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Does regional innovation policy really work for Industry 4.0? Evidence for industrial districts

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ABSTRACT

Industry 4.0 threatens established lock-in paradigms in some districts. In this study, we compare different innovation policies aimed at facilitating Industry 4.0 awareness and its adoption in three Marshallian Industrial Districts (MIDs), asking: 'What' types of innovation policies work for Industry 4.0 in industrial districts? And, where they do, 'how' are those innovation initiatives designed, developed and implemented for digitizing districts? Using qualitative evidence based on 24 interviews and the review of existing literature concerning Industry 4.0 in three MIDs, results show different mechanisms and approaches for creating awareness and maximizing the diffusion of Industry 4.0 in each district, as a result of each local 'cognitive structure'. One size-fits-all policies are not realistic for digitization: collective actors leading place-based collective actions that are bottom-up and co-designed with public and private local actors is what works best. For policymakers, this study presents guidance for developing Industry 4.0 in MID settings.

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1. Introduction

Oesterreich and Teuteberg (2016) established that the term Industry 4.0 is comprised of a variety of enabling technologies (e.g. Cloud Computing, Internet of Things, Big Data, Artificial Intelligence, etc.) which seek to develop a digital and automated manufacturing environment as well as the digitization[1] of the value chain. Industry 4.0 in manufacturing and other business activities, alters companies, industries and value chains, as well as their associated production, distribution and consumption systems, provoking a digital disruption that has configured a new manufacturing paradigm. In this study, Industry 4.0 is the digitization of manufacturing due to the introduction of enabling technologies, such as Cyber-Physical systems, Big Data and others. Industry 4.0 is said to bring positive outcomes, such as new business models, better productivity and better sustainability, (e.g. Porter and Heppelmann 2014; Lepore and Spigarelli 2020; Teixeira and Tavares-Lehmann 2022).

While SMEs face difficulties in adopting Industry 4.0, especially due to their lack of resources (e.g. finance, IT systems and other resources; Matt et al. 2021; Yüksel 2020), SMEs in districts also present an additional obstacle: strong local networks and lock-in

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institutions (rules, norms, assumptions, paradigms, etc.) that prevent change and promote uniformity, along with avoiding radical changes (see Glasmeier 1991). The introduction of Industry 4.0 in regions and districts addresses a different system level of analysis that facilitates a more sensitive 'place-based' approach. Industry 4.0 in regions and districts remains under-researched (e.g. Lazzeretti et al. 2022; Pagano et al. 2021; Bettiol et al. 2021; Bellandi, de Propris, and Santini 2019; Bellandi et al. 2020; De Propris and Bailey 2020; Hervas-Oliver 2021), especially in terms of innovation policies. The latter constitutes the goal of this article. In this study we integrate both perspectives, analysing collective initiatives to introduce Industry 4.0 in districts and their local SMEs, approaching the micro- and meso-level of analysis.

In particular, this study researches the following questions: 'What' types of innovation policies work for Industry 4.0 in industrial districts? And, where they do, 'how' are those innovation initiatives designed, developed and implemented for introducing collectively Industry 4.0? This study analyses and compares Industry 4.0 initiatives to collectively introducing Industry 4.0 in industrial districts (MIDs).

This study's focus is the design and development of Industry 4.0 in three different districts in Spain: the 'Vinalopo' Footwear district, the Toys-Plastics district and the Ceramic tile district of Castellon. We perform a critical review and analysis of existent evidence in those districts complemented with additional empirical factors obtained by interviews.

In our study, the focal process is the analysis and comparison of different policy initiatives to foster Industry 4.0 adoption in MIDs, and the setting are three MIDs in Spain: the 'Vinalopo' Footwear district, the Toys-Plastics district and the Ceramic tile district of Castellon. Our access to the Industry 4.0 policy development process and its main actors, makes these districts well suited to our purpose. Following Eisenhardt and Graebner (2007), we develop case studies for theory-building, along with a critical review of literature on those districts, answering research questions that address 'how' and 'why' in unexplored research areas. Our study and method are both justified by the fact that although we observe that innovation policies in districts are ubiquitous, yet literature is poor on policies for Industry 4.0.

Our results contribute to understand the factors that support effective policies to support collectively the introduction of Industry 4.0 in MIDs (e.g. Bellandi, de Propris, and Santini 2019; Hervas-Oliver et al. 2019; Bellandi et al. 2020), contributing to industrial districts (e.g. Belussi and Sedita 2009; Hervas-Oliver, Belso-Martínez, and Díez-Vial 2022).

The remainder of the paper is organized as follows: After this introduction, Section 2 presents a literature review. Then, Section 3 shows methodology and data. Section 4 shows the district analysed and the empirical results comparing innovation policies. Finally, conclusions are presented in Section Five.

2. Literature review

2.1. Industry 4.0 in MIDs: what do we know?

2.1.1. SMEs in districts

MIDs are socio-economic contexts characterized by cooperation and competition among local SMEs in low-tech environments where 'innovation without research' is the usual business (Galletto and Domènech 2014; Hervas-Oliver et al., 2015; Boix, Galletto, and

Sforzi 2019), except for the large firms that orchestrate the local networks ('leading or technology gatekeepers' in the sense of Lazerson and Lorenzoni 1999). These 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 districts and districts (e.g. Munari, Sobrero, and Malipiero 2012). The local SMEs hardly perform any R&D activities, substituting them with intense cooperation, social ties and interactions with other local counterparts, including learning from and imitation of those leading firms. On the contrary, the leading firms are the ones performing R&D activities, as well as local support organizations, such as research institutes or universities. SMEs in this context might potentially suffer lock-in and cognitive inertia due to the excessive reliance on locally-based assumptions and paradigms, in no small part due to the fact that the local learning process is primarily based on 'incremental' innovation from knowledge interaction and exchange based on trust, social capital and repetitive interactions (e.g. Glasmeier 1991).

As regards 'Industry 4.0' of SMEs, as Moeuf et al. (2020) show, smaller companies present poorer integration of digital enablers and knowledge management in manufacturing facilities. As digitization is a capability in itself, related to IT and information systems, digitizing requires organization capabilities and knowledge management that enable learning and capabilities reconfiguration for introducing digital enablers in SME resources and capabilities. Such knowledge and the pre-conditioning of assets, especially those related to IT and software know-how that underpin digitization, however, are not particularly well developed in SMEs. Similarly, digitization also needs investments in machinery and facilities and supply chain re-organization, which are also more complicated for SMEs (Müller, Buliga, and Voigt 2018).

SMEs in districts, like other types of SMEs, do not know what to do about Industry 4.0 and other radical changes, due to their low level of capabilities to digitize and insufficient resources (Sommer 2015). As Matt et al. (2021) and Yüksel (2020) show, smaller companies present poorer integration of digital enablers and knowledge management in manufacturing facilities, that is, poor IT capabilities. Industry 4.0 is considered a disruption that involves radical organizational changes (see Bellandi et al. 2020), far beyond the local learning process based on incremental innovations. In the case of MIDs, SMEs are typically conducting incremental innovation lock-in technology and assumptions established by leading incumbents that organize local networks (see Munari, Sobrero, and Malipiero 2012). SMEs in districts are reluctant to change in front of radical innovations (see Glasmeier 1991; Hervás-Oliver et al. 2018; Hervas-Oliver 2021). Industry 4.0 is considered a disruption that involves radical organizational changes (see Bellandi et al. 2020), far beyond the local learning process based on incremental innovations. Corò and Volpe (2020) point out the difference between Industry 4.0 awareness and adoption, the latter at a very low rate (10% for Veneto SMEs). In addition, SMEs either in or outside districts, do not frequently engage with universities or research technology centres, preferring largely to cooperate and learn from other firms along their value chain (suppliers and customers).

Therefore, SMEs are very constrained in terms of adopting Industry 4.0, especially because the legitimization needed to be in the networks of learning orchestrated by leading firms. Radical changes are not easily welcomed in districts, where lock-in technologies, institutions and paradigms facilitate incremental, but discourage radical

changes (Gilbert 2012; Hervás-Oliver et al. 2018). All these constraints, along with the usual ones when it comes to the digitization of SMEs (e.g. Moeuf et al. 2020; Müller, Buliga, and Voigt 2018) complicate the change towards digital technologies.

2.1.2. The district advantage for Industry 4.0: cooperation, collective actors and actions

SMEs in districts, nevertheless, have an additional advantage, due to the logic of competition–cooperation. Put differently, districts facilitate collective actions that can be very useful to signal change and show the way to digitize among local SMEs (see Hervas-Oliver 2021; Hervas-Oliver et al. 2019; Pagano et al. 2021). Bellandi, Chaminade, and Plechero points out this factor calling it the 'collective rerouting' in districts, facilitating the incorporation of new knowledge and the transformation of networks, all supported by existing social relations and an institutional local system. SMEs in districts, by developing collective actions, might transit towards digitizing using the power of local cooperation. This cooperation is effectively applied to real cases, such as 'open-factories' or 'living-labs' for co-creation of new digital technologies in districts that foster cooperation and knowledge recombination to attract SME imitation, even facilitating open-doors policies to spread the awareness of change and show the way to do it (see Hervas-Oliver et al. 2019; Pagano et al. 2021). The collective actions are led and orchestrated by local actors and are based on open innovation and collaborative co-design and implementation, sharing common visions of the local cognitive structure required to digitize.

In any case, Industry 4.0 in regions and districts is said to be a place-based phenomenon that requires adaptation to those local assumptions, technologies, local networks, cognitive structures and institutions. In this respect, Sandulli, Gimenez-Fernandez, and Rodriguez Ferradas (2021) empirically show how it is not possible to define a single 'one-size-fits-all' policy for promoting Industry 4.0 that is generalizable to all regions but that it is dependent on the specific characteristics of each regional innovation system and, therefore, each district. Even the European DIH initiative[2] from RIS3 is based on bottom-up initiatives where local actors co-organize and co-design their digitization activities.

2.2. Placed-based innovation policies

What is the nature of place-based innovation policies? We refer to place-based innovation policies (e.g. Barca, McCann, and Rodríguez-Pose 2012; Magro and Wilson 2019) as initiatives built upon locally-sensitive associative structures of governance that are bottom-up, decentralized, open and consultative. These initiatives also involve local actor coordination and allow the collaborative co-design of actions by public and private joint efforts aimed at achieving collective goals by sharing common understanding about the local territory and its potential change. Similarly, Feldman and Lowe (2018) posit that effective policies are based upon bottom-up endogenous negotiations among local actors that include subsequent adaptations and incremental changes in response to changing conditions. These initiatives are constructed upon creative actions and joint collective decisions that take into account local social conditions and the interactions of actors in the policy. These collective actions are based on social practice and interactive learning, building upon the basis of collectively shared understanding of a

territory's strategic needs and priorities (Ebbekink and Lagendijk 2013, 749). These initiatives are oriented to solve future problems, present a diversity of multi-actors, and are oriented to joining complementary capabilities from different actors and industries, enticing cross-fertilization of ideas and promoting joint or collective action (e.g. Uotila, Harmaakorpi, and Hermans 2012). In a similar vein, Magro and Wilson (2019) refer to a similar concept, highlighting the open debate, trial and error and co-design of initiatives by different local stakeholders that cross-fertilize ideas to find a win-win solution in a collaborative atmosphere.

National initiatives for digitizing (e.g. 'HUBS, Catapults', etc.), as mentioned above, are based upon the idea of open innovation, collaboration and the development of networks for inter-firm interaction and innovation. For instance, the 'Digital Innovation Hubs' created by the European Union (see Hervas-Oliver et al. 2021) are one- stop-shops for SMEs, mid- caps and more mature or established companies, which provide a range of supporting services, including technology testing, financing advice, market intelligence, training, promotion and marketing, and networking opportunities for Industry 4.0 adoption. At the national level, digitization policies follow the principle of 'place-based initiatives', where location matters. For instance, the German 'Hubs' (defined as partnerships that connect SMEs, startups, corporation, research and science-based organizations for promoting digitization) located the leading 'Fintech' technology centre in Frankfurt, the financial capital, and the 'Mobility' platform in Munich and Bayern, the heart of the automotive industry in the country. Through these 'Hubs', the German government promotes alliances among universities, researchers, investors, institutions and companies, for creating digital innovation hubs sponsored by its national programme established in 2017 ('Digital Hub Initiative' from the 'Digitale Strategie 2025'). Similarly, the UK Innovate policy[3] fosters the digital transition through different programmes, such as the 'Catapult'[4] initiative that encourages the creation of connected centres in the country primarily aimed at converting the country's research and development into commercial products or solutions available for manufacturing firms. The programme is aimed at bridging the gap between business and academia, helping to turn great ideas into reality by providing access to world-class research and development facilities and expertise that would otherwise be out of reach for many businesses in the UK. In order to achieve this transformation, the initiative is based upon cooperation among companies, research workers and institutions (R&D centres, universities, accelerators, etc.), promoting the formation of networks and ecosystems to facilitate the application and commercialization of research.[5]

All in all, we posit that the design, development and implementation of collective actions based on cooperation in the digitization of districts becomes a very district-specific and place-based process. Thus, we point out that place-based initiatives for digitizing, need to embrace those above-mentioned principles such as being centred around place-based sensitive and common goals, open innovation, bottom-up co-design of initiatives, trial and error, involving local private and public actors in cooperation and the leadership of collective actors (see Hervás-Oliver 2021). By 'collective actor', we refer to public and private organizations formed by a coalition of industry, government and science representatives that are geographically, institutionally and socially embedded (e.g. York, Hargrave, and Pacheco 2016).

3. Method, data and settings

3.1. Methodology

This study utilizes a literature review (for the digitization of the Spanish Ceramic tile district, the Vinalopo Footwear and the Toy-Valley district), along with 24 additional interviews. A literature review concerning the introduction of Industry 4.0 in the Ceramic tile district (from Hervas-Oliver et al. 2019) is complemented by access to the empirical material (transcriptions, secondary reports, etc.; 30 interviews). Similarly, the approach to understanding innovation initiatives for digitization of the Toy Valley (from Hervás-Oliver 2021), is complemented by access to the transcriptions and material from the district (54 interviews during 2017 and 2020). In a similar way, for the Vinalopo Footwear district we follow suit, accessing the empirical material (45 interviews, from Hervás-Oliver 2022).

Lastly, in 2021, 24 additional interviews were carried out to evaluate innovation policies in each district. This qualitative approach through local business associations and RTIs leading digitization initiatives (8 in the Vinalopo Footwear, 8 in the Toy-Valley and 8 in the Ceramic tile district of Castellon), extend our knowledge on each district. Interviews include a basic current description of the districts, complemented by the Industry 4.0 policies implemented in each district. The three districts are considered traditional Marshallian Industrial Districts (see Boix and Galletto 2009, among many others).

3.2. Settings: industrial districts in the analysis

Each District's features are summarized and explained in Tables 1 and 2. See Tables 1 and 2.

As observed in both tables, the three districts analysed present common features of their MARK III status,[6] all of them showing a high degree of specialization, the significant presence of foreign (and indigenous) multinationals and a high-quality supportive structure of training and scientific research (e.g. local business associations, vocational training centres, research and technology transfer institutes devoted to local technologies and highly embedded in the territories, etc.). In particular, the interviews commented on the importance of the global value chains, the benefits of hosting foreign multinationals and the necessity to turn the tide towards digitization and sustainability.

These districts present vertical Research and Transfer Institutes (RTIs) that are well embedded in the territory and focused on local technologies. These RTIs ('ITC' at the Castellon ceramic tile; 'Inescop' at the Vinalopo footwear and, AIJU at the Toy-Valley) are world-class organizations in their fields that belong to the Valencian REDIT (network of institutes[7]) and enjoy coalitions of public and private stakeholders, being public organizations (in ownership) but privately run by a Board of Directors voted among the local firms in each district focused on. They present a mixed finance portfolio, with public (around 60%) and private (around 40%) funding, the latter form the services that are provided to firms (testing, product certification, R&D, etc.) and others (European Projects participation, other national competitive funding, etc.). These RTIs are 'public' labs that nurture districts with new technology and innovation for supporting the firms' innovation processes. They also provide support services

Table 1. Main districts' features I.

Districts	Description/type of district	Local supporting organizations and infrastructure	Local value chain and industries located
Footwear (Vinalopo, Alicante)	• Description: A vibrant world-class footwear production specialized in women shoes (high-heel and high-medium end). • Strengths: very good local supporting organizations, many multinationals operating, European hub for footwear-related business.	• RTI (Inescop) • Local business association (AVECAL) • Vocational training centres • Exhibitions, show rooms • Spanish Association of Footwear Components Firms (AEC) • Federation of Spanish Footwear Industries (FICE) • Others	Auxiliary industry: producers of footwear components, packaging for footwear, all different stages of footwear (design, R&D, production, logistics, marketing, etc.).
Ceramics (Castellon)	• Description: A vibrant world-class ceramic tile production and leading district for tile decoration (glazing firms in the chemistry industry for tiles); • Strengths: very good local supporting organizations, many multinationals operating, European hub for ceramic-tile related business.	• RTI (ITC) • Local business association (ceramic tile ASCER; cermic equipment, Asebec; ceramic decoration, Anffec) • Vocational training centres • Exhibitions, show rooms, fair trade (CEVISAMA) • Others	Auxiliary industry: producers of decoration (chemistry) and equipment for ceramic tiles, packaging for ceramics, all different stages of ceramic tile production (design, R&D, production, logistics, marketing, etc.).
Toys-Plastics (Ibi)	• Description: A vibrant world-class district for plastics-packaging and toys production • Strengths: specialized in moulding for plastic injection; very good local supporting organizations, many multinationals operating, European hub for packaging and plastics related business.	• RTI (AIJU) • Local business association (IBIAE) and cluster association (Toy Valley cluster association) • Vocational training centres • Exhibitions, show rooms • Spanish Association of Toy Producers (AEFJ) • Others	Auxiliary industry: producers of plastics, plastic components, packaging for different markets (pharmacy products, health care, beverages, automotive, furniture, toys and other industries), all different stages of plastic-packaging production (design, R&D, moulding, production, logistics, marketing, etc.).

Source: Own, based on literature.

Table 2. Main districts' features II.

District	Specialization Index **	Number of firms
Footwear (Vinalopo)	469% Exporting >60%	• Around 2,300 very small firms, predominantly around 1–9 employees • Around 30,000 manufacturing jobs in the local technology (footwear production and auxiliary industries)
Ceramics (Castellon)	338% Exporting >80%	• Around 120 tile producers plus 60 in auxiliary industries; small firms predominantly starting from 50–100 employees; • Around 20,000 manufacturing jobs in the local technologies
Toys-Plastics (Ibi)	170%+ Exporting >40%	• Around 400 firms, predominantly around 1–9 employees • Around 7,000 manufacturing jobs in the local technologies

Source: Own elaboration, also from interviews;** Valencian Region over Spanish (data in specific NACE activity codes), https://argos.gva.es/documents/165533218/172307874/Entregable+7_Especializaci%C3%B3n+productiva+de+la+Comunitat+Valenciana/e3e701d6-2bad-4753-a707-454a3aab57bf; for Toys is about 200%.

tailored to the districts' needs. The districts are also well represented by local business associations.

Each of the three districts displays a very different local value chain and division of labour, showing different concentration indexes (measured through 'Specialization

Indexes' using Spanish data according to specific NACE activity codes), firms and export intensities. See Tables 1 and 2 for details.

The local 'networks' display very interesting differences, showing different structures and mechanisms for knowledge diffusion. In the Castellon ceramic tile district, all firms manufacture the final product (ceramic tiles) and the equipment and chemical firms (production and decoration, respectively) are the ones transferring new knowledge and innovation. Despite the fact that all firms compete, we observe inter-firm cooperation not only in the producer-user spectrum (ceramic tile firms with equipment and chemical firms) but among ceramic tile firms that specialized in different types of products and then exchange them to complete product portfolios or to serve a single customer with a full range of products. Inter-firm cooperation among competitors, not only along the division of labour, is observed and also fosters an intense process of local imitation.

As one interviewee revealed at the ITC:

> The reality of this district is a very intense cooperation, not only in collective efforts but the way that informal groups based on trust and good relationship trade types of products among themselves, allowing for high specialization of firms. Having said that, competition is also very intense.

The Vinalopo footwear district is quite different, as not all firms produce the final product (footwear) but the different components (leather, soles, heels, fastening, rubber, etc.). The division of labour, therefore, is orchestrated by the leading firms that produce (coordinate the assembling of) the final product. These firms are also the ones that concentrate design, marketing and access to the distribution channels (even with their own physical or online stores). ZARA's subsidiary (Tempe) constitutes one example of these firms. Cooperation is non-intense among competitors. Cooperation, therefore, is especially observed along the division of labour (user-producer, outsourcing agreements) but in a quasi-hierarchical approach, as small producers of components are very dependent on those 'leading' firms.

The Inescop interviewees reported:

> A critical mechanism of knowledge transfer in the district are the leading firms that orchestrate networks of SMEs that produce footwear components. As there is a quite hierarchical structure, SMEs learn primarily form those leading firms that train them to be more efficient and thus improve the whole network.

Finally, in the Toy-Valley district cooperation among competitors is less frequent than in the ceramic tile district, and significant cooperation is observed through the division of labour (producer-user). As members of AIJU reported:

> Cooperation between suppliers-users is very intense, but not among competitors. Imitation, however, is capital in this territory.

> Social ties and informal networks really diffuse knowledge around focal local technologies.

4. Industry 4.0 innovation policies for Industry 4.0 in districts

As reported in the reviewed cases, in all the three districts, the regional policymaker (IVACE, belonging to the Economic branch of the Valencian Regional Government)

launched an initiative to digitize SMEs ('Agenda Industria 4.0'[8]) in the region. In particular, the principal actors for leading the co-design and implementing the initiative were the different Research and Transfer Institutes operating in each territory. In the ceramic tile district, the project 'CEBRA+' was co-designed with the 'ITC' and the local business association in ceramics (ASCER); in the footwear district, the 'I4FOOTWEAR' was arranged by 'Inescop'; and, in the Toy-Plastic district, the 'TALLER4.0' was co-organized with 'AIJU'.

According to the reviewed literature the sequence of learning aimed at signalling change to SMEs is consistently developed in all the districts: (a) Collective actors (e.g. Research and Transfer Insitutues) access to new digital technology through R&D and open innovation (R&D for digitizing, technology gatekeeping, technology watch, roadmapping, European Union R&D projects, alliances with universities, learning with the information and technology industry, etc.); (b) Collective actors co-design the innovation initiative with public and private local stakeholders in a place-based approach (bottom-up, private and public collaboration, local actors, etc.); (c) The initiative is tailored to the local learning and institutional setting, identifying the main actors to diffuse and contaminate the territory with the new technologies; (d) The collective initiative signals change, shows a roadmap to start from; (e) Diffusion and contamination of the new technology utilizes the district-specific learning and institutional structure, fostering change through imitation and interaction[9]: either diffusing knowledge to leading incumbents that subsequently will 'contaminate' their networks of SMEs (interaction) and/or fostering imitation through managing living-labs to spread imitation. See Table 3 for a more detailed summary of facts.

4.1. The Vinalopo footwear district: 'I4FOOTWEAR' initiative[10]

In the case of the footwear district, the division of labour is very fine-grained and decomposed into multiple parts, from design to leather cutting and sewing but also producing components such as soles, heels, textile parts, plastic parts and many more. Each subsector is very specialized along a multi-step process. Only large or medium-size firms manufacture or coordinate the assembling of the final product (footwear) and those are the ones organizing local suppliers of many footwear components. Therefore, the structure of the networks combines cooperation but also shows a quasi-hierarchical structure where large/medium firms orchestrate networks of SMEs. As reported in Hervás-Oliver (2022), 'Inescop' developed the technology to digitize (CAD/CAM design and 3D printing for prototyping) and primarily targets those firms that orchestrate SMEs to accomplish dissemination of these new digital technologies. This Research and Transfer Institute transfers digital technologies to those leading firms and then, these firms interact with their networks of SMEs to diffuse the new technologies. This is reported to be the learning process in the focal district. Interviewees from Inescop commented (interviews in 2021):

> Small firms cannot absorb new digital technologies, except when they are technology-based startups. These small firms, very specialized in some particular stages of the footwear production, only rely on their customers that outsource them with very precise instructions regarding materials, design and technology. Therefore, we transfer primarily to the leading firms and then, inter-firm interaction diffuses digital technologies to the SMEs.

Table 3. Innovation policies to digitize districts: footwear, plastics-toys and ceramics MIDs.

Dimensions	Footwear MID	Plastics-toys MID	Ceramics MID
Automation and production processes	Labour-intensive, low level of automation.	Medium-low level of automation	High-automation level
Industry 4.0 enablers	Lead and developed by the transfer institute 'Inescop'; 'I4FOOTWEAR' project: CAD-CAM design and 3D printing, among others. Focus on design and marketing activities; less in manufacturing	Lead and developed by the transfer institute 'AIJU'; 'TALLER4.0' project: Augmented reality, 3D printing, Big Data, Robots, others. Focus on manufacturing activities	Lead and developed by the transfer institute 'ITC'; 'CEBRA +' project Sensoring and tracking; Big Data, Robots, others; in two main projects, 'CEBRA' for digitizing manufacturing and 'CEBRA+' for digitizing distribution and sales through on-site digital kiosks for digital display of the product and data collection. Focus on manufacturing activities.
Goal of the policy initiative	Foster change in the district, showing the way to firms; avoid cognitive inertia; facilitating to IT industry the entrance into the industry	Foster change in the district, showing the way to firms; avoid cognitive inertia; facilitating to IT industry the entrance into the industry	Foster change in the district, showing the way to firms; avoid cognitive inertia; facilitating to IT industry the entrance into the industry
Collective initiative in action	Industry 4.0 technology demonstration platform	Industry 4.0 Living-lab demonstration platform at local SMEs	Industry 4.0 Living-lab demonstration platform at a local SME (CEBRA project) Also CEBRA+ digitization of the distribution channel through digital kiosks.
Diffusion mechanism	Utilizing **leading firms** as recipients of the digital knowledge; then, indirect effects (subsequent diffusion and also imitation).	Utilizing **SMEs** (around 50 employees) to place the living-lab for fostering imitation by other local firms.	Utilizing **SMEs** (200-250 employees) to place the living-lab for fostering imitation by other local firms.

Source: Own from literature analysis and empirical evidence (Hervas-Oliver et al. 2019; Hervás-Oliver 2021; Hervás-Oliver 2022), along with subsequent interviews.

> These leading firms orchestrate the networks of SMEs. They design the product and then outsource the production to local SMEs and control it. When these leading firms adopt new digital design technologies, subsequent outsourcing adds new requirements and additional cooperation with their SMEs that are required to learn and utilize new technologies. In the end, leading firms spread the new technology.
>
> We show leading firms the way to digitization. Then, they teach SMEs and also pass down the new way of doing things. It works this way in this district.
>
> Most leading firms work with us and they utilize the new CAD/CAM technologies for footwear, requiring their local SMEs to start to change to the new requirements. It is a very effective diffusion that only works (here) this way.

In this particular case, as reported by Hervás-Oliver (2022), the local cognitive structure showed quasi-hierarchical networks orchestrated by leading firms that coordinate production. SMEs are not really using Research and Transfer Institutes but leading firms do (as they also conduct R&D). This way, the activation of knowledge diffusion in the territory works this way: the Research and Transfer Institute transfers to leading firms that also diffuse to the local networks of SMEs. Inescop has developed a demonstration platform for digitizing and the leading firms use it and engage. It is like a double step process in order to create awareness of

change among local SMEs (indirectly through the leading firms that orchestrate local networks).

4.2. The ceramic tile district: CEBRA and CEBRA+

The Ceramic tile district, however, is very different to the footwear district. In accordance with Hervas-Oliver et al. (2019), in the ceramic tile district most firms produce the final product (ceramic tile), albeit there is an ample division of labour (clay extraction, chemical products for decoration, etc.), but the ceramic tile is not decomposable as in the previous case of footwear. Also, the ceramic process is highly automated. Rather, the 'ITC' seeks more to diffuse the new technology by seeking local imitation, rather than using leading firms diffusing within their local networks. As Hervas-Oliver et al. (2019) shows, the 'ITC', along with ASCER (local business association) chose one advanced SME to install a demonstrative living-lab of Industry 4.0 activities. The specific activities for digitizing were primarily sensors and traceability, including data analytics and others. The 'ITC' supported the trial-and-error optimization of the new demonstrative line of production, and then organized open-doors shows to foster subsequent imitation by local firms. Open doors are a capital feature of the initiative, as public (pre-arranged) visits to the living-lab open to local competitors were required. This is possible because of the intense cooperation in the district, including the fact that the local business association considered the initiative as a collective action for the district, to the extent that it chose the company (named 'Colorker') for the living-lab. As interviewees from 'ITC' stated:

> The living-lab demonstration line for Industry 4.0 (CEBRA project) is a way to show the way to local firms, supporting them to start to change.
>
> We are also training the equipment suppliers for ceramic tile machinery to show them how to digitize local ceramic tile firms. We expect that dissemination of best practices by equipment suppliers and imitation in the district will push diffusing new technologies.

After the implementation of this technology demonstration platform, the 'ITC' performed more activities to support change in the district, such as a digital catalogue of new processes to the local equipment auxiliary industry, training activities for digitization, as well as developing a 'simulator' of ceramic tile digitization to show in real terms the expected outcomes. All these activities were focused on ceramic tile production. In addition, the CEBRA+ project started a digitization of sales, creating an on-store 'digital kiosk', as concept, for digitizing sales in physical stores. The new machine, based on Artificial Intelligence, Virtual Reality (immersion technologies) and Machine Learning allows showing real ambiences and spaces where the ceramic tile fits and also collects data from the customers. In this pilot project, 3 local ceramic tile firms ('Azteca, Colorker and Fustecma') and also one store participated.[11] Instead of production, this extension of digitizing is applied to ceramic tile marketing departments.

In this particular case, as Hervas-Oliver et al. (2019) report, the configuration of the local cognitive structure and the local networks favour more diffusion by imitation. Just the opposite to the Footwear initiative, the CEBRA project wanted to utilize SMEs to signal awareness to change, showing the way and to seek pervasive imitation. This differs remarkably from the Footwear diffusion system (through leading firms). In

addition, the social ties and extensive cooperation in the territory (e.g. joint purchasing is the norm for gas and utilities, the local business association organizes the largest ceramic tile fair trade in Europe, named CEVISAMA, etc.) facilitate the 'open-doors' policy, where local firms (competitors) could visit the local living-lab at 'Colorker' SME in order to learn the way to change. Imitation is working, as observed by the interviewees.

> It is a very competitive advantage to show the way to digitize to local firms, we did not find these types of initiatives in the industry in any other country.

4.3. The Toy-Valley district: 'TALLER 4.0 initiative'

Lastly, in the Toy-Plastics district, network structure is more socially and relational-based than footwear. In particular, it displays more relational-based networks, similar to ceramics, and most companies produce the final product.

Focusing on the specific local cognitive structure, 'AIJU' undertakes a similar approach to that of the ceramic tile district, seeking imitation and co-designing a living-lab for Industry 4.0 technology demonstration in a SME (the 'Vicedo Marti' firm) with the purpose of developing plastic process oriented Industry 4.0 technology. The latter includes, primarily, tools for developing Artificial Vision, 3D Printing, Augmented Reality and Data Analytics applied to plastics, among other technologies. It also follows an 'open-doors' approach, as stated by Hervás-Oliver (2021). This means that local competitors can visit the digitized production line to see how to do it and what the outcome could be. This initiative signals change and spread 'me too' or imitation among local SMEs in that industry. In this case, the substantial difference with the ceramic tile district is primarily based on the fact that firms are rather smaller than the ceramic ones, meaning less resources to digitize. In this case the advanced SME (size around 50 employees) chosen for the living-lab is very different from the one chosen in the ceramic tile district (size over 200 employees). As interviewees in 'AIJU' pointed out:

> It was not our intention to choose the best or most advanced firms, but one that can inspire other SMEs to follow suit. Our purpose is to prepare the district for change and show the way but also to give the message: all firms can do it.

> We expect imitation in the district, as the firm is a reference point for other SMEs

> Large firms in the district have their R&D funds for digitizing and their headquarters' support. These firms are not within our realm. Rather, SMEs are the core of the district and our purpose.

4.4. General insights

In all cases, all the Research and Transfer Institutes manifested the crucial importance of the co-design of the innovation policy instrument, interacting both formal and informally with local business associations, local companies and the public policymakers (named IVACE). All in all, those initiatives are built upon associative structures of governance that are bottom-up, decentralized, open, consultative and involve local actor coordination, allowing co-design by public and private stakeholders that present a common understanding about the territory and its change (e.g. Feldman and Lowe

2018). In addition, each place followed a specific place-based initiative. There is no point in creating a single one-size-fits-all initiative for different places.

As 'AIJU' indicated:

> We visited the Ceramic tile (CEBRA) living-lab, nice as an inspiration, but there is no point in creating a single one-size-fits-all initiative for different realities. Our district is very different in all dimensions.
>
> We co-designed the initiative, bringing our vision to the negotiation with policymakers. They trust us, we have plenty of experience in the territory
>
> This bottom-up approach is the best for the territory, as it also decides what to do from consultation with the real actors: local firms and local support organizations
>
> The Taller 4.0 created awareness, showed the way to SMEs, achieved imitation and created a new IT industry specialized in the territory and its needs.

As 'Inescop' stated:

> Policymakers just set the goal (digitization) and we proposed the best possible way for the territory, considering many different factors such as the local technology, the type of networks and other factors. We explained it and they agreed, setting some boundary conditions. This co-creation is very fruitful, as the local place is put first.
>
> We adapt the Industry 4.0 initiative for our local system: leading firms organize production and innovation. Diffusion through leading firms is how learning occurs in this district
>
> Also imitation is important, as everybody knows each other. What leading firms do is the next step for SMEs.
>
> We did not choose a living-lab, because cooperation mainly occurs in the user-producer interaction and because there are many different activities in the local value chain … ..diffusion based on leading-SMEs interaction has always worked in here … ..
>
> I4FOOTWEAR has proved to be successful, most of the leading firms have initiated the change and utilize our technology. The spread it throughout the territory.

These type of indirect effects on SMEs, are evidenced as non-targeted SMEs might improve their performance when they are in the networks (as suppliers or customers) of target leading firms that receive the knowledge from the universities or research centres (see Fotso 2022; Chai and Shih 2016).

As 'ITC' reported:

> Allowing the local organizations to lead the change is the best way, as we are permanently in touch with the territory and know its technology and needs. Thus, we negotiated with policymakers and the local business association (ASCER) what we should do and how to do it, and after some changes and refinements, all actors agreed on the plan.
>
> CEBRA is the first digitization initiative for the ceramic tile industry founded on a living-lab and open doors basis, to the extent that many international competitors were interested to visit the plant, from Brazil, Mexico, Italy, etc.
>
> When policymakers allow local actors to show the way, it works much better as it is not something imposed.

> Each local company is going to use CEBRA in its own way, as each of them have different capabilities. We wanted mainly to show the way and to show that is possible to do it, for this reason we chose an SME.
>
> We went further and also proposed the CEBRA+, adding digitization of sales, through digital kiosks, and going beyond the initial idea of just digitizing production. This was a need from the local firms that was not previously considered by policymakers who were just thinking about production improvements.
>
> The territory is changing and most companies are investing in digitization, as we achieve the generation of best practices and legitimization of the new paradigm. Nevertheless, awareness is larger than adoption at this moment.

The policy instrument for all districts was also supported by an innovation voucher scheme for incentivizing SMEs to start to adopt Industry 4.0 ('DigitalizaCV' programme, launched by policymaker named IVACE), training courses, demonstration events, seminars, etc.

In each MID, the policy was a place-based effort where local stakeholders (especially RTIs but also some local business associations) negotiated what to do and how to do it. Notice that the local Research and Transfer Institutes are organized by local businessmen, researchers and scientists and policy-makers' representatives.

As reported in the literature, each district initiative was totally tailored to local productive 'chorality' of places (Becattini 2015), that is, place-based and collective in nature: actors, technology, networks-institutions and collective actors.

As regards local actors, we identified important differences across the three MIDs compared, as indicated in the previous Section. Then, for the case of local technologies, there are remarkable differences not only in the type of technologies but their level of automation in each district. While the footwear district is still a very labour-intensive industry, the toy-plastic is intermediate and the ceramic tile district is almost totally automated. Thus, automation facilitates digitization, as most digitization processes consists of adding new sensors to existing automated processes. The type of local networks and their structure in the district, i.e. how the division of labour is organized and how the final product is accomplished, is also very important. It describes not only how value is added, but how the learning process occurs and how collaboration is organized.

5. Conclusions

This study approaches innovation policies for Industry 4.0 in MIDs by analysing collective initiatives undertaken in different industrial districts. In this context, we answer the following research questions that constitute this study's goal: 'what' types of innovation policies work for Industry 4.0 in districts? And, where they do, 'how' are those collective innovation initiatives designed, developed and implemented? We assume that SMEs in districts struggle to adopt radical changes and they also present the typical problems of SMEs (e.g. poor financial resources and competences, weak information and technology systems, etc.). For this reasons, initiatives aimed at collectively signalling change towards Industry 4. 0 and showing how to do it are very interesting: collective and cooperative place-based initiatives.

By reviewing existing literature and performing additional empirics (24 interviews in 2021) on three industrial districts in Spain (i.e. the Vinalopo footwear district, the Toy-Valley district and the Ceramic tile district of Castellon, all in the Valencian Region, the one with more districts in Spain, see Boix and Galletto 2009), we are able to build theory inductively by comparing each territory's collective initiative for Industry 4.0. Results reveal that the same Industry 4.0 programme led to different policy initiatives or instruments by involving local actors' co-design, negotiation and implementation: these collective actors, mainly RTIs and local business associations, tailored each initiative to their focal territories and idiosyncratic characteristics.

Industry 4.0 policies in these settings were place-based: co-designed, openly discussed, tailored and implemented in a very local-sensitive approach. Findings suggest that the relevant factors of these policies are:

First, the composition of local firms and their characteristics, especially size, organizational strategies, technology, etc., matters: it really makes a difference local SME capabilities (e.g. finance, information systems, managerial, etc.) and their industries that require different digital enablers.

> Proposition 1: Typologies of local SME capabilities and industries agglomerated in the focal district influence Industry 4.0 initiatives.

Second, the structure and function of institutions and local networks, especially defining the local production, innovation and learning process: each territory presents an idiosyncratic 'way of learning'. As we consider that both learning from (imitation) and learning with (interaction) 'à la Staber' are very important in districts, this dimension really influences diffusion of the new digital technologies. Thus, open doors policies (and their open living-labs), based on intense social capital, differs in each of the three districts analysed.

> Proposition 2: Local institutions and networks interaction and learning process in the focal district influence Industry 4.0 initiatives.

Third, collective actors lead and organize the cooperative collective action. Local collective actors (local business associations, Research and Transfer Institutes, etc.) are very important in these policies, as they mediate the public and private local actors, share a collective understanding of local needs and also legitimate the new Industry 4.0 technology for being accepted in the territory as a new sub-identity. They signal change and avoid cognitive inertia, especially among SMEs. Also, collective actors utilize the cooperation–competition logic of MIDs, aligning interests and coordinating all actors required for the change (new companies from information system industries, new complementary activities, etc.).

> Proposition 3: Local collective actors shape the Industry 4.0 initiative utilizing the cooperation-competition logic of MIDs, legitimizing change and aligning common interests of the focal districts.

One of the main differences between regional and national policies for Industry 4.0 is the place-based approach of the former (see more at Hervas-Oliver et al. 2021): tailored to the local context, coordinated and co-designed with local actors and promoting change but considering the local technology and institutional setting. Space-blinded

national policies are interesting for changing skills and capabilities across industries (e.g. training in digital technologies, financial schemes for adopting Industry 4.0) but do not understand the collective and competition–cooperation idiosyncratic nature of districts, nor their local networks. Hence, national ones are a good complement to the regional ones that are the core ones. Coordination, nevertheless, should be considered from regional policies to avoid overlapping.

The study's results contribute to the Marshallian literature (e.g. Belussi and Sedita 2009; Hervás Oliver 2015; Hervas-Oliver, Lleo, and Cervello 2017) and the Industry 4.0 topic (e.g. Bellandi, de Propris, and Santini 2019; Bellandi et al. 2020; Hervas-Oliver 2021; Lazzeretti et al. 2022).

Notes

1. See more on the differences between digitization and digitalization (e.g. Yoo et al. 2012).
2. https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs.
3. https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future.
4. https://catapult.org.uk/.
5. Department for Business, Energy & Industrial Strategy (2017). Catapult Program: A Framework for Evaluating Impact. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/662319/catapult-programme-evaluation-framework.docx.pdf.
6. From local endogenous and incremental learning, Mark III category goes to more show district openness to connect to trans-local and trans-international value chains, *servitization*, multinational companies and more radical changes. See more in Bellandi's works.
7. https://www.redit.es/en/home/
   ITC: Ceramics Technology Institute; Inescop: Footwear Technology Institute; AIJU: Toys and Plastic Technology Institute.
8. https://www.ivace.es/images/Industria_4.0/Agenda_Industria_40_CV_v0_web.pdf.
9. See Staber (2009).
10. Based on Hervás-Oliver (2022).
11. See more here: https://ceria.es/category/itc/.

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