Industry 4.0 in industrial district SMEs: understanding collective knowledge transfer by research and transfer institutes.

Key words: industrial districts; research and transfer institutes; Industry 4.0; innovation policy.

1. Introduction

Digitisation and Industry 4.0 (e.g. *3D printing, Artificial Intelligence, Cloud, Augmented Reality, IoT, Social Media, Online Stores, Cybersecurity*, etc.) encourages a transformative digital disruption (e.g. Autio et al., 2018; Martinelli et al., 2021) among SMEs (Müller et al., 2018), products and industries (e.g. Porter and Heppelmenn, 2014; 2015) with well evidenced impacts on innovation performance (e.g. Dalenogare et al., 2018). Despite Industry 4.0 emergent research focused on SMEs (e.g. Sommer, 2015; Müller et al., 2018; Müller et al., 2020; Moeuf et al., 2020; Cucculelli et al., 2021), collective digitisation of local production systems or industrial districts remains under-researched (e.g. Bettiol et al., 2021). In this chain of thought, this study analyses the collective digitisation (Industry 4.0) of SMEs in industrial districts (IDs) by research and transfer institutes. This study is positioned in the literature concerning knowledge transfer in spatially-bounded areas where social capital is important (e.g. Agostini et al., 2020; Pucci et al., 2020) and, in particular, concerning digitisation in regions and IDs (e.g. De Propris and Bailey, 2020; Bellandi et al., 2020b; Hervas-Oliver et al., 2021).

We set our argument in SMEs in traditional industrial districts and low-tech environments, those where innovation without R&D is conducted. In this context, we analyse the role of research and transfer institutes to digitise local SMEs, assuming that most SMEs are reluctant to engage with RTIs (e.g. Knockaert and Spithoven, 2014; Spithoven et al., 2011). By research and transfer institutes (RTIs), we refer to non-university research institutes (like Fraunhofer institutes in Germany, e.g. Intarakumnerd and Goto, 2018) or collective research centres (e.g. Knockaert and Spithoven, 2014) that are spatially-bounded and are knowledge providers in districts, cluster and regions (Cooke et al., 1997; Koch and Simmler, 2020).

In this context, we ask the following research question that constitutes this study's goal: how local support organisations such as RTIs facilitate digitising to SMEs in IDs? This study's rationale is based on the idea that for radical changes, such as those from Industry 4.0 (e.g. Martinelli et al., 2021), SMEs present difficulties to change because of their poor capabilities (IT, budget, technology, etc.) (Müller et al., 2018). In addition, SMEs in IDs are potentially suffering lock-in and cognitive inertia due to the excessive reliance on locally-based assumptions and paradigms. The reason is that in IDs knowledge is primarily generated from the recombination of regional/local knowledge based on trust, social capital and repetitive interactions within local networks of SMEs that generate and exchange primarily tacit knowledge for incremental innovation (e.g. Glasmeier, 1991; Grabher, 1993; Hervas-Oliver et al., 2018). We argue that, in that context, introducing Industry 4.0 in IDs requires the support of RTIs acting as *collective actors*. By collective actor, we refer to RTIs as public and private organisations formed by a coalition of industry, government and science representatives that are geographically, institutionally and socially embedded. Collective actors are defined as a set of members that share outcomes and are in effective communication networks (Laumann and Marsden, 1979), legitimising new technology (I4.0 in this case) and contributing to technology transitions (e.g. York et al., 2016). RTIs perform R&D and R&D-related activities, the latter being those based on diffusion (training, information, demonstration), intermediation or brokerage and others such as consulting (testing, certification, etc.) (e.g. García-Quevedo and Mas-Verdú, 2008:13).

SMEs do not frequently engage with RTIs, but leading firms do (Albors-Garrigos et al., 2014; Glasmeier, 1999). As a matter of fact, Olazaran et al. (2009) evidence that there is a manifested mismatch between what SMEs need and demand and what RTIs offer, arguing that they do not speak the same language. Overall, SMEs mostly prefer to cooperate with other firms (suppliers and customers), present low planning of technology needs and low absorptive capacity (e.g. Knockaert and Spithoven, 2014; Albors-Garrigos, et al., 2014). In IDs, SMEs are typically conducting incremental innovation lock-in technology and assumptions established by leading incumbents that organise local networks (see Munari et al., 2012). On the contrary, leading firms diffuse knowledge within their networks of SMEs through intense network relationships based on trust, reputation, custom, reciprocity, reliability, and openness to learning that are pervasive in

clusters and districts (Boari and Lipparini, 1999; Cooke, 2001; Munari et al., 2012). In this vein, we ask: how is possible to channel the RTI technology to SMEs in districts? Based on this framework, the study contributes to understanding much better the *collective* role of RTIs in industrial districts and advances how to digitise local innovation systems of SMEs. This study, therefore, contributes to respond to a crucial question: how to diffuse from RTIs to SMEs when the latter do not usually engage with them?

This study's focal change is digitisation and our setting is the case of the Vinalopo Footwear district in Spain. The *Vinalopo* footwear district is labelled as a typical ID (e.g. Belso-Martinez, 2010) and it is a vibrant district in Europe along with *Riviera del Brenta* in Veneto, Italy, where top global brands, such as ZARA, have their footwear-dedicated headquarters. This setting is chosen because it represents a novel case of digital (digital design and 3D printer technologies) change supported through RTI activities performing its role as a collective actor. Empirically, this study presents evidence through 45 interviews about the role of a focal RTI fostering digital change in an ID.

The main contribution of this paper is based on the fact that, according to results, RTIs in IDs utilize leading anchors that control and orchestrate local networks of SMEs for introducing digitization indirectly: first, transferring knowledge to the leading firms and then, support the knowledge diffusion to SMEs within leading firms' networks. This indirect mechanism, is built upon cooperation and competition existent in IDs and capitalizes on the natural knowledge diffusion path in IDs: leading firms introduce major changes and also interact with science-based organizations, such as RTIs, and SMEs primarily learn from those leading firms by imitation and inter-firm interaction.

The remainder of the paper is organised as follows. After this introduction, Section 2 addresses theoretical issues in IDs, then Section 3 presents the Vinalopo footwear district and empirical results. Section 4 discusses results from the empirical analysis. Finally, conclusions are presented in Section 5.

2. RTIs as facilitators of change in industrial districts

2.1 RTIs in clusters and districts

Under the umbrella of RTIs, we include generally those non-university research institutes, like collective research centres (e.g. Knockaert and Spithoven, 2014) or public research organisations (Belussi et al., 2010), designed to support primarily SMEs (e.g. Belso-

Martinez et al., 2018; Hervas-Oliver and Albors-Garrigos, 2014). RTIs present different objectives and dynamics, many different forms in terms of ownership (e.g. public, private, hybrid, etc.), diverse funding sources and show a rather heterogeneous portfolio of activities that encompass from classic R&D and licensing to training, sales of equipment or access to technical library, certification and others.

In industrial districts, the role of RTIs has been discussed since the 90s (see Bellini and Pasquini, 2018; Brusco, 1992) as a mechanism to strengthen local innovation systems and especially supplementing local deficiencies (Feller et al., 1996). Despite the fact that RTIs are primarily devoted to SMEs (e.g. Cruz-Castro et al., 2012), the regional innovation perspective evidences a relatively weak and limited use of RTIs by SMEs (e.g. Albors-Garrigós et al., 2014; Glasmeier, 1999; Hassink, 1997; Hervas-Oliver et al., 2012). Similarly, as pointed out by Knockaert and Spithoven, (2014), without absorptive capacity, in-house R&D capabilities and intense and frequent interactions, SMEs are unable to generate innovation through external knowledge access facilitated by RTIs.

Despite the evidence of low RTI utilisation by SMEs, literature generally assumes that RTIs support and facilitate innovation and knowledge transfer in industrial districts and clusters. For instance, Belso-Martinez et al. (2018) show how RTIs and local business associations coordinate and act as inter-firm interconnectors in the technical and business network, activating networks, and channeling resources. The question is, therefore, how do RTIs support SMEs, when the latter do not usually engage with them? How are RTIs contributing to digitise IDs?

2.2 Collective action: RTIs digitising IDs

When zooming into clusters and industrial districts, anchor or leading firms (e.g. Hervas-Oliver et al., 2018; Lazerson and Lorenzoni, 1999) orchestrate local networks of SMEs, driving the innovation and production function, legitimising technologies and establishing the norms and institutions that legitimise the access to those *knowledge clubs* (à la Breschi and Lissoni, 2001) that networks constitute. As Lazerson and Lorenzoni (1999) state, larger firms in IDs, even with their small size compared to outside of the district firms, orchestrate subcontracting and invest in R&D, supporting small businesses to adapt to new requirements. These leading firms, as Boari and Lipparini (1999) point out, impact on the whole district. They outsource the production to local firms, support

their suppliers to develop their own competencies and contribute to reinforcing the district by diffusing best practices. Munari et al. (2012) show for the Northern Italy packaging district that leading firms characterised by a larger size and stronger innovation capabilities, relative to other ones in the district, access new knowledge much better and diffuse it within their local networks of SMEs, spilling it over the entire district.

As SMEs interact poorly with RTIs, leading firms are the primary source of knowledge. RTIs, therefore, can activate leading incumbents, using them as a catapult to diffuse change in districts, as Pagano et al. (2021) evidence. RTIs transfer knowledge to leading firms and the latter diffuse it within their networks of SMEs. As SMEs learn more from imitation and interactions along the supply chain, rather than from RTIS, leading firms can diffuse new knowledge among SMEs when organising production.

As Spithoven et al. (2011) point out, RTIs conduct R&D activities that target the local/regional system on a collective basis. These activities, such as monitoring external technological (technology watch and road-mapping) developments and projects to demonstrate technology, perform a function that is *collective* in nature. In particular, these R&D and R&D-related activities are aimed at improving and adapting the entire local/regional innovation system to new technological trends or industry disruptions, performing a role of collective actors by signaling change to SMEs in districts through diffusion mechanisms and demonstration of technologies to avoid lock-in in districts and clusters (e.g. Hervas-Oliver et al., 2019; Pagano et al., 2021). As Hervas-Oliver et al. (2019) indicate, collective actors perform collective actions such as: removing potential institutional and SME barriers to digitise the territory; aligning collective interests of the local district; creating awareness about the necessity to change towards digitisation; presenting, developing and legitimising new (digital) paradigms; supporting change through diffusion and training programmes.

Following Hervas-Oliver et al. (2019), these collective initiatives led by RTIs are crucial for IDs. These actions attempt to counteract the fact that in IDs there are some institutions (rules, norms, assumptions, paradigms, etc.) that prevent change and promote uniformity, as imitation is pervasive and especially relevant in clusters and districts. Change is difficult to achieve in these environments because managers from SMEs tend to focus on competitors inside the cluster, a habit supported and facilitated by dense and repetitive social and professional interactions, good knowledge of local competitors and shared local suppliers (e.g. Gilbert, 2012; Staber and Sautter, 2011). Therefore, a strong

collective identity is built in those agglomerated settings and cognitive inertia prevails, making change complicated (e.g. Glasmeier, 1991; Hervas-Oliver et al., 2018), as it entices the transformation of local tacit knowledge, the core advantage of IDs, into useless knowledge.

When addressing digitisation, RTIs can initiate *collective actions* to signal change and also legitimate new digital technologies, showing the way to local SMEs. As argued, the diffusion of new technologies is built upon the knowledge transfer mechanisms existent in IDs: targeting leading firms that do interact with RTIs and, subsequently, promoting interaction between leading firms and their networks of SMEs in order to "contaminate" local SMEs.

The specific transfer of digital knowledge in IDs can occur first from RTIs and leading firms' interaction. Subsequently, leading firms will contaminate local SMEs when orchestrating networks, as Pagano et al. (2021) evidence. Therefore, we assume the following propositions here:

P1: In industrial districts, RTIs, as collective actors, signal change and organise for diffusing new digital technologies.

P2: In industrial districts, leading firms are active users of RTIs but not SMEs, which prefer to learn from supply-chain collaborations.

P3: In industrial districts, RTIs can capitalise on leading firms that control and orchestrate SMEs for introducing digitization.

3. Empirical research

3.1 Method

This study is built upon direct visits and interviews to representative firms in the district (36 interviews) and local support organisations: six interviews were conducted at Inescop, the local RTI and three interviews at AVECAL, the regional footwear trade association. In total, 45 footwear-dedicated informants were face-to-face during 2019 and TEAMS-based interviewed in 2020. Each interview lasted, on average, 1 hour.

Interviews were fully dedicated to development of the Industry 4.0 to digitise the industrial district, an initiative led by *Inescop* and commissioned by the Innovative Branch of the Regional Government (IVACE). The principal and most important question for the initiative was how to implement Industry 4.0 in the district. For that particular

goal, *Inescop* decided to implement a *footwear digital technology demonstrator* in its facilities, a permanent technology exhibit, like a simulator, that is open to the entire territory to show that digitisation is the new imperative and show how to undertake it. The idea is to show that digitisation is possible, show the tools and diffuse the technology to the territory. Interviews with different agents were conducted on the basis of understanding how the digital solution would disseminate throughout the focal territory, considering that there are primarily SMEs of very different sizes. Around that central question, different questions were formulated encompassing the principal users of the new technology, how to diffuse it, how the technology impacts the focal industry or how SMEs can engage with that I4.0 novelty. Table 1 summarizes interviewees. See Table 1.

Table 1 List of interviewees.

3.2 Setting: the Vinalopo Footwear cluster

The Vinalopo footwear district integrates around 30,000+ manufacturing jobs in more than 2,700 firms, predominantly SMEs with up to nine employees, representing a low-tech and traditional district in Alicante, Spain. Along the Vinalopo river in the Alicante province, different municipalities, like Elche, Elda or Villena among others, are highly specialised in footwear-related activities. For instance, Elche, with around 13,000 manufacturing jobs in 2018, constitutes the largest concentration of footwear activity in the district and in Spain, with around 80% of its industrial base dedicated to footwear industries (footwear, heals, soles, decorative materials, machinery, etc.). Its concentration index (LQ, locational quotient) is around 400%, compared to other Spanish provinces[1]. It hosts the majority of Spanish innovation in the industry and around 60% of production. Many multinationals with leading brands, such as Prada or Armani, source in the district; also, the leading fashion multinational ZARA has its footwear headquarters there and leading footwear brands, such as Stuart Weitzman, manufacture their collections there.

[1] http://www.indi.gva.es/es/web/industria-e-i-d-i/estrategia-politica-industrial

The district presents all necessary activities for footwear design and production, as Belso-Martínez (2010) explains[2]. Most of the top fashion brands operate there, organising manufacturing by subcontracting, buying or just commercialising. There are sub-industries dedicated to the chemical aspect of footwear, leather, general components (e.g. soles, heels) manufacturers, supporting industries (specialised logistics, warehouses, packaging and others) and anchor firms that concentrate the high value-added activities (branding, design, marketing, etc.). These firms organise subcontracting and managing of local networks of SMEs.

As regards the structure of the district, it is articulated around support organisations, vocational training schools, trade associations, specialised press and trade fairs, permanent show rooms, etc. Inescop is the local RTI focused on footwear design and manufacturing. Historically, it was founded in 1971, as a private association of local entrepreneurs for collective services. It was then incorporated into the IVACE regional innovation branch of the regional government as a tool for policymaking in the industry. Inescop is similar to what Cruz-Castro et al. (2012) define as a hybrid RTI. It operates under a private status but nonprofit legal form and is publicly supervised, with structures and strategies based on combining excellence and relevance. It is a public-private organisation to support the production and innovation function of the local system, providing services such as test & quality, R&D, software for footwear, adhesive consulting technologies, training or environmental management support. It is a leading hub in adhesive technologies (very important in the footwear industry) that are applied to other industries (plastics, automotive, etc.). Its fields of expertise within footwear production are in CAD/CAM design technologies, 3D printing, robotics, chemicals for footwear, adhesives and biomechanical and healthcare technologies for footwear. Furthermore, AVECAL is the local footwear trade association, representing local firms and providing services for trading, exporting, legal or lobby support, among others.

3.3 Evidence: implementing Industry 4.0 through the *I4FOOTWEAR* programme

The footwear industry, in general, is not automated. Despite being a craft and labour-intensive process, it is an industrial process and some of its activities are starting to be more industrially organised. In any case, the intensive labour utilised has made the industry quite different for adopting Industry 4.0 enablers, compared to other more

[2] http://www.indi.gva.es/es/web/industria-e-i-d-i/estrategia-politica-industrial

technology-intensive industries, such as plastics or automotive. The industry is well represented by small firms (usually with fewer than nine workers) that work as subcontractors of specific components (soles, heels, decorative materials, etc.).

Interviewees commented on the strength of the district and its robust innovation and production system.

"The strength of the district is its hub for the footwear business: all types of component suppliers, marketing, logistics, excellent craftsmanship, innovation, design, patents and trademarks. All the key players in the industry (ZARA, Armani, Nordika's, Stuart Weizmann, etc.) are located or buy here in the district. The know-how, especially for expensive women's shoes is well recognized"

"One key factor explains the vitality of the district: ZARA, the largest fashion retailer has all its footwear value-adding activities located at the district"

The local university representatives interviewed also pointed out the specific process of shoe manufacturing and how difficult is to digitise:

"This industry is a typical one for offshoring to low-cost countries. The reason is the very high labour-intensive process required. These labour-intensive activities are complex for digitisation, as the industry is not really automated as others are. For this reason, highly-qualified skills are a core in the process, and less IT technologies that might organise a firm better but do not directly add value directly to the product. Digitisation is the future but it is going to be very gradual in this industry".

At the AVECAL trade association they stressed the point of sustainability:

"Traditional design, involving manufacturing prototypes, suffering problems related with lack of accuracy, and all waste problems (discarding prototypes) was an important part of the cost of manufacturing, especially relevant for short batches. This is now much better with the digital technology and it also represents a favorable attitude towards sustainability in that particular set of processes".

Inescop reported its main interest with digitisation, stressing its collective-based role:

"Our goal is to introduce change and technologies that support local competitiveness. Our mission is to introduce innovation in the district, supporting its evolution and adaptation to major changes".

"We want to show the right way to local firms, how to be more competitive. They need to consider digitisation".

"Digitisation is a priority in all industries, and our purpose is to communicate that to our focal territory".

The core digital technology for the demonstrator at Inescop is Computer-Aided Design and Manufacturing [CAD/CAM] and 3D printing for prototyping (not manufacturing), consisting of a digital and computerised technology supporting the integration of design, manufacturing execution systems (MES) and product development (e.g. prototyping,

customization). In particular, CAD/CAM technologies are strongly related to operational gains, based on productivity, cost reduction or better visualisation and prototyping (e.g. Dalenogare et al., 2018).

As commented by Inescop, the technology demonstration platform is also connected to seminars, training and specific adaptation to demand. From interviews, Inescop points out the role of anchor firms tractioning the diffusion system. In fact, Inescop's diffusion programme includes the use of anchor firms in the territory that orchestrate local networks of SMEs, to test the new technologies and diffuse them. Once the local leading incumbents test, modify and adopt the technology, they start to spread it through their networks of subcontractors, disseminating the new protocols and requirements that will be gradually adopted by SMEs. Inescop, along with the leading firms pioneering the new digital technology, digitize the new digital technologies as they both are reference points for benchmarking. Step by step, the new technology will be sedimented as part of the local know-how nuclei, in combination with existing technologies and paradigms.

The digital enablers considered were oriented to digitise footwear design and related activities (design, prototyping, 3D printing for sampling selection, web-based virtual catalogues and digital manufacturing of some shoe producing activities). Design is the core activity to digitise because it is vital for the territory.

As members of Inescop reported:

"Design really makes a difference and we cannot compete on costs basis. We need to differentiate our products from lower-cost countries. Servitisation is a fact in the territory through design intensive firms, marketing firms that build brands, commercialize, set trends and use intensively social networks. Design is capital for the survival of the district because it adds value and opens new markets."

"In this industry, design is one of the activities that could be digitised. The industry is not fully automated, not all the activities can be digitised in the short-medium term"

As commented in the interviews with Inescop, design is of utmost importance for the vital and high value-adding process to the final product and because it is not a candidate for offshoring. Generally, design of shoes is developed by leading incumbents that organise local networks of SMEs. Usually, these leading incumbents used to be shoe producers and became key actors of the *servitisation* (Bellandi et al., 2019) of the district. Their core activities are design, prototyping, marketing (including managing their own stores) and

organising the manufacturing process through a coalition of local SMEs that are following the leading incumbent's decisions (Lorenzoni and Lipparini, 1999). Thus, local networks of SMEs specialised in specific components of the shoe (e.g. heels, soles, decorative materials, leather, etc.) are orchestrated by those leading incumbents that concentrate high-value adding activities. These leading firms propose new designs, invest in market intelligence, attend international trade fairs to learn new trends and recruit good designers. Also, they have better and stronger IT capabilities to integrate new technologies.

The diffusion mechanism, starting with anchor tenants, is evidenced by Inescop's representatives:

"Only the companies that have a good technical or R&D department are able to really exploit these new digital design technologies. They constitute the front-runners that can test and improve the technology, diffusing it within their networks. They help us not only to test but to legitimise the new digital technology."

"Small companies with poor internal capabilities and weak IT systems are also our target but they need first to be upgraded and invest in their own capabilities. New digital technologies might be too intangible for them. We think they can change and gradually digitise when their customers (those leading firms) ask them to change and when they observe other similar firms changing. This is more effective that imposing a change upon them."

"It is a cascade process. First, the ones that can implement the change. Then, those that imitate the leading ones. Finally, the small firms within the leaders' networks and imitating what is done in networks."

As regards the type of firms used for testing and diffusion of the technology, Inescop's executive commented:

"We wanted to use smaller firms, primarily SMEs, but they lack the necessary IT capabilities to integrate the new technologies. Also, the design activity itself is not predominantly a typical activity of those firms that are more component manufacturing oriented. For this reason, we decided to target leading incumbents with in-house design of footwear that are actively engaging with the RTI."

"These leading firms have plenty of experience in international markets, know the fashion trends and assume that digitisation is capital and are active users of the RTI".

As observed from informants, leading firms within the industrial district assume the role of diffusion, introducing the knowledge from RTIs into the district, legitimising, diffusing and improving local technical capabilities of SMEs in the territory.

According to Inescop, the new Industry 4.0 digital process based on CAD/CAM and 3D printing, the process of designing a new model is fully digital and employs less than 20% of the time utilised in the traditional process. Virtually, the sketch is converted into a digital last that incorporates, through CAD/CAM systems for the footwear industry,

different soles, heels, colours, pieces, decorations, variations or materials, obtaining immediately the virtual prototypes in the monitor. It also permits scanning (3D/2D) different components (heels, pieces) to see how the product changes. The virtual prototype rendered: i) is exchanged throughout the supply-chain, ii) is shared with customers to get approval or discard, iii) does not need to be manufactured until the final decision of selection is made, iv) reduces the cost of manufacturing prototypes (most of them discarded by customers or the marketing department), v) reduces waste; vi) connects the final prototype to manufacturing machines; and vii) incorporates all costs and carbon footprint and; viii) generates physical prototypes through additive manufacturing (3D printing). Additive manufacturing of footwear *lasts* for footwear prototyping or for shoes prototyping permits having the exact prototype (that can even be shared by email) with any factory of the world or any subcontractor in the supply-chain. In addition, testing prototypes quickly with lower costs permits; (x) reducing lead-time; (xi) improving communicating and sharing ideas and concepts through the value chain; (xii) more efficiency across activities and actors: upgrading the efficiency of the supply chain, minimizing errors and improving information; (xiii) co-creation: user or customer can co-create with the producer and broaden an open innovation approach to innovation in the industry; (xiv) the fragmentation of complex processes into separable activities that can be easily coordinated.

Also, evidence points out the barriers of SMEs for digitisation. Other informants at the AVECAL trade association also stated that:

"Firms in this territory are very small and specialised on specific activities of shoe manufacturing, competing basically on the basis of costs. The majority are not ready to utilise digital technologies because they do not possess specific assets or technology to support that transition."

One businessman in the industry reported:

"The know-how of this territory is shoe manufacturing. We know how to do this and the artisan skills are highly appreciated in the market. SMEs, in general, have very good knowledge and expertise but not the necessary IT capabilities to support new digitisation. I am not even sure to what extent they really need it. For instance, they have ERPs but they exploit them in a very basic way, primarily connecting accountancy and stocks, not much."

Firms in the interviews point out the integration and connection that digital technology permits:

"I can send my virtual prototypes to China and get them operational immediately, with no errors of interpretations and not necessarily sending physical lasts or products. I can reduce time-to-market

considerably and check many times with the customer or even change colours or materials in subsequent batches. It is very functional"

"Digital technology permits integrating much better the networks of components, circulating specifications, measures and others a lot better. Errors are minimised and we can even scan new components proposed by our suppliers and see how they look in the product without manufacturing or spending money on them."

Other related technologies in the demonstration platform at Inescop are collaborative robotics, digital cutting processes, cloud computing and IoT; but due to the specific process of the industry they are more in a trial-and-error stage, constrained by the low automation level of the industry.

Effects from Industry 4.0 in the industry coincide with those general effects from Industry 4.0 (e.g. Büchi et al., 2020; Kapetaniou et al., 2018; Mitra et al., 2018; Porter and Heppelmann, 2014a, 2014b; Tucker et al., 2018). See Table 2.

Table 2 Effects of digital and 3D printing technologies in footwear

General effects	**Examples**
Improvement of product customization	- Customers/users are central in the co-creation process
Improvement of product quality	- Less errors from design to production
Increase productivity	- Reducing time-to-production - Reduction of operational costs of prototyping
Reduction of product launch time	- Reduction of time-to-market and time-to-production - Rapid prototyping and final design selection, improving decision-making process
Improvement of sustainability	- Eco-design applied to footwear - Footwear carbon foot-print calculation - Reduction of waste from prototyping
Supply-chain integration facilitation	- Facilitate distributed production to sub-contractors, minimising errors - Easy connection and integration of factories across countries

Source: own

4. Discussion of results

Results indicate how low the engagement of SMEs with RTIs is, especially in settings of low-technology and traditional industries, in line with extant literature (e.g. Albors-Garrigós et al., 2014; Hassink, 1997; Knockaert and Spithoven, 2014; Olazaran et al., 2009; Spithoven et al., 2011). These findings perfectly corroborate what Kauffeld-Monz

and Fritsch (2013) and Knockaert and Spithoven (2014) point out: not all firms are going to improve innovation when interacting with supporting organisations such as RTIs. In fact, it found that absorptive capacity at member firm level is crucial for generating innovation speed: without this absorptive capacity, in-house R&D capabilities and intense and frequent interactions, firms are unable to generate higher levels of innovation through external knowledge access facilitated by the RTIs. This expected result, however, co-exists with the fact that RTIs are primarily SME-oriented, especially for industrial districts (e.g. Albors et al., 2014; Hervas-Oliver et al., 2012). Transferring knowledge from RTIS to SMEs is not an easy task, neither from universities nor from research centres, which are hardly used by SMEs (e.g. Ebersberger et al., 2012; Rõigas et al., 2018) that lack sufficient absorptive capacity, especially in those contexts of non-R&D innovation in traditional and low-technology contexts (Spithoven et al., 2011; Hervas-Oliver et al., 2012).

As results show, beyond R&D activities, RTIs perform collective-based initiatives to promote change and diffuse new technologies, capitalising on leading firms that orchestrate knowledge in districts and clusters. Overall, results show that understanding RTIs' effects on districts cannot be measured only in terms of R&D projects or activities. On the contrary, R&D-related diffusing activities based on the local networks organised by leading firms and their intense and pervasive interactions with SMEs constitute a channel from which to target the local innovation system of SMEs through collective-based initiatives. In general, our evidence shows a real case that allows us to understand collective actions by RTIs as knowledge providers. Our results also show how different the role of RTIs focusing on SMEs can be, at least when compared to more R&D efforts performed by universities not really focused on SMEs (e.g. Kauffeld-Monz and Fritsch, 2013). Our findings also align with those of Spithoven et al. (2011), which show how important R&D-related activities are in low-tech environments, accounting for almost 50% of the innovation effort carried out by RTIs. Specifically, these R&D-related activities are very relevant in non-R&D or 'innovation without research' environments (e.g. Apa et al., 2018), particularly low-tech and traditional industrial districts where knowledge spillovers from user-producer interactions or even labour mobility and competitors' collaboration prevails.

Table 3 shows a summary of empirical results from the field work. See Table 3.

Table 3 RTI collective action for digitising the Vinalopo Footwear district

Dimensions of the innovation policy for digitising	**Explanation**
Collective initiative design	Technology demonstration platform
Collective initiative lead and implement by	Local RTI (Inescop) in the ID
Average size of SMEs in the territory	Very small: predominantly 1-9 employees highly specialised
Automation and processes in the local technology of the ID	Labour-intensive, based on craftsmanship and low level of automation (typical from footwear).
Activities that can be digitized in the collective initiative	Design and related; marketing. Production is more complex due to low automation.
Scope of the collective initiative	Entire local innovation system
Directly, collective initiative target firms	Leading firms orchestrating networks of local SMEs. These firms are primarily, albeit not exclusively, *servitising* manufacturing firms. Indirectly, final target, local SMEs
R&D activities for the RTI learn on digitization.	R&D for digitising design of footwear; technology gatekeeping (technology watch, road-mapping, European Union R&D projects, alliances with universities, etc.)
R&D-related activities for diffusion of 4.0 technologies in the ID	-Technology demonstration platform: open doors to allow firms to visualise how to digitise -Seminars, visits, training -Diffusion through local networks of SMEs orchestrated by leading firms
Specific digital technologies (Industry 4.0)	-Digital design of footwear (design, prototyping, 3D printing for sampling selection, web-based virtual catalogues and digital manufacturing of some shoe producing activities).
Change and effects on the focal district: impacts from digitisation	Productivity Sustainability Supply-chain integration Customisation and co-creation.

Source: own

Table 3 shows the characteristics of the collective action by Inescop in the district. First, in Table 3 it is shown how important are contextualisation and place-based initiatives, and the privileged position that embedded RTIs present in industrial districts. Rather than utilising one-size-fits-all initiatives, tailoring to the specific context (technological, institutional and social layers) of districts can be a useful initiative to incorporate local context specificities that enable the local system to turn the tide towards change, in this particular case to digitisation. This initiative developed and implemented in the Vinalopo cluster represents specific idiosyncratic features as a result of its local and contextual specificities. In particular, due to the low automation in the industry, the activity chosen to digitise was design through specific digital enablers (3D printing and related technologies). Also, the small average size of local firms and the traditional low-tech intensive component of the footwear industry and the weak IT capabilities of the local SMEs directed efforts to digitise primarily local leading firms. The local leading incumbents utilised to test and improve the digital technology are servitising

manufacturing firms (Sforzi and Boix, 2019), firms that used to manufacture but are developing intensive activities such as marketing, design and other related activities to the process, orchestrating local networks of SMEs that manufacture specific parts of footwear as subcontractors. Thus, the purpose consisted of diffusing digitisation through leading incumbents' design activities and then achieving dissemination of the digital enablers within their local networks of SMEs. These results confirm previous literature, albeit they were not focused on RTIS, that leading incumbents in districts support small business, support capability development of their suppliers (SMEs) and diffuse new knowledge and best practices within their local networks of SMEs, spilling over into the entire district (Munari et al., 2012). Therefore, they constitute "diffusion mechanisms" to leverage knowledge dissemination in districts.

In Table 4 a summary of the propositions and quotes are presented. See Table 4.

Table 4 Propositions confirmation and quotes from interviews

Propositions	**Some quotes from interviews**
(P1) *In industrial districts RTIs, as collective actors, signal change and organise for diffusing new digital technologies.*	*"Digitisation is a priority in all industries, and our purpose is to communicate that to our focal territory".*
(P2) *In industrial districts, leading firms are active users of RTIs but not SMEs, which prefer to learn from supply-chain collaborations.*	*"(Leading firms are) …. the front-runners that can test and improve the technology".* *"leading incumbents with in-house design of footwear that are actively engaging with the RTI".*
	"SMEs…. lack of the necessary IT capabilities to integrate the new technologies". *"New digital technologies might be too intangible for them (SMEs)".* *"The majority (SMEs) are not ready to utilise digital technologies because they do not possess specific assets or technology to support that transition".*
(P3) *In industrial districts RTIs can capitalise on leading anchors that control and orchestrate SMEs for introducing digitisation.*	*"(SMEs) …can change and gradually digitise when their customers (those leading firms) ask them to change".*

5. Conclusions

This study analyses the digitisation of industrial districts and SMEs capitalising on local research and transfer institutes' collective actions. Through a qualitative analysis based on 45 face-to-face interviews, this study contributes to enrich the emerging topic of Industry 4.0 in Marshallian Industrial Districts.

Results suggest that, despite little utilisation of RTI by SMEs, RTIs, as collective actors, perform both R&D and R&D-related activities to support change and innovation aimed at provoking change in SMEs in IDs. In IDs, RTIs are locally engaged, being technologically, geographically and institutionally embedded in local/regional innovation systems. RTIs cope with the fact that SMEs present poor absorptive capacity, limited resources and low propensity to use research infrastructure. As a response, RTIs develop collective change-oriented activities to gradually introduce new technology within SME networks through transferring knowledge to leading or anchor firms that orchestrate those networks. These leading firms, presenting R&D functions and strong absorptive capacity, organise local networks of SMEs and gradually introduce change, legitimising new technologies and demanding different types of activities to their networks' SMEs. The stated propositions, therefore, are confirmed. Thus, (P1) in industrial districts, RTIs, as collective actors, signal change and organise for diffusing new digital technologies; (P2) in industrial districts, leading firms are active users of RTIs but not so SMEs, which prefer to learn from supply-chain collaborations; (P3) in industrial districts, RTIs can capitalise on leading anchors that control and orchestrate SMEs for introducing digitisation.

Overall, these insights contribute to the better understanding of research and transfer institutes (e.g. Koch and Simmler, 2020), particularly how knowledge is transferred in local innovation systems (e.g. Belso-Martinez et al., 2018; Hervas-Oliver et al., 2019; Pagano et al., 2021). This study's insights contribute to the better understanding of knowledge transfer in IDs where social capital is important (e.g. Agostini et al., 2020; Pucci et al., 2020), improving our knowledge of digitisation in IDs (e.g. Hervas-Oliver et al., 2019; 2021a).

As Edler and Fagerberg (2017)[3] state, what really matters for innovation policy is to support not only the novelty and the creation of new solutions (i.e. R&D activities) but their exploitation and diffusion in the economic and social system (i.e. R&D-related activities). The role of RTIs activating leading firms that, subsequently, diffuse through their networks of small firms is certainly related to the idea of diffusion and not only the creation of the solution. As it is recognized that SMEs with low absorptive capacity are hardly interacting with RTIs, leveraging on the leading firm-SME interaction is an indirect way to diffuse knowledge into the territory by capitalising on the SMEs' frequent

[3] Comment on Kline and Rosenberg (1986)

and intense interactions within local networks. As results evidence, while the diffusion to leading firms from RTIs is supported by strong absorptive capacity, its subsequent diffusion and exploitation through leading firm-SME interaction is based on local user-producer interactions that are the principal way of SMEs learning equivalent to doing, using and interacting modes of learning (DUI, Jensen et al., 2007). Therefore, this mechanism targets the entire local/regional innovation systems and its local networks and constitutes an additional way of diffusing innovation through knowledge spillovers beyond R&D activities. Results show how effective RTIs can be when they are contextualised to local specificities and are measured not only on R&D projects but also their collective diffusion and exploitation in the focal innovation system.

The main contribution of this paper is based on the fact that, according to results, RTIs in IDs utilize leading anchors that control and orchestrate local networks of SMEs for introducing digitization indirectly: first, transferring knowledge to the leading firms and then, support the knowledge diffusion to SMEs within leading firms' networks. This indirect mechanism, is built upon cooperation and competition existent in IDs and capitalizes on the natural knowledge diffusion path in IDs: leading firms introduce major changes and also interact with science-based organizations, such as RTIs, and SMEs primarily learn from those leading firms by imitation and inter-firm interaction.

As results have shown, RTIs as collective actors in IDs develop activities that are oriented to introduce and legitimise change, bearing in mind that the bulk of SMEs with low capabilities and absorptive capacities might resist change. Thus, beyond traditional R&D and other service-related activities, RTIs implement mechanisms to legitimise new technologies, promote collective-based initiatives and facilitate the development of an institutional framework that collectively stimulates change and promotes knowledge transfer for the purpose of digitisation.

The paper is not free from limitations, as it is specifically focused on a low-tech and the traditional but vibrant Spanish district, not generalisable to other cases. For future research, more experiences on digitising districts in different settings, countries and technologies can improve our knowledge of how IDs function, joining together digitisation and ID literature.

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