Everything must change for us to remain the same. Resilience in the face of disruptive innovations in industrial districts

This version is a post-Print.
Final version published in European Planning Studies (09/02/2023)
https://doi.org/10.1080/09654313.2023.2183766

Francesc Xavier Molina-Morales[a], Valentina De Marchi[b], Luis Martínez-Cháfer[c] and David Valiente-Bordanova[d]*

[a] *Department of Business Administration and Marketing. Universitat Jaume I, Av. De Vicent Sos I Baynat, s/n, 12071, Castellón de la Plana, Spain, 0034 964 72 80 00, xavier.molina@emp.uji.es;*
[b] *Department of Economics and Management, University of Padova, Via del Santo 33, 35123, Italy, +39 049 827 782, valentina.demarchi@unipd.it;*
[c] *Department of Business Administration and Marketing, Universitat Jaume I, Av. De Vicent Sos I Baynat, s/n, 12071, Castellón de la Plana, Spain, 0034 964 72 80 00, chafer@emp.uji.es;*
[d] *Department of Business Administration and Marketing, Universitat Jaume I, Av. De Vicent Sos I Baynat, s/n, 12071, Castellón de la Plana, Spain, 0034 964 72 80 00, dvalient@uji.es*
**Corresponding author*

This paper explores to what extent and under what conditions resilience can be developed to cope with disruptive innovations in the industrial district context. Based on an in-depth comparative analysis of two districts, this paper investigates the transformation that was undergone by these agglomerations of firms thanks to the introduction, development, and diffusion of disruptive technologies. Our findings identify the specific key actors involved during the different phases of the innovative process. Additionally, different measures of district resilience are proposed.

Keywords: industrial district; industrial district evolution; disruptive technological innovation; comparative case study; resilience

JEL codes: O32, O33

1. Introduction

Industrial districts (IDs) have represented the engine of development in manufacturing industries in several European countries during the 1970s-1990s; evidence suggests that in more recent years just few of them still remained competitive, confronted with profound structural changes in globalized markets (De Marchi and Grandinetti, 2014; Ottati, 2018; Rabellotti et al., 2009). What allows some industrial districts to be resilient while others succumb?

The concept of resilience has been used to explain the differential adaptability and flexibility of territories to external changes (Asheim et al., 2011; Bristow and Healy, 2018; Cooke, 2017). Initially developed at the regional level, it has been increasingly adopted to explain industrial districts' (IDs) ability to face current challenges (Gilly et al., 2014; Pike et al., 2010). With respect to the emerging literature interested in explaining the causes of resilience in different IDs (Henry et al., 2021; Klepper, 2010) or to look for driving forces impact district trajectories to resilience (Eisingerich et al., 2010; Suire and Vicente, 2014), we contribute by investigating the conditions under which districts exhibit resilient behaviours in the face of disruptive innovation (DI) processes. Empirical analysis focused on a different territorial scale – regions – suggest indeed that innovation – considered as the introduction of novel technologies on the market – can represent an important driving force behind new path of development and resilience (Mossig and Schieber, 2016). Our main research question is: under what conditions can district resilience be developed confronting external or internal disturbances caused by a disruptive innovation? This question is of utmost importance for (local) policy makers. Nowadays IDs are required to face several structural transformations – such as digitisation of processes related to industry 4.0 (Götz and Jankowska, 2017; Grashof et al., 2020; Hervas-Oliver et al., 2021) – which require them to heavily adapt their structures and strategies to new external global conditions (Cooke et al., 2012; Elola et al., 2017; Santner, 2018; Sedita and Ozeki, 2022). As IDs are usually more suitable for incremental innovations

(Elche-Hortelano et al., 2015), being challenged to face problems with the development of radical or disruptive innovative processes (Molina-Morales et al., 2002), understanding how IDs might succeed to be resilient to radical transformation can be a powerful lesson in the development of policies aimed at supporting IDs.

To address this research question, we examine in depth two illustrative cases of districts that proved resilient in the face of a disruptive innovation (DI) an infrequent yet occurring case (Hervás-Oliver and Albors-Garrigós, 2014; Molina-Morales et al., 2017): the Montebelluna Sportsystem (Italy) and Castelló ceramic tile district (Spain). By considering similarities across cases, we contribute to the literature by investigating what IDs characteristics enable resilience when facing the introduction and diffusion of disruptive technologies and contribute to the literature by developing measures of resilience specific to the ID level.

2. Conceptual background

2.1 Resilience in regions and industrial districts

After the seminal contribution by Simmie and Martin (2010), resilience became a buzz word for academic and policy makers interested in understanding the ability of territories to resist or respond to major shocks (Martin and Sunley, 2015; Ormerod, 2010; Pendall et al., 2010). The most adopted definition of resilience in regional studies is that of 'adaptive resilience', which is defined as "the capacity of a regional or local economy to withstand or recover from market, competitive and environmental shocks to its developmental growth path, if necessary by undergoing adaptive changes to its economic structures and its social and institutional arrangements, so as to maintain or restore its previous developmental path, or transit to a new sustainable path characterized by a fuller and more productive use of its physical, human and environmental resources" (Martin and Sunley, 2015, p.13). Such an ‘adaptive’ approach to resilience is connected to what other studies have explicitly named transformation, i.e., the ability to implement radical change after having experimented market, technological or economy-wide disruptions (Holm and Østergaard, 2015; Sedita et al., 2017). Resilience can be understood, within the evolutionary-Schumpeterian theory of regional development as such shocks which can ‘set off gales of creative destruction’ (Martin and Sunley, 2015), i.e., re-orienting the technological and production system of a region (Boschma, 2015; Bristow and Healy, 2018).

Accordingly, resilience is a useful concept for understanding how territorial agglomerations of firms respond to change. In the context of industrial districts (IDs), resilience is “an adaptive capability that allows a cluster to make changes to overcome internal and external disturbance and still function with its identity as a cluster” (Østergaard and Park, 2013: 4). Indeed, resilience has been used to identify and classify different evolutionary development paths (Martin and Sunley, 2011), to explain why some districts evolve while others disappear in the face of external challenges such as globalization, recession, and natural disasters (Cainelli et al., 2018; De Marchi et al., 2018).

IDs are defined as a geographically bounded areas, where a population of firms, mostly small and medium-sized enterprises, perform different productive activities related to the same business field (Pyke et al., 1990). These IDs are formed by end-product firms and specialized firms, as well as a range of local institutions such as educational centres, research institutes, trade associations, and governmental agencies (Molina-Morales and Martínez-Cháfer, 2016). IDs have been known to increase flexibility and efficiency in regions, and considered as cost reduction drivers for companies (Giuliani and Bell, 2005; Lazzeretti et al., 2014; Molina-Morales, 2001). However, their ability to generate competitive advantages for the embedded firms is increasingly being questioned (Grandinetti and Camuffo, 2011), mainly due to globalization (e.g., De Marchi et al., 2014) and technological shifts (e.g., Østergaard and Park, 2015). While some have been successful in resilience, many cases of stagnation and decline have emerged due to lock-in (Alberti, 2006; De Marchi et al., 2018; Henry et al., 2021; Pouder and St. John, 1996), making the question on what determines such heterogeneous performance more compelling.

2.2 Determinants of resilience and DI in districts

What determines district resilience? Suire and Vicente (2009) suggested that resilience is based on knowledge recombination of three different forces: decision externalities, composite technologies life cycle and structural properties of knowledge networks. Other factors that have been found to influence ID resilience include new firm formation, technological diversity, transversality, technology recombination, and the role of multinationals (Gilly et al., 2014; Østergaard and Park, 2013; Ryan et al., 2020).

Drawing on literature on the resilience of regions (e.g., Bristow and Healy, 2018; Caro et al., 2017; Filippetti et al., 2020), we suggest that localized innovative capabilities are important for understanding the resilience of IDs. Following the 'adaptive cycle model of cluster evolution' proposed by Martin and Sunley (2015), we argue that resilience is linked to the presence of innovative firms that can reorient the industrial and technological specialism of the district, and the existence of local networks that enable the diffusion of innovation capabilities. ID performance is influenced by the strength and openness of these networks (Grashof et al., 2019). This view is consistent with studies that focused on the different evolutionary trajectories of IDs in response to globalization shocks. In their comparative analysis of three districts with opposite performances, De Marchi et al., (2018) suggest that the presence of a variety of actors with innovative capabilities and connections with external sources of knowledge (thanks to multinational firms) is a distinctive feature of resilient IDs.

DIs have been defined as new technologies enabling new paths and technological fields (Christensen, 1997). Similar concepts include radical innovation (Andriani and Cattani, 2016) and breakthrough innovation (Mascitelli, 2000; O'Connor, 2008), all referring to the replacement of existing products or technologies by radical new ones. We follow the perspective of Markides (2006), who reviewed the approach of Christensen (1997) and distinguished between radical (referring to products) and disruptive innovation (for technologies). Consequently, we consider a DI as an external shock involving a technological change that incorporates new knowledge, resources or skills and questions the value of incumbent systems and technologies in the ID (Carignani et al., 2019; Markides, 2006).

To study how disruptive innovations might challenge resilience in IDs, we must consider IDs' peculiar features. IDs are considered as locus for contextual and tacit knowledge (Asheim, 1999; Camuffo and Grandinetti, 2011; Belussi and Pilotti, 2002), spurring experience-based gradual learning processes (Bellandi, 1996) and incremental innovations. However, the same dynamics that favour incremental improvements can inhibit the diffusion of new ideas and disruptive innovations (Molina-Morales et al., 2002). Lock-in mechanisms can be generated (Østergaard and Park, 2015; Pouder and St. John, 1996) which can be detrimental to district resilience when facing disruptive innovations. In a seminal work, Glasmeier (1991) described how Swiss watchmaking companies, which at that time were leaders in the industry, were unable to convert their production to digital technology, a radical change developed outside the ID. On the other hand, Hervas et al., (2018a) explain the phenomenon of disruptive innovation in IDs based on a comparative study of the ceramic industry in Spain and Italy. Also, according to this study, the idiosyncrasies of IDs make them more prone to incremental innovations. However, Hervás et al., (2018a) observe how the appearance of certain elements can counteract the negative effect of cognitive inertia and lock-in to overcome the barriers of dense networks of knowledge transmission. Among these elements that favour the development of disruptive innovations in IDs they find the existence of knowledge or novel technologies outside the ID and the emergence of new companies that renew the relational framework to facilitate their adoption.

In summary, studies about innovation in districts argued that the general characteristics of IDs make them better suited to deal with incremental or contextual innovations rather than radical ones (Elche-Hortelano et al., 2015). Also, studies suggested other characteristics impacting on how innovations might be developed or diffused. For example, studies suggested that having gatekeepers and visionary agents (Morrison, 2008; Giuliani, 2011) – enabling the joint "exploitation of local knowledge structures" and "exploration of distant knowledge structures" (Belussi and Sedita, 2012) – may be beneficial during the development phase. Specialized firms and local institutions may play a greater role in the diffusion phase (Molina-Morales and Martinez-Chafer, 2016). Additionally, the support of outsiders can also play a role in the development of a DI (Molina-Morales et al., 2021).

Against this background, we aim at understanding the conditions that enable the development of resilience in situations where industrial districts face shocks resulting from the introduction of disruptive innovations. In particular, we are interested in unravelling what features of IDs are supportive of its ability to overcome lock-ins and successfully cope with the development and adoption of DIs.

3. Methodology

3.1.Research design and description of cases

Different measures and methodological approaches can be adopted to proxy resilience, including statistical models and detailed case-study analysis, which could be partly or wholly qualitative in nature (Boschma, 2015). We use a multiple case-study approach, as it suitable for addressing ‘how’ and ‘why’ research questions, exploring causal mechanisms and gaining a deeper understanding of an underdeveloped research area (Yin, 1994). This qualitative method has been considered appropriate to understand resilience at the regional level (Martin and Sunley, 2015) and has been used in the literature to measure and assess regional economic resilience (Evans and Karecha, 2014; Simmie and Martin, 2010).

We used a theoretical sampling strategy and selected two exemplary cases of districts that proved resilient when facing the adoption of a DI. The first case is the plastic ski boot innovation in the Montebelluna sportsystem ID (Italy) in the 1970s – a radical product innovation based on a disruptive process innovation, resulting in a rise of ski boot production by more than 20 times within 5 years (Codara and Morato, 2002). The second case is the digital tile printing innovation in the Castelló ceramic tile district (Spain) in the 2000s, which is suggested to be behind the business evolution of the ceramic tile ID in Spain even during the 2008-2009 crisis (Molina-Morales et al., 2017). More details can be found in Appendix A[1].

Analysing two cases allows more robust results with respect to a single case study, as comparison supports generalizability and reduces potential biases such us misjudging the representativeness of a single event or estimate bias because of unconscious anchoring (Tversky and Kahneman, 1986). As supported by Appendix A, based on the interviewees' testimonies and the industrial reports reviewed, the two differ in terms of district life cycle stage and structure, but are similar in terms of characteristics of the market, innovative ID culture and impact of the innovations over previous technologies. The evidence of such similarities informed the selection of the cases, allowing extraneous variation to be reduced and clarification of the domain of the findings (Eisenhardt, 1989).

[1] For a detailed description of the Montebelluna case see Corò et al., 1998; Molina Morales et al., 2021; of the Castellò case see: Molina-Morales et al., 2017; .

We use a multi-level approach to study the resilience of industrial districts by focusing on the ID as a whole and the firms that supported innovation outcomes, similarly to previous research (Gilly et al., 2014). This approach considers the heterogeneity of ID firms in terms of specialization and competitive ability, which is increasingly relevant in districts. (Giuliani, 2011; Grashof, 2021; Hervas-Oliver et al., 2018b; Martínez-Cháfer et al., 2018).

3.2.Sources of data

Our approach, a comparative case study, utilizes two strategies, as classified by Langley (1999), to understand the data. These strategies include the narrative strategy and grounded theory approach ("bottom up") – which give us accurate meanings to the stories and to create patterns from detailed information about similar incidences in both cases. Several data sources have been employed and triangulated. The triangulation of evidence from different sources allows us to describe the phenomena in their entirety and avoid retrospective data collection biases. Data collection has been tailored to each case (Langley, 1999), as the innovations were not contemporaneous and the IDs involve different industries and sociocultural features (for more information, see Appendix B).

The main sources in the Montebelluna district are documentation and archival records, given the time span of the analysis and the availability of high-quality records. Another important source was the multidisciplinary academic contributions describing the evolution of the ID, the technology developed and implemented by ID firms, and the strategies implemented by them. Such data has been triangulated with extensive archival data, including: press reviews, thorough descriptions of all the firms in the ID, memos on the early history of the ID, and the results of a survey conducted annually by the ID firms' organization (OSEM) to investigate firms' organizational structure, product and market specialization and overall strategy. Finally, we performed 4 focused and in-depth interviews with key informants of ID firms and district's associations.

Research on the digital tile printing innovation in the Castelló district was mainly conducted by collecting data through participant observation. A member of the research team were working in the R&D department of a leading company in the ID and were the project manager for the development of this new technology, thus allowing valuable information to be obtained from an internal perspective (Mayring, 2002). Our research took advantage of a 15-year period of observation (from 2002 to 2016) of the innovation's implications for the ID both in its natural setting and in real time, as well as with preferential access to information. (Punch, 2013). Additionally, more than 30 interviews were carried out from 2010 to 2017 with ID company managers responsible for the technology, marketing, production, and R&D departments. Finally, different secondary sources have been used, mainly consisting of reports from professional journals of the sector, public industry documents as well as technical journals, reports, and academic literature.

4. Findings and discussion

A key point in the literature on resilience is how to measure it. Focusing on the regional level, Bristow and Healy (2018) and Ray et al. (2017) measured resilience in terms of post-shock outcomes. The effects of the resilient behaviour in the face of the shocks produced by DIs can be considered as post-innovation outcomes. These effects are analysed at both firm and ID level. Table 1 compares the two cases following an evolutionary approach proposed by Simmie and Martin (2010). Accordingly, we established an analogy between the different phases of the innovation processes and the different phases of the adaptive model of regional resilience they developed. Empirical evidence can be found in Appendix C.

4.1.DI: introduction and development

The comparison study found similarities in the introduction and development phase for both cases in terms of: (a) the source of the knowledge adopted to generate the innovation, (b) knowledge transmission that triggers the innovations, and (c) the role of external firms and knowledge brokers.

The Castelló and Montebelluna IDs found new knowledge beyond their territories. In the ceramic ID, the inkjet technology was first patented in UK and later improved by American and Japanese companies. In the ski boot ID, the idea was developed and patented by an American inventor (Bob Lange), while the polymer was formulated by a German multinational.

INSERT TABLE 1 HERE

In both cases, visionary agents played a key role in finding external sources of knowledge. These agents, having deep knowledge of the district, provide new and original knowledge and favour radical changes within the ID's network (Hervás-Oliver and Albors-Garrigos, 2014; Molina-Morales et al., 2017; Tellis, 2006). In Castelló, Mr. Tomas played this role by founding Kerajet (one of the most important printer manufacturers worldwide for ceramic digital printing) and adapting the digital printing technology already present in the imaging and graphic art industries to ceramic processes. Similarly, in Montebelluna, Mr. Vaccari, owner of the already well-known end-product firm Nordica, improved the initial idea by Lange, recognizing the commercial potential of this novelty.

The emergence of knowledge gatekeepers as a specific type of knowledge broker was observed once the technology was detected and innovations were initiated. These gatekeepers act as intermediaries, transferring and combining existing ideas and knowledge among unconnected firms and institutions (Boari et al., 2017). They generate novelty by drawing on both local and external knowledge sources within regions (Graf, 2011).

In Castelló, supporting industries like Kerajet (printer manufacturer), Ferro (frits and glazes manufacturer) and others performed an essential role by creating ties with key players in the digital industry by transcoding all the knowledge that they were able to provide and transferring best practices to the ceramic tile industry. In Montebelluna, a technical consultant connected Nordica with external firms that had the specific knowledge required (plastic and machinery producers, also supporting industries). Specialized firms outside the IDs also substantially assisted the innovation development. The development of digital printing required expertise from outside the ceramic field, such as fine-particle material treatment, solvent formulation, or microelectromechanical systems. Alternatively, the ski boot manufacturing necessities were based on plastic manufacturing and processing expertise.

Finally, the role played by local institutions is similar: they had null or little relevance. Nevertheless, the reasons differ. In Montebelluna there were no local district institutions at that time as it was still developing. As a young ID, Montebelluna faced typical problems associated with early stages of the life cycle, including lack of formal institutional structures to foster innovation. As reported in the literature, Initiatives influenced by policy may aid innovation development at this stage (Brenner and Schlump, 2011). In contrast, the ceramic ID had an established institutional ecosystem when the printing technology was developed (Molina-Morales and Martínez-Cháfer, 2016). However, this institutional environment did not participate significantly in the exploration and research phases of the innovation development. For instance, the Institute of Ceramic Technology (ITC), a local technological institution widely recognized as the reference in the ID, did not participate actively in the exploration and research stages or establish any collaboration agreements with the introducers and developers of the innovation. Nonetheless, the reasons for the low institutional influence are different from the Montebelluna case. In fact, the Castelló ID represents one of those cases where mature industries suffer from problems of cognitive inertia similar to those we can also find in the literature (Glasmeier, 1991; Menzel and Fornahl, 2010).

4.2. DI diffusion

Our analysis of the innovation diffusion phase after DIs development focused on the role of specific actors in IDs: (a) end-product firms: wall and floor ceramic tile manufacturers in Castelló and boot producers, in Montebelluna; (b) specialized firms: digital printer producers and frits/glazes manufacturers in Castelló and the plastic suppliers and injection machinery manufacturers in Montebelluna; and (c) local institutions: mainly the ITC, Institute of Ceramic Technology, in Castelló.

Like the previous phase, apart from the local institutions' role, the two cases are similar. In Castelló, end-product firms (the potential adopters of the technology) were mostly passive regarding the innovation. Only a few were quick to understand the potential benefits of such distant technology. In Montebelluna only a few companies adopted the technology; the others either moved to serve different markets or specialized in different activities (becoming specialized suppliers of different parts of the boots).

This passive behaviour is due to different inhibiting factors in each case. The tile decoration technology implied the development of new and non-related competences and a deep understanding of its unapparent industrial potential. Also, traditional machinery technology leaders influenced end-product firms to protect their dominance and markets. For the plastic ski boot innovation, financial concerns were the most important, followed by the distance of new competences and mindset barriers.

In both cases, local specialized firms, actively involved in the introduction and development of the innovation, also played a key role in the diffusion of the novelty into the ID. They were the drivers of the incremental innovations introduced in the following years to improve both technologies and products. In Castelló, frits/glazes producers (which also started to produce new digital inks) and new digital printer manufacturers drove the diffusion after being the key actors in the development phase. During this phase they struggled to transmit to end-product firms the know-how of the new printing technology as well as its benefits in terms of efficiency, user-friendliness, versatility, and product differentiation potential; novelty was too distant from the standard in this D. Similarly, in Montebelluna, plastic and plastic injection machinery producers diffused the novelty by selling machines or inputs to firms that decided to imitate the first mover, Nordica. They had the know-how to do it properly, as they were a relevant part of the new knowledge production.

A dissimilarity arises regarding the role of local institutions. In Montebelluna, the institutional framework was not developed, and so no significant role could be played. Conversely, in the ceramic tile ID, the ITC and other organizations were very active by providing training, technology transfer and joint R&D projects with end-product firms. These institutions shifted from passivity in the previous phase to activity in this stage of the innovative process.

4.3. Post-innovation outcomes

4.3.1. Innovations' effects at the ID level

Our comparative case reveals conflicting impacts of the resilient behaviour in the face of the technological innovation adoption. Although our work collected basically qualitative information, some conclusions can be drawn. In Montebelluna, unlike Castelló, many companies did not adopt the technology and were forced to exit the market. However, this does not necessarily imply a negative impact. Many firms were pushed to develop diversification strategies to face different markets or segments where existing technologies were still efficient and even more profitable.

In the Ceramic ID, previous research (Molina-Morales et al., 2017) confirms that the new technology was adopted by the majority of companies. Only a marginal number of companies continued to use previous technologies. Findings show that speed of adoption is a determinant of companies' outcomes, suggesting that lagged companies received negative effects of the technological process.

In addition, success in dealing with the challenge of both innovations caused similar and major positive changes. First, they enabled the possibility of enlarging product portfolios and markets served, for example, by producing larger tiles for kitchen worktops in Castelló or ice skates, trekking shoes or climbing shoes in Montebelluna. Second, they supported the enlargement of the number and types of industrial activities performed inside the IDs, leading to the introduction of new auxiliary activities, which were previously unneeded. For instance, we saw how digital design or mechanical services grew substantially in Castelló after digital printing introduction. Similarly, new product activities like new stage suppliers, machinery production and mechanical activities started spread in Montebelluna after the new plastic ski boot introduction. Third, by being resilient to DIs, the district population expanded: new firms focused in final product manufacturing or in specialized activities became established. While the overall balance was positive, this should not be interpreted as evidence that the size of the IDs increased in terms of numbers of firms. Several companies were not able to adapt to the new scenario and were mainly forced to go out of the market or to struggle to diversify (i.e., find new market segments where the existing capabilities were still efficient). This fact happened in both cases but is less evident in Castelló, where only few companies decided to continue using previous technologies.

Fourth, both innovations had a similar impact on the district leadership, as they positioned themselves as world leaders in their industry. The ceramic ID became the locus of digital printing technology, attracting the attention of other ceramic producers worldwide (China, India, Brazil, etc.), that were willing to learn more and adopt the new technology, and also the concrete, fibrocement, or wood panel industries. They followed the digital change in the ceramic field, and they expected to be able to promote it in their respective industries.

Montebelluna also became a global reference in its industry, attracting the attention of many sports firms. Most of them, such as American Spalding or Canstar, acquired Montebelluna companies to be close to the new product development.

In both cases, innovation led to a change in the life cycle stage. In Castelló, it revitalized a mature district. In Montebelluna, it accelerated its consolidation as a district. Before the innovative process, Montebelluna was rather unstructured despite the strong sense of identity perceived by members. During the 1970s and 1980s, due to the innovation, it transformed from a vertically integrated model to a network model where division of labour was carried out across final-product companies and suppliers, leading to the development of supporting industries. However, such an overall positive shift for the ID do not necessarily mean that all firms benefitted from the change – indeed a (small but relevant) portion of firms which disappeared in both districts proved a potential negative impact due to the introduction of the DI´s. There could be different reasons to explain this negative effect; some firms were not able to adapt to the new technological scenario, others were not able to overcome the investments needed to adapt with additional revenues. Heterogeneity in the firms' response and in their ability to gain from the DI can indeed be identified.

4.3.2. Effects of innovations at the firms' level

We evaluated the effects of DIs by distinguishing between end-product firms and specialized firms. We also distinguished the roles played by end-product firms regarding the innovation: (a) innovation leaders: firms which actively adopted the novelty in the early stage of development; (b) early-majority adopters: first wave of adopters; (c) laggard-majority adopters: sceptical firms or second major wave of adopters; and (d) non-adopters: fully sceptical firms regarding the new technology or non-adopters for other reasons.

Although similarities and dissimilarities between cases appear when comparing the same category of firms, the underlying effects show consistent similarities regarding improvement of competitiveness, access to new markets and creation of diversification opportunities, which are the core measures of resilience in both districts.

In both cases, not only the innovation leaders (a few firms in Castelló and only one in Montebelluna) but also the early adopters improved their competitiveness and reinforced their market position. Nevertheless, the reason behind this outcome is different. In Castelló, it was achieved not only through a product differentiation (new types of tiles with higher quality appeared) but also through a cost reduction strategy (DI increases the process efficiency). In Montebelluna, improvement was obtained exclusively by product differentiation (the new ski boot was clearly superior, so the market promptly moved). Unfortunately, in Castelló this double strategic advantage would disappear as the technology was maturating and disseminating among companies.

Additionally, specialized firms in both IDs were able to access new market segments. In Castelló, these companies, which played a capital role during the development and diffusion phases, consolidated their technological leadership as they had the digital know-how and the links with the digital locus outside the district. Therefore, frits/glaze manufacturers (and later digital ink manufacturers) like Ferro or Esmalglass-Itaca found two ways to expand. It can be performed by selling new digital products for the new technology or by cross-selling (selling traditional products to customers obtained through the new digital ink business). In Montebelluna, new markets were opened for the industries involved in the development of the innovation, but in a different way. The plastic moulding machinery (like Lorenzin) and, more importantly, chemical producers (like API) gained a strong leadership in the Montebelluna market and beyond (initially local demand was so high that they focused just on the internal market, but later they also became preferential suppliers of foreign end-product firms).

Furthermore, diversification opportunities took place in both cases, although they involved different firms. In Castelló, specialized firms moved to other industries outside the ceramic business (such as the textile, fibrocement, or wood panel industries), offering a competitive industrial decorative-digital solution. Conversely, in Montebelluna, the non-adopters strove to find diversification opportunities as the market for traditional leather boots disappeared. Trekking shoes, motorbike or biking shoes and skates were the new product possibilities for them.

5. Concluding remarks

IDs gained international attention in the 1980s and 1990s as an alternative development path with respect to integrated firms, representing the backbone of the success in international markets for advanced countries such as Italy or Spain. More recently, however, the effectiveness of such a model to respond to external pressures and shocks has been questioned, given the evidence that just some districts proved resilient (Bellandi et al., 2021; Belussi and Hervás-Oliver, 2016; De Marchi et al., 2018). Therefore, understanding under what circumstances IDs can be resilient became a key policy goal.

We contribute to this debate by focusing on the shocks that disruptive innovations produce and the circumstances that favour a specific trajectory that can lead to resilience in districts. The similarities emerging from an in-depth comparison of two exemplary cases, the plastic boot innovation in the Sportsystem ID in Montebelluna (Italy) and digital printing in the Castelló tile district (Spain) allows to contribute to the understanding of conditions that enable an ID (and not just some of its firms) to cope with the introduction of a novel and disruptive technology and therefore be resilient toward these external shocks. For the introduction and development stage, *visionary agents* are needed to detect new, valuable, and external opportunities and to start the innovation process, in a Schumpeterian approach to innovation. DI necessarily requires knowledge external to the ID and, consequently, new partners, who are *outsiders* to the district, are needed to support the development of such distant innovation. Internal firms playing a *gatekeeper* role are needed to ensure that external knowledge can be absorbed and recombined with existing knowledge. This result contributes to the literature by suggesting the key role of (technological) gatekeepers to support innovation in districts (Giuliani, 2011; Morrison, 2008). Further, in line with Giuliani (2005), our analysis supports the idea that the development of DIs by a limited number of district actors is not enough to improve resilience at the ID level. The diffusion of such innovation among other ID firms is essential to support the perfection of the innovation and to enable resiliency. In this phase, in both cases, *supporting industries* proved to play a pivotal role as the drivers of both the incremental innovation that supports the adoption of the technology by a broader audience and of the diffusion of innovation towards other (final) firms. Such evidence also contributes to the growing debate on the role of external knowledge sources and networks for opportunity exploitation, rather than exploration (e.g., Foss et al., 2013). Our results are in line with previous studies analysing the path development of IDs. The observed behaviour of the two IDs resembles that described by Bellandi and Santini (2017) in their analysis of the different ways in which IDs cope with maturity. According to them, the existence of factors such as the emergence of a core group of firms with sufficient know-how to exploit novel knowledge, a workforce determined to take the plunge, and changes in relational dynamics driven by industrial or institutional leadership are key to these adaptive processes. Our results, to some extent, corroborate these points.

Also, we contribute to the literature by identifying a set of measures to capture resilience originated when confronting and adapting to the introduction and diffusion of DIs in IDs. The literature has identified several measures of resilience like the ones proposed by Dubé and Polèse (2016) or Davies (2011). However, our qualitative and in-depth approach enables the acquisition of a deep and detailed knowledge of the phenomenon under study. Under this circumstances and following the adaptative resilience perspective (Martin and Sunley, 2015), our analysis suggests that ID resilience can alternatively be measured as: (a) the increase in the portfolio of products offered or performed activities, which might involve new or existing firms, specialized in different stages; (b) the increase in the firms' population; (c) an improved leadership in the industry; and (d) a positive shift in the district life cycle phase. Such changes are grounded in an important transformation at the firm level, consisting of: (a) an increase in the competitive capabilities; (b) the opening of new markets and diversification opportunities; and (c) a re-positioning towards higher-end markets.

INSERT FIGURE 1 HERE

Figure 1 visually summarizes the key contributions derived from the paper. Our results contribute to the literature as we pin down the circumstances in which disruption occurs in a district context as suggested by Christensen et al. (2018), in line with existing studies such as the Portuguese footwear district described by Marques et al. (2017) where an innovation-focused strategy is considered to be behind the recovery of its performance since 2009. Nevertheless, some ID companies did not undergo the same positive effects as they were not able to get involved in the new technologies implementation (Marques et al., 2017). These results support the notion that resilience in IDs can take place when facing DI development and diffusion.

It is also important to stress, following the “evolutionary resilience” perspective (Davoudi et al., 2012; Simmie and Martin, 2010), that the achievement of resilience is not to be considered as a permanent outcome but needs to be continuously renewed. The Montebelluna’s success responding to the introduction of the DI did not prevent it from suffering when faced by other important external shocks occurring in the 1980s and1990s (e.g. the increase in foreign competition or the reduction in the demand for winter sports), (Codara and Morato, 2002). Further research should investigate whether IDs that proved resilient to DI shocks can be considered *serial resilient* districts and what strategies were implemented at the collective level to support the renewal of the ability to cope with shocks over time.

In both IDs, DIs took place spontaneously, driven by companies that leveraged a network of other firms, within and outside the district, which opens a discussion about the possibility of planning this effective trajectory of change. The paper provides interesting intellectual nourishment for the literature on the role played by ID supporting organizations during district innovative processes (McEvily and Zaheer, 1999). Indeed, while the presence of an active institution does not seem to be necessary, evidence from the most recent case of Castelló suggests that they can play an important role in the diffusion phase. Future research should address which institutions (R&D centres, industry associations, etc.) can play what role and how, not regarding diffusion but also for the innovation's development, which can be seen as a more challenging phase.

As a final caveat, it is important to bear in mind that such research is exploratory in nature, and its contributions rely on industry (case) specific factors. More research is needed to understand to what extent the results emerging from this study can be generalized to different domains, i.e., by considering less developed countries and/or higher-tech industries.

Acknowledgements

This work was supported by MCIN / AEI /10.13039/501100011033 / FEDER, UE under Grant PID2021-126516NB-I00

6. References

Alberti FG (2006) The decline of the industrial district of Como: recession, relocation or reconversion? *Entrepreneurship & Regional Development* 18(6): 473–501.

Andriani P and Cattani G (2016) Exaptation as source of creativity, innovation, and diversity: introduction to the Special Section. *Industrial and Corporate Change* 25(1): 115–131.

Asheim BT (1999) Interactive learning and localised knowledge in globalising learning economies. *GeoJournal* 49(4): 345–352.

Asheim BT, Boschma R and Cooke P (2011) Constructing regional advantage: Platform policies based on related variety and differentiated knowledge bases. *Regional studies* 45(7): 893–904.

Azzariti, F., & Candoni, I. (2007). *Oltre il distretto: interviste, modelli aziendali e teorie di un fenomeno italiano*. FrancoAngeli.

Bellandi M (1996) Innovation and change in the Marshallian industrial district. *European Planning Studies* 4(3): 357–368.

Bellandi M, Plechero M and Santini E (2021) The supporting and hampering role of place leadership in Italian industrial districts. *Handbook on City and Regional Leadership*: 187–202.

Bellandi, M., & Santini, E. (2017). Resilience and the role of arts and culture-based activities in mature industrial districts. *European Planning Studies*, *25*(1), 88-106.

Belussi F and Hervás-Oliver JL (2016) *Unfolding Cluster Evolution*. Routledge. DOI: 10.4324/9781315648712.

Belussi, F., and Pilotti, L. (2002). Knowledge creation, learning and innovation in Italian industrial districts. *Geografiska Annaler: Series B, Human Geography*, *84*(2), 125-139.

Belussi, F., & Sedita, S. R. (2012). Industrial districts as open learning systems: combining emergent and deliberate knowledge structures. *Regional Studies*, *46*(2), 165-184.Bernard HR (2017) *Research Methods in Anthropology: Qualitative and Quantitative Approaches*. Rowman & Littlefield.

Boari C, Molina-Morales FX and Martínez-Cháfer L (2017) Direct and Interactive Effects of Brokerage Roles on Innovation in Clustered Firms. *Growth and Change* 48(3).: 336–358.

Boschma R (2015) Towards an evolutionary perspective on regional resilience. *Regional Studies* 49(5): 733–751.

Brenner T and Schlump C (2011) Policy measures and their effects in the different phases of the cluster life cycle. *Regional Studies* 45(10): 1363–1386.

Bristow G (2010) Resilient regions: re-'place'ing regional competitiveness. *Cambridge Journal of Regions, Economy and Society* 3(1): 153–167.

Bristow G and Healy A (2018) Innovation and regional economic resilience: an exploratory analysis. *The Annals of Regional Science* 60(2): 265–284.

Cainelli G, Fracasso A and Marzetti GV (2018) Natural Disasters and Firm Resilience in Italian Industrial Districts. *Advances in Spatial Science*: 223–243.

Camuffo, A., & Grandinetti, R. (2011). I distretti industriali come sistemi locali di innovazione. *Sinergie Italian Journal of Management*, (69), 33-60.

Carignani G, Cattani G and Zaina G (2019) Evolutionary chimeras: a Woesian perspective of radical innovation. *Industrial and Corporate Change*.

Caro P Di, Fratesi U, Paolo PB, et al. (2017) Regional determinants of economic resilience. *The Annals of Regional Science 2017 60:2* 60(2): 235–240.

Christensen CM (1997) *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Boston, Mass.: Harvard Business School Press.

Christensen CM, McDonald R, Altman E, et al. (2018) Disruptive Innovation: An intellectual History and directions for future research. *Journal of Management studies, 55(7), 1043-1078*.
Ciappei, C., & Simoni, C. (2005). Drivers of new product success in the Italian sport shoe cluster of Montebelluna. *Journal of Fashion Marketing and Management: An International Journal*, *9*(1), 20–42.
Codara L and Morato E (2002) il distretto di Montebelluna tra locale e globale. In: G. P (ed.) *Le Istituzioni Dello Sviluppo. I Distretti Industriali Tra Storia, Sociologia Ed Economia*. Rome: Donzelli.
Colonna, M., Nicotra, M., & Moncalero, M. (2013). Materials, Designs and Standards Used in Ski-Boots for Alpine Skiing. *Sports*, *1*(4), 78–113.
Cooke P (2017) Resilience in ruins: The idea of the 'arrested dialectic'in art after resilience's failures. *European Planning Studies* 25(1). Taylor & Francis: 48–66.
Cooke P, Parrilli MD and Curbelo JL (2012) *Innovation, Global Change and Territorial Resilience*. Edward Elgar Publishing.
Corò G, Gurisatti P and Rossi A (1998) Il distretto Sport System di Montebelluna. In: *Percorsi Locail Di Internazionalizzazione. Competenze e Auto-Organizzazione Nei Distretti Industriali Del Nord-Est*. Milan: Franco Angeli.
Crestanello, P. (1997). I distretti industriali in Veneto: cambiamenti e tendenze. In *Le risposte locali e regionali alla pressione globale: il caso dell'Italia e dei suoi distretti industriali* (pp. 101–140).
Davies S (2011) Regional resilience in the 2008–2010 downturn: comparative evidence from European countries. *Cambridge Journal of Regions, Economy and Society* 4(3). Oxford University Press: 369–382.
Davoudi S, Shaw K, Haider LJ, et al. (2012) Resilience: a bridging concept or a dead end? *Planning theory & practice* 13(2): 299–333.
De Marchi V and Grandinetti R (2014) Industrial districts and the collapse of the Marshallian model: looking at the Italian experience. *Competition & Change* 18(1): 70–87.
De Marchi V, Gereffi G and Grandinetti R (2018) Evolutionary Trajectories of Industrial Districts in Global Value Chains. In: De Marchi V, Di Maria E, and Gereffi G (eds) *Local Clusters in Global Value Chains: Linking Actors and Territories Through Manufacturing and Innovation*. Abingdon: Routledge, pp. 33–50.
De Marchi V, Lee J and Gereffi G (2014) Globalization, recession and the internationalization of industrial districts: experiences from the Italian gold jewellery industry. *European Planning Studies* 22(4): 866–884.
Dubé J and PolèSe M (2016) Resilience revisited: assessing the impact of the 2007–09 recession on 83 Canadian regions with accompanying thoughts on an elusive concept. *Regional Studies* 50(4): 615–628.
Eisenhardt KM (1989) Building theories from case study research. *Academy of management review* 14(4): 532–550.
Eisingerich AB, Bell SJ and Tracey P (2010) How can clusters sustain performance? The role of network strength, network openness, and environmental uncertainty. *Research policy* 39(2): 239–253.
Elche-Hortelano D, Martínez-Pérez Á and García-Villaverde PM (2015) Bonding capital, knowledge exploitation and incremental innovation in clusters of cultural tourism: the World Heritage Cities in Spain. *Investigaciones Europeas de Dirección y Economía de la Empresa (IEDEE)* 21(3).
Elola A, Valdaliso JM, Franco S, et al. (2017) Public policies and cluster life cycles: insights from the Basque Country experience. *European Planning Studies* 25(3): 539–556.

Evans R and Karecha J (2014) Staying on top: why is Munich so resilient and successful? *European Planning Studies* 22(6): 1259–1279.

Filippetti A, Gkotsis P, Vezzani A, et al. (2020) Are innovative regions more resilient? Evidence from Europe in 2008–2016. *Economia Politica* 37(3).: 807–832.

Foss JN, Lyngsie Z and Zahra S. (2013) The role of external knowledge sources and organizational design in the process of opportunity exploitation. *Strategic Management Journal* 34(12): 1453–1471.

Gilbert BA (2012) Creative destruction: Identifying its geographic origins. *Research Policy* 41(4): 734–742.

Gilly J-P, Kechidi M and Talbot D (2014) Resilience of organisations and territories: The role of pivot firms. *European Management Journal* 32(4): 596–602.

Giuliani E (2005) Cluster absorptive capacity: why do some clusters forge ahead and others lag behind? *European urban and regional studies* 12(3): 269–288.

Giuliani E (2011) Role of Technological Gatekeepers in the Growth of Industrial Clusters: Evidence from Chile. *Regional Studies* 45(10). Taylor & Francis: 1329–1348.

Giuliani E and Bell M (2005) The micro-determinants of meso-level learning and innovation: evidence from a Chilean wine cluster. *Research Policy* 34: 47–68.

Glasmeier A (1991) Technological discontinuities and flexible production networks: The case of Switzerland and the world watch industry. *Research Policy* 20: 469–485.

Götz M and Jankowska B (2017) Clusters and Industry 4.0 – do they fit together?. *European Planning Studies* 25(9): 1633–1653.

Graf H (2010) Gatekeepers in regional networks of innovators. *Cambridge Journal of Economics* 35(1): 173–198.

Grashof N, Hesse K and Fornahl D (2019) Radical or not? The role of clusters in the emergence of radical innovations. *European Planning Studies* 27(10): 1904–1923.

Grashof N, Kopka A, Wessendorf C and Fornahl D (2020) Industry 4.0 and clusters: complementaries or substitutes in firm's knowledge creation? *Competitiveness Review: An International Business Journal* 31(1): 83–105.

Grashof N (2021) Spill over or spill out? – A multilevel analysis of the cluster and firm performance relationship. *Industry and Innovation* 28(10): 1298–1331.

Henry N, Angus T and Jenkins M (2021) Motorsport Valley revisited: Cluster evolution, strategic cluster coupling and resilience. *European Urban and Regional Studies*.

Hervás-Oliver, J-L., Estelles-Miguel, S., Mallol-Gasch, G., & Boix-Palomero, J. (2019). A place-based policy for promoting industry 4.0: the case of the Castellon ceramic tile district. *European Planning Studies*, 27(9), 1838-1856,

Hervás-Oliver, J-L., Albors-Garrigos, J., Estelles-Miguel, S., and Boronat-Moll, C. (2018a). Radical innovation in Marshallian industrial districts. *Regional Studies*, 52(10), 1388–1397.

Hervás-Oliver J-L, Sempere-Ripoll F, Rojas Alvarado R, and Estellés-Miguel, S. (2018b) Agglomerations and firm performance: who benefits and how much? *Regional Studies* 52(3), 338–349.

Hervás-Oliver, J-L., & Albors-Garrigós, J. (2014). Are technology gatekeepers renewing clusters? Understanding gatekeepers and their dynamics across cluster life cycles. *Entrepreneurship & Regional Development*, *26*(5–6), 431–452.

Hervás Oliver, J. L., di Maria, E., & Bettiol, M. (2021). Industry 4.0 in firms, clusters and regions: the new digital imperative. *Competitiveness Review*, 31(1), 1-11.

Holm JR and Østergaard CR (2015) Regional employment growth, shocks and regional industrial resilience: a quantitative analysis of the Danish ICT sector. *Regional Studies* 49(1): 95–112.

Inkjet Report. (2010). *Técnica Cerámica*, *369*, 1306–1315.

Klepper S (2010) The origin and growth of industry clusters: The making of Silicon Valley and Detroit. *Journal of Urban Economics* 67(1): 15–32.
Lange, R. B., & Lange, P. B. (1966). *3239952*. United States.
Langley A (1999) Strategies for theorizing from process data. *Academy of Management review* 24(4). Academy of Management: 691–710.
Lazzeretti L, Sedita SR and Caloffi A (2014) Founders and disseminators of cluster research. *Journal of Economic Geography* 14(1). Oxford University Press: 21–43.
Le, H. P. (1998). Progress and trends in ink-jet printing technology. *Journal of Imaging Science and Technology*, *42*, 49–62.
Markides C (2006) Disruptive innovation: In need of better theory. *Journal of Product Innovation Management*.
Marques CS, Marques CP, Leal CT, et al. (2017) Knowledge, innovation, internationalisation and performance: Insights from the Portuguese footwear industry. *International Journal of Entrepreneurship and Small Business* 32(3): 299–313. DOI: 10.1504/IJESB.2017.087026.
Martin R and Sunley P (2011) Conceptualizing cluster evolution: beyond the life cycle model? *Regional studies* 45(10): 1299–1318.
Martin R and Sunley P (2015) On the notion of regional economic resilience: Conceptualization and explanation. *Journal of Economic Geography* 15(1).
Martínez-Cháfer L, Molina-Morales FX and Peiró-Palomino J (2018) The cluster is not flat. Uneven impacts of brokerage roles on the innovative performance of firms. *BRQ Business Research Quarterly* 21(1): 11–25.
Mascitelli R (2000) From experience: harnessing tacit knowledge to achieve breakthrough innovation. *Journal of Product Innovation Management:* 17(3): 179–193.
Mayring P (2002) Qualitative Sozialforschung. *Eine Anleitung zu qualitativen Denken* 5.
McEvily B and Zaheer A (1999) Bridging ties: A source of firm heterogeneity in competitive capabilities. *Strategic Management Journal* 20(12): 1133–1156.
Menzel M-P and Fornahl D (2010) Cluster life cycles—dimensions and rationales of cluster evolution. *Industrial and corporate change* 19(1). Oxford University Press: 205–238.
Molina Morales FX, De Marchi V and Martínez-Cháfer L (2021) Absorptive capacity and radical innovation in industrial districts. *Technology Analysis & Strategic Management* 33(9): 1088–1100.
Molina-Morales FX (2001) European industrial districts: Influence of geographic concentration on performance of the firm. *Journal of International Management* 7(4): 277–294.
Molina-Morales FX, López-Navarro MA and Guia-Julve J (2002) The role of local institutions as intermediary agents in the industrial district. *European urban and regional studies* 9(4): 315–329.
Molina-Morales FX, Martínez-Cháfer L and Valiente-Bordanova D (2017) Disruptive Technological Innovations as New Opportunities for Mature Industrial Clusters. The Case of Digital Printing Innovation in the Spanish Ceramic Tile Cluster. *Investigaciones Regionales*: 39–57.
Molina-Morales FX and Martínez-Cháfer L (2016) Cluster Firms: You'll Never Walk Alone. *Regional Studies* 50(5): 877–893.
Morrison A (2008) Gatekeepers of knowledge within industrial districts: who they are, how they interact. *Regional Studies* 42(6): 817–835.
Mossig I and Schieber L (2016) Driving forces of cluster evolution–growth and lock-in of two German packaging machinery clusters. *European urban and regional studies* 23(4): 594–611.

O'Connor GC (2008) *Grabbing Lightning: Building a Capability for Breakthrough Innovation*. 1st ed. San Francisco, CA: Jossey-Bass. Available at: http://www.loc.gov/catdir/enhancements/fy0805/2007045003-t.html.

Ormerod P (2010) Resilience after local economic shocks. *Applied Economics Letters* 17(5). Taylor & Francis: 503–507.

Østergaard C and Park EK (2013) Cluster decline and resilience-The case of the wireless communication cluster in North Jutland, Denmark.

Østergaard CR and Park E (2015) What makes clusters decline? A study on disruption and evolution of a high-tech cluster in Denmark. *Regional Studies* 49(5): 834–849.

Ottati GD (2018) Marshallian Industrial Districts in Italy: The end of a model or adaptation to the global economy? *Cambridge Journal of Economics* 42(2): 259–284.

Pendall R, Foster KA and Cowell M (2010) Resilience and regions: building understanding of the metaphor. *Cambridge Journal of Regions, Economy and Society* 3(1): 71–84.

Pike A, Dawley S and Tomaney J (2010) Resilience, adaptation and adaptability. *Cambridge Journal of Regions, Economy and Society* 3(1): 59–70.

Pouder R and St. John CH (1996) Hot spots and blind spots: Geographical clusters of firms and innovation. *Academy of management review* 21(4). Academy of Management Briarcliff Manor, NY 10510: 1192–1225.

Punch KF (2013) *Introduction to Social Research: Quantitative and Qualitative Approaches*. Sage.

Pyke F, Becattini G, Sengenbergen W, et al. (1990) *Industrial Districts and Inter-Firm Co-Operation in Italy*. Geneva: International Institute for Labour Studies.

Rabellotti R, Carabelli A and Hirsch G (2009) Italian industrial districts on the move: where are they going? *European Planning Studies* 17(1). Routledge: 19–41.

Ray DM, MacLachlan I, Lamarche R, et al. (2017) Economic shock and regional resilience: Continuity and change in Canada's regional employment structure, 1987–2012. *Environment and Planning A* 49(4): 952–973.

Rayleigh, Lord. (1878). On the instability of jets. *Proceedings of the London Mathematical Society*, *s1-10*(1), 4–13.

Reig-Otero, Y., Edwards-Schachter, M., Feliú-Mingarro, C., & Fernández-de-Lucio, I. (2014). Generation and Diffusion of Innovations in a District Innovation System: The Case of Ink-Jet Printing. *Journal of Technology Management & Innovation*, *9*(2), 56–76.

Ryan P, Giblin M, Buciuni G, et al. (2020) The role of MNEs in the genesis and growth of a resilient entrepreneurial ecosystem.: 36–53.

Sammarra, A., & Belussi, F. (2006). Evolution and relocation in fashion-led Italian districts: evidence from two case-studies. *Entrepreneurship and Regional Development*, *18*(6), 543–562.

Santner D (2018) Cluster-internal and external drivers of cluster renewal: evidence from two German agricultural engineering case studies. *European Planning Studies* 26(1)174–191.

Sedita SR, De Noni I and Pilotti L (2017) Out of the crisis: an empirical investigation of place-specific determinants of economic resilience. *European Planning Studies*.

Sedita, S. R., & Ozeki, T. (2022). Path renewal dynamics in the Kyoto kimono cluster: How to revitalize cultural heritage through digitalization. *European Planning Studies*, *30*(9), 1736-1754.

Simmie J and Martin R (2010) The economic resilience of regions: towards an evolutionary approach. *Cambridge Journal of Regions, Economy and Society* 3(1). Oxford University Press: 27–43. DOI: 10.1093/cjres/rsp029.

Spradley JP (2016) *Participant Observation*. Waveland Press.

Suire R and Vicente J (2009) Why do some places succeed when others decline? A social interaction model of cluster viability. *Journal of Economic Geography* 9(3). Oxford University Press: 381–404.

Suire R and Vicente J (2014) Clusters for life or life cycles of clusters: in search of the critical factors of clusters' resilience. *Entrepreneurship & Regional Development* 26(1–2). Routledge: 142–164.

Tellis GJ (2006) Disruptive technology or visionary leadership? *Journal of Product Innovation Management* 23(1). Wiley Online Library: 34–38.

Tversky A and Kahneman D (1986) Rational choice and the framing of decisions. *Journal of business*. S251–S278.

Yashwant Sahu & Sumiran Satsangi. (2017). *Digital Textile Printing Inks Market. Global Opportunity Analysis and Industry Forecast, 2015-2023*.

Yin RK (1994) Case study research. Design and methods. *Thousand Oakz: Sage*.

Appendix A: Main characteristics of the DIs analysed and the districts where they took place.

		Castelló DI	Montebelluna DI
District characteristics at the time of the innovation development			
Location		Castelló province (Spain)	Montebelluna area (Italy)
Main activity		Ceramic wall and floor tile manufacturing	Woodsmen and ski boots manufacturing
Life Cycle stage		Maturity	Development
Structure		Well-structured	Unstructured but strong identity
Local institutions		Educational centres, research institutes, trade associations.	None
DI under study			
Designation		Digital tile printing technology	Plastic ski boot
Time period of innovation		2000-2010	1965-1975
Novelties introduced	Core competences	From manual/mechanical to software/digital	From manual to engineering and chemical
	Competence acquisition	From learning by doing to explicit training	From learning by doing to explicit training
	Key inputs	From traditional pigments to high-performance inks	From leather to plastic
	Key resources	From experienced employees to digital printer and skilled designers	From experienced employees to injection machinery and financial resources
	Key advance	Efficiency and product quality improvements	Product quality improvement
	Production techniques	From trial-and-error to pre-set	From labour-intensive to capital-intensive

Appendix B: Main sources of information.

Montebelluna Sportsystem district

Structured interviews		# interviews
District association	CEO (starting 2013)	1
	Former CEO (until 2013)	1
Supp. Ind. firm (Plastic producer)	CEO	1
Supp. Ind. firm (Prototyping and engineering)	CEO	1

Secondary sources	
<u>Type</u>	<u>References</u>
Sectorial journals and press reviews	Press releases collected from the website http://aldodurante.weebly.com
Industry reports	OSEM report 2008
Academic literature	Azzariti and Candoni (2007), Belussi (2003), Ciappei and Simoni (2005), Codara and Morato (2002), Colonna et al. (2013), Corò et al. (1998), Crestanello (1997) or Sammarra and Belussi (2006)

Castelló Ceramic tile district

Participant observation	
15-year observation and participation in the phenomenon (from 2002 to 2016)	12 countries visited assessing digital printing impact and feasibility in different sectors

Structured interviews		# interviews
Supporting industry firm (Digital printer)	CEO	1
	Technical manager	3
	Business manager	3
	Engineer	2
Supporting industry firm (Inkjet technology)	Technical manager	1
	Business manager	2
Supporting industry firm (Digital ink)	CEO	1
	Project Manager	2
	R&D Manager	1
Supporting industry firm (Chem. products)	Business manager	2
Final firm (Tile manufacturing)	CEO	1
	Plant manager	1
	Business manager	3
	Design and product manager	3
Non-ceramic and non-inkjet firms	CEO	2
	Project Manager	6
	Business manager	2

Secondary sources	
<u>Type</u>	<u>References</u>
Sectorial journals	https://www.anffecc.com/es; https://www.ascer.es
Industry reports	Inkjet Report (2010)
Academic literature	Le (1998); Albors-Garrigos and Hervas-Oliver (2014; 2013); Hervas-Oliver and Albors-Garrigos (2014); Reig-Otero et al. (2014); Molina-Morales et al. (2017)

The main sources used to study the innovation that took place in the Montebelluna district are documentation and archival records, given the time span of the analysis and the availability of high-quality records. Additionally, another important source was the multidisciplinary academic contributions describing the evolution of the district, the technology developed and implemented by district firms and the strategies used by them. The evidence emerging from these sources has been triangulated with the extensive information developed and collected by the district association over time. This includes an extensive press review, thorough descriptions of all the firms in the district, memos on the early history of the district and the surrounding areas, and the results of a survey conducted annually by the district firms' organization (OSEM) to investigate firms' organizational structure, product and market specialization and overall strategy. Finally, we performed focused interviews with key informants.

The digital tile printing innovation in the Castelló district was investigated mostly by data collected through participant observation (Bernard, 2017; Spradley, 2016). In fact, some members of the research group participated in the innovative phenomenon for a long period of time by remaining in permanent contact with the main actors taking part in the technological change and actively participating in the development and diffusion phases. In particular, one of the researchers worked in the R&D department of a leading company in the district and was the project manager for the development of this new technology, thus allowing valuable information to be obtained from an internal perspective (Mayring, 2002). Therefore, we may say that our research took advantage of a 15-year observation (from 2002 to 2016) of the innovation's implications for the district; (a) in its natural situation; (b) in real time; and (c) with preferential access to information (Punch, 2013). Additionally, more than 30 interviews were carried out from 2010 to 2017 with district company managers, and managers responsible for the technology, marketing, production and R&D departments. Finally, different secondary sources have been used, mainly consisting of reports from professional journals of the sector, public industry documents as well as technical journals, reports and academic literature.

Appendix C

Table: (Dis)similarities in the introduction and development phase of "Digital printing (Castelló)" and "Plastic ski boot (Montebelluna)" DIs: Illustrative evidence[1].

Similarities
Source of knowledge for the innovation: external **CDI**: Inkjet digital printing technology was initially developed in Japan, England and USA. (PME; Le, 1998; Inkjet Report, 2010; Rayleigh, 1878) The development idea was in the air because previously similar-form products were already printed. (Reig-Otero et al., 2014) **MDI:** Bob Lange (former ski athlete from USA) had the initial idea of producing a boot in plastic while Bayer (Germany) first created the thermoplastic polyurethane compound. (PM; Lange and Lange, 1966; Colonna et al., 2013)
Primary district's actor in the innovation: visionary agent **CDI:** In 1998 a mechanical engineer applied for a patent at the Spanish patent office and, in 2000, he sent an application to the European Patent Office. He was proposing a unique single-pass solution as an alternative to others who were working in imaging and graphic arts. (PMCEO; Reig-Otero et al., 2014) **MDI:** The founder of Nordica (Vaccari) discovered the idea of the plastic boot at a trade fair in the US and decided to try introducing a plastic boot by funding the research on it. (PM; Codara and Morato, 2002)
Gatekeeper role: essential **CDI:** External networks were created by developers of the first ceramic IJP machine, mainly with consultants in the Cambridge printing cluster and also other Japanese printhead suppliers. (PO; PMCEO; DICEO; Hervás-Oliver and Albors-Garrigos, 2014; Molina-Morales et al., 2017; Reig-Otero et al., 2014) **MDI:** Mr. Zizola was engaging and interacting with agents from outside the district to develop the new boot on behalf of Mr. Vaccari, who did not engage in the research and development phases. (Codara and Morato, 2002; Giancarlo Corò et al., 1998; PM)
Role played by district outsiders: relevant **CDI:** The success of digital printing necessarily required the know-how of other industries, which soon started to cooperate with the developers of the innovation. Fine milling equipment manufacturers, solvent producers or MEMs manufacturers supported the innovation development from the early stage. (PO; OtCPM; DPE; DIPM; Hervás-Oliver and Albors-Garrigos, 2014; Molina-Morales et al., 2017; Reig-Otero et al., 2014) **MDI:** API plastic and Lorenzin machinery worked in harness with Mr. Zizola to develop and industrialize the process to produce the new plastic boots (Codara and Morato, 2002; Giancarlo Corò et al., 1998; PM).
Role of local institution: Not relevant or little relevance **CDI:** Local institutions such as the ITC (the most important local technical institution) did not take part in the development of the innovation. In fact, involvement of the ITC did not start on a regular basis until 2007 through digital cooperation projects or courses. (Reig-Otero et al., 2014; PO) **MDI:** As the district was in a developing stage, no local institution was present or involved at that time. (Codara & Morato, 2002)

Table: (Dis)similarities in the diffusion phase of "Digital printing (Castelló)" and "Plastic ski boot (Montebelluna)" DIs: Illustrative evidence[2].

Similarities	Dissimilarities
Specialized firms: drivers of diffusion **CDI**: "We made a big effort to convince the tile manufacturers to move to digital – at first they didn't think it was a competitive solution". (SIM; PME) **MDI:** End-product firms that aimed to imitate Nordica could count on its plastic and machinery producers. They became not only the drivers of diffusion but also the drivers of the incremental innovations introduced in the following years to improve the product. (Codara and Morato, 2002; Corò et al., 1998)	**CDI: Local institutions played an active role in technology diffusion** The ITC did not participate in the exploration and R&D stages, but played a key role in the diffusion of and further improvement to IJP technology. (Reig-Otero et al., 2014; PO) **MDI: Local institutions did not exist at that time** Local institutions started to be developed in the 1990s. (Codara and Morato, 2002)

Table: (Dis)similarities in the post-innovation outcomes of "Digital printing (Castelló)" and "Plastic ski boot (Montebelluna)" DIs: Illustrative evidences[3].

Similarities	Dissimilarities
District leadership: re-positioned **CDI:** "Many people from other industries came to Spain to learn about what was being done". (PME) **MDI**: Ski boot production rose from 700,000 in 1969 to 4,100,000 in 1979. Montebelluna became a locus of innovation and production for the rest of world sportsystem industry. (Codara and Morato, 2002; Corò et al., 1998) **District's life cycle: shifted** **CDI:** Digital printing became a key element to rejuvenate the mature ceramic district. (Hervás-Oliver and Albors-Garrigós, 2014; Molina-Morales et al., 2017) DIPM; PO **MDI**: The high market demand generated, and the high investments needed to buy the machines to produce some components of the boots moved the companies towards different organizational needs. Montebelluna developed a district form because companies looked for benefit from externalities. (Codara & Morato, 2002)	**CDI: Specialized firms created diversification opportunities and accessed new markets** "The fact of being a reference in digital printing for ceramic tiles gave us the opportunity to sell to ceramic tile companies which weren't our customers before". (DIPM) Supporting industries, which control the digital technology, decided to move to other industries out of the ceramic business. The textile business is an example: the global digital textile printing inks market was valued at $698 million in 2016, and is expected to reach $2,114 million by 2023, registering a CAGR of 17.2% from 2017 to 2023. (Sahu & Satsangi, 2017; PO; DICEO; PME) **MDI: Specialized firms accessed new activities and reinforced their market leadership rather than move towards a new market** The API company remained a monopolist for many years. Lorenzin was replaced as industry leader after a few years, also because it became interested in entering into new markets. (Corò et al., 1998)

Innovation leaders: improved their competitiveness and reinforced their market leadership position **CDI:** As a big change in mentality was needed to adopt this technology, only a few leader companies in the district adopted it in the early stages of the launching of the new technology. The majority of the end-product firms later followed their example. This fact allows the leader firms to open a new gap with the rest of the firms in terms of prestige and sale price differentiation. (PO; PMCEO; TPM) **MDI**: Nordica was almost a monopolist: the very high margins achieved during the first years and its expertise supported its subsequent R&D effort, so that it has been at the forefront of new product improvements even in the following years. (Corò et al., 1998)	**CDI: non-adopters of innovation lost market opportunities** Those tile manufacturing firms that decided not to follow the innovation struggled to compete. They lost a certain number of market opportunities mainly due to a cost gap with adopters and in other cases because of the higher quality of adopter companies. (PO; TCM) **MDI: non-adopters of innovation either left the market or followed diversification opportunities** The non-adopter firms soon failed, as there was no longer a market for the leather boot. In particular, some became stage suppliers for plastic ski boot producers, specializing in specific production phases (e.g. sole production); others moved towards the production of different types of products. (Codara and Morato, 2002; Corò et al., 1998)

[1] For the sake of brevity, we provide examples of empirical evidence for some (dis)similarities. CDI: Castelló case; MDI: Montebelluna case; PME. Printer manufacturer engineer; PM: Plastic manufacturer; PMCEO: CEO of printer manufacturing firm; DICEO: CEO of digital ink manufacturing firm; DIPM: Digital ink project manager; PO: Participative Observation; DPE: Digital printer engineer; OtCPM: Other-than-ceramic company product manager.

[2] For the sake of brevity, we provide examples of empirical evidence for some (dis)similarities. CDI: Castelló case; MDI: Montebelluna case; PME. Printer manufacturer engineer; PMCEO: CEO of printer manufacturing firm; DICEO: CEO of digital ink manufacturing firm; DIPM: Digital ink project manager; PO: Participative Observation; SIM: Supporting industry manager; TPM: Tile plant manager; TCM: Tile company manager.

[3] For the sake of brevity, we provide examples of empirical evidence for some (dis)similarities. CDI: Castelló case; MDI: Montebelluna case; PME. Printer manufacturer engineer; PMCEO: CEO of printer manufacturing firm; DICEO: CEO of digital ink manufacturing firm; DIPM: Digital ink project manager; PO: Participative Observation; SIM: Supporting industry manager; TPM: Tile Plant Manager; TCM: Tile company manager.