is considered the main aspect that triggers OI mechanisms, positioning the DIH as a trustful mediator of knowledge.

Our findings offer four main theoretical contributions. First, we defined the process of digital imprinting and highlighted that the inner characteristics of KBs impact the outputs of SMEs' DX process when DIHs act as both a KB and knowledge source. Second, we combined the KS and OI

literature to highlight how DIHs act to overcome inter-organizational barriers. Third, we pointed out the importance of DIHs in facilitating the connections between the actors involved in the DX process. Fourth, DIHs act as external enabling factors that foster connections with other companies and institutions fostering the development of innovation ecosystems.

Like all studies, our paper has some limitations which may be addressed through future researches. The first limitation lies in the small number of DIHs included in the study and their relatively inhomogeneous geographical distribution. The second limitation is the focus of the study, as it considers only DIHs' perspective. Further investigations should analyze SMEs' perceptions of the services that are offered in order to corroborate and expand the findings presented here, for example considering a larger scale of DIHs differentiating per structure, sector and technology, examining also the partners' view (e.g., large firms and universities).

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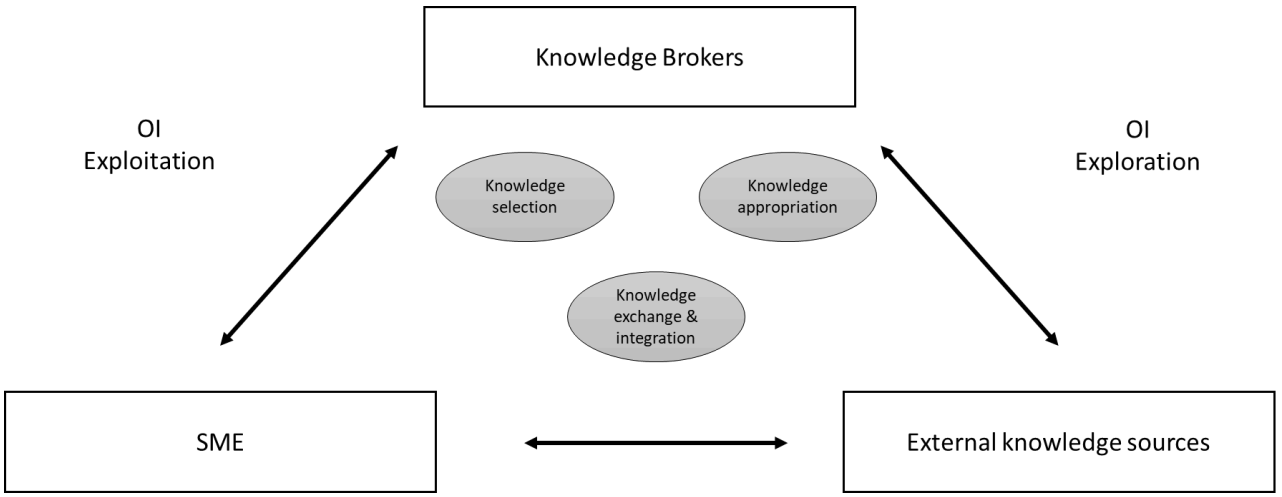
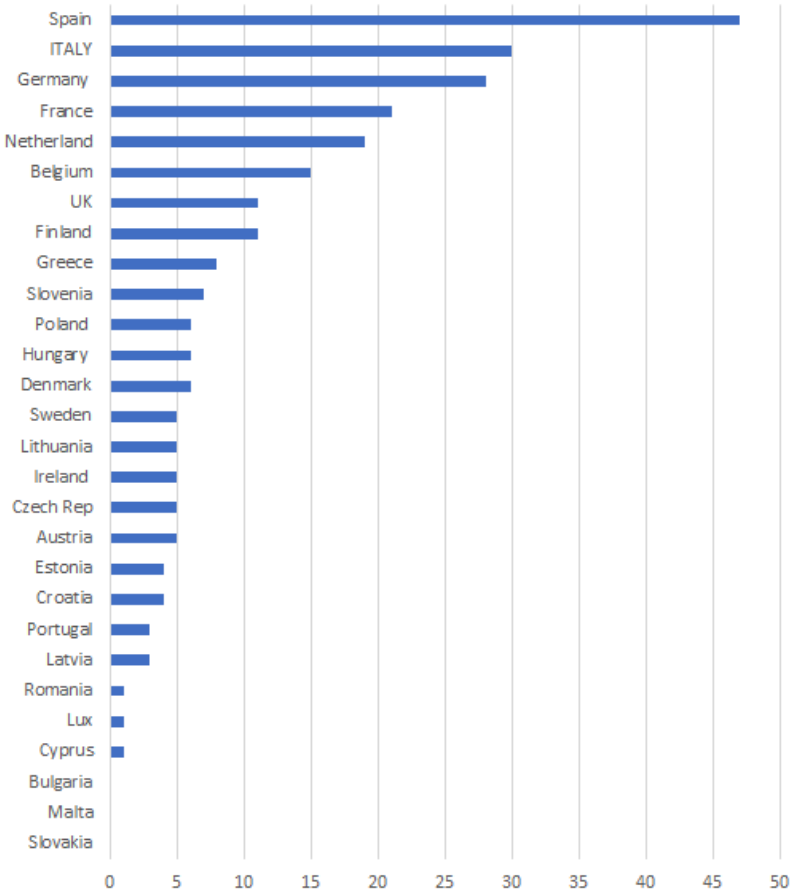
Figure 1. Conceptual Model: Knowledge Brokers for SMEs' Digital Transformation



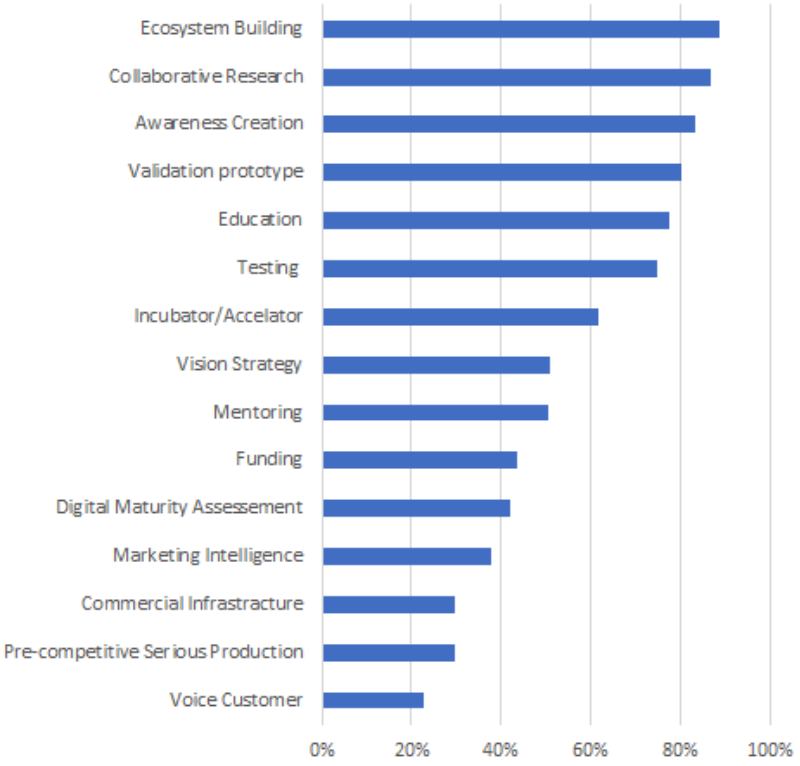
Authors' elaboration

Figure 2 - Distribution of DIHs in Europe



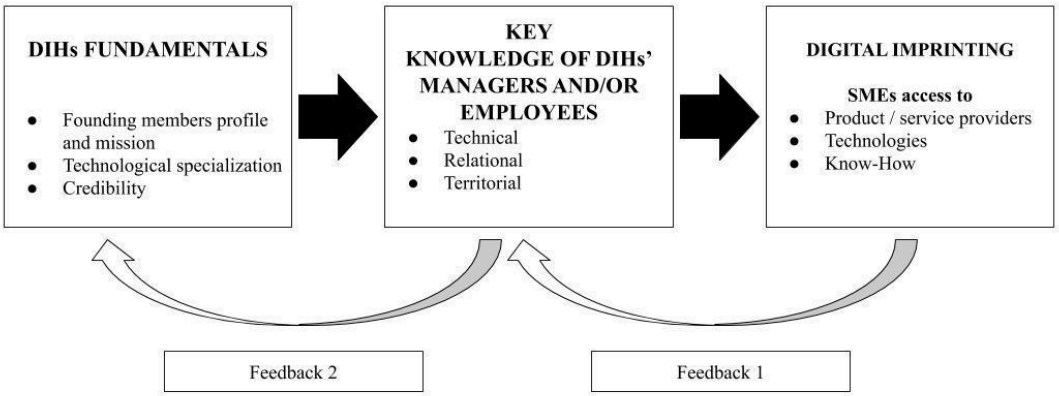
Authors' elaboration

Figure 3 – Services offered by DIHs



Authors' elaboration

Fig. 4 - the Digital Imprinting Process



Authors' elaboration

Table 1 -KBs activities and OI

Knowledge Brokerage activity	Integration with OI	Sources
Knowledge Selection	Definition of innovation processes Identification of relevant knowledge	Wallin and von Krogh (2010)
Knowledge Exchange - Integration	Recruitment of Partners Integrating mechanisms Governance mechanisms Incentives and control	Wallin and von Krogh (2010)
Knowledge Appropriation	Opportunity seeking Market value potential Assessment Value capture Innovation Supply Extending	Fetterhoff and Voelkel (2006)

Authors' elaboration

Table 2 – DIHs services and KM -OI

DIH Services	**KM and OI**	**OI Exploitation**	**OI Exploration**
DIH EU Catalogue (May 2018)	Wallin and von Krogh, 2010 Fetterhoff and Voelkel, 2006	Van de Vrande et al. (2009)	
Digital Maturity Assessment Vision and Strategy Development. Awareness Creation: Education	Selection Define Innovation Process; Identify Relevant Knowledge	Involvement Employee	

Mentoring			
Ecosystem Building Collaborative Research Validation And Prototyping: Testing And Validation: Pre-Competitive Serious Production Incubator/Accelerator	Exchange, Integration Recruit Partners Integration Mechanisms Governance Mechanism Incentives And Control	Venturing	External Network External Participation; R&D; Inward IP
Sales Infrastructure Market Intelligence Access Funding/Investor Readiness Voice Of Customer & Production Consortia	Knowledge Appropriation Seek Opportunities Evaluating Market Potential; Value Commercialization; Extend Innovation Supply	Outward IP Customer Involvement	

Authors' Elaboration