Radical innovation in Marshallian industrial districts

Abstract: Radical innovation is under-researched in the geography of innovation strand and, it is very noticeably missing in that of industrial districts. In this paper, the focus is on understanding how radical innovations occur in *Marshallian* industrial districts (MIDs), a phenomenon mostly overlooked by scholars. This study theorizes upon industrial districts as a distinct socio-economic innovation system mostly based on incremental innovation and challenges this assumption. Using exploratory and in-depth longitudinal case study methodology in two European MIDs, covering from 1998-to-2015, this paper analyzes radical innovation in MIDs and finds that the introduction of technology-distant knowledge (to the MID) and the entrance of new firms from different (to the focal) industries are both necessary mechanisms but not sufficient for radical innovation to occur. Access to leading incumbents' networks, based on social norms, becomes a crucial *social factor* necessary for radical innovation to occur in MIDs.

Key words: Radical innovation, industrial districts, leading incumbents, networks, ceramic tile industry

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1-Introduction

As regards the literature of Marshallian industrial districts (MIDs), innovation has been mostly assumed under continuous or incremental innovation (Robertson and Langlois; 1995:558; Bianchi and Giordani, 1993:31), under-researching the occurrence of radical innovation. At most, the literature has merely described lock-in and cluster decline as opposed to disruption (e.g. Glasmeier, 1991; Grabher, 1993; Staber and Sautter, 2011; Ostergaard and Park, 2015) or explained why inertia restricts or prevents change (Martin and Sunley, 2006; Martin and Sunley, 2011), omitting the explanation of *how* radical innovation occurs in MIDs and how MIDs are transformed when successfully overcoming lock-in and inertia. The transition and rejuvenation of a MID, through a process of creative destruction or radical innovation, has not been covered yet in the MID literature, as explained below. Put differently, deciphering how radical innovation occurs and transforms MIDs is a new phenomenon in the MID literature.

Specifically, this study addresses *radical innovation* focused on MIDs, being the latter a particular case of agglomerations where social capital plays a prominent role. We argue that the intrinsic socially-based characteristics of MIDs, based on strongly tied networks, mostly following a supplier-driven innovation pattern[1] and embedded in local institutional structures that support a dynamic mix of cooperation and competition (e.g. Piore and Sabel, 1984), represent an unaddressed space from which to understand and frame radical innovation. Hence, explaining how radical innovation occurs in MIDs constitutes this study's goal. In this study

[1]Typical from low-tech settings, in the sense of Pavitt (1984)

radical innovation refers to technological discontinuities which incorporate new knowledge that destroys the value of incumbent systems and technologies in the marketplace (Anderson and Tushman, 1990), similar to the *disruptive* innovation term used by Christensen (1997) or *creative destruction* pointed out by Gilbert (2012). Thus, when applying the idea of radical innovation to MIDs, we are not referring just to an improvement or minor change: we mean that current specific technology or knowledge performed within a MID and embedded in its knowledge architecture becomes obsolete in contrast to new knowledge and technology that can be both created or adopted. This creative destruction is said to occur, for instance, in the advent of electronics in the Jura watch cluster in Switzerland and was an example for lock-in (see Glasmeier, 1991). Our paper, however, presents a theory and a case where radical innovation successfully occurred and rejuvenated an MID, transforming the entire world focal industry.

Why has radical innovation in MIDs been studied less? In MIDs, existing networks orchestrated by leading incumbents are vital for ID functioning (Scott, 1989), in so far as they provide legitimacy to access tacit knowledge (Scott, 1992:16), Leading firms in MIDs are said to orchestrate knowledge and organize those networks (Munari et al., 2012; Lorenzoni and Lipparini, 1999) and avoid radical innovation in order to maintain their status quo and their central positions in the cluster's networks (e.g., Gargiulo and Benassi, 2000; Allarakhia and Walsh, 2010), a fact in line with the above mentioned inertia or lock-in (e.g. Glasmeier, 1991; Grabher, 1993). The point is that those local networks of small SMEs in MIDs, led by large and powerful leading firms that transfer knowledge in a supplier-driven pattern, only receive the type of knowledge that maintains leading firms' centrality. That knowledge tends to prevent any major change in the existing local networks that may alter leading incumbents' centrality, therefore avoiding disruptions and thus promoting inertia (Pouder and St. John, 1996). The main goal prevailing in those networks seems to be to maintain and protect leading firms' status and centrality, and not to renew networks or clusters, presenting an interesting paradox. Moreover, the trust, repetitive inter-firm interactions and other social aspects make SMEs in those networks dependent of the leading knowledge-provider firm. Hence, MIDs and their specific strong-tied and socially-based networks of SMEs constitute a special setting where radical innovation does not frequently occur and for this reason that phenomenon has not been fully considered in the MID literature. For instance, Garofoli (1991) stresses that MIDs are better suited for gradual change rather than for disruption a fact supported empirically in both technological change (Glasmeier, 1991) and managerial literature (Sull, 2001).

This study attempts to unfold and to shed light on this specific phenomenon, contributing to the geography of innovation. We ask the question: how does radical innovation occur in MIDs? To this end, and given the gap in the current theory of MIDs, we use an exploratory longitudinal case study research based on the analysis of two leading intertwined industrial districts in Europe. The focal process is radical innovation in MIDs, as above defined, and the setting is the Castellon[2] ceramic tile (Spain) industrial district and its firms. Apart from that, we also studied the Sassuolo MID (Italy), due to the fact that both MIDs are intertwined and most innovation in both places has occurred due to their interconnections (see Hervas-Oliver and Boix, 2013). Those settings are chosen because both IDs underwent a process of radical innovation very recently with different outcomes. Our study and method are both justified by the fact that, although we observe that the study of MIDs and innovation are ubiquitous, yet the vast geography of MIDs in fact has not explained the occurrence of radical innovation, its mechanisms, processes, actors and effects.

2- Intersecting MIDs and radical innovation: a review of the literature

2-1 Radical knowledge in MIDs: how overcoming inertia?

As abovementioned, innovation in MIDs is supposed to be based on continuous or incremental innovation based on local knowledge. The excessive reliance on the combination of existing local knowledge, however, and a manifested reluctance to change brings lock-in in agglomerations (Martin and Sunley, 2006; Maskell and Malmberg, 2007; Ostergaard and Park, 2015; Hervas-Oliver, 2016). Glasmeier (1991) describes this phenomenon on the advent of the new wristwatch technology in the Jura region in Switzerland. In this case, leading incumbents did not show any inclination to switch to new electronic technologies. As Glasmeier (1991:478) states: "…*industry leaders were often skeptical about the viability of new proposals, particularly if they implied a radical reorientation".* Sull (2001) offers a similar description referring to the Akron tire cluster in Ohio, detailing how the cluster evolved from a community of innovation to a community of cognitive inertia and showing how the cluster was unable to change to the new radial tire technology developed by the French competitor Michelin, a fact also manifested in other works (e.g. Pouder and St. John 1996). Leading firms in MIDs are said to orchestrate knowledge and organize networks (Munari et al., 2012; Lorenzoni and Lipparini, 1999) and avoid radical innovation in order to maintain their status

[2] This ID is cited in Porter's (1990:298-299) seminal work, along with the Italian Sassuolo one in Italy.

quo and their central positions in the cluster's networks (e.g., Gargiulo and Benassi, 2000; Allarakhia and Walsh, 2010), a fact in line with the above mentioned inertia or lock-in (e.g. Grabher, 1993; Sull, 2001).

Firms, however, can avoid competency traps by searching outside their technological boundaries and by exploring in novel technology-distant areas (Rosenkpof and Nerkar, 2001) a fact also pointed out in districts and clusters (e.g. Eisingerich et al., 2010). Also, Menzel and Fornahl (2010:231) refer to the importance of openness to new technology-distant knowledge by pointing out that there is a need for the introduction of knowledge from *"outside the thematic focus of the cluster"* in order for creative destruction in geographic clusters to occur. Lastly, Gilbert (2012:738) states that in order to occur radial innovation needs knowledge from other industries, that is, technology-distant knowledge not available in the ID that usually is set by other different (to the focal) local industries.

2-2 New firms and incumbents interplay: battle or alliance?

At the MID level, the entrance of new firms has been seen as an indicator of cluster renewal and improvement (e.g. Eisingerich et al., 2010). Leading on from Gilbert (2012:734), leading incumbent cluster firms are generally described as being 'caught off guard' when new paradigms emerge in the marketplace (Glasmeier, 1991), since the capabilities demonstrated by new firms can turn the incumbents' capabilities into core rigidities (Henderson, 1993). There is no doubt that new entrants are the quintessential driver of the cluster renewal (Saxenian, 1990). In order to diffuse new knowledge, new firms may also need to access established networks led by incumbents. The existing value chain tends to favour the incumbents and constrain new challengers (Teece, 1986). This implies that incumbents cannot respond to radical innovations due to their commitments to current value networks and technological paradigms, giving new entrants an advantage (Henderson, 1993). On the contrary, new entrants need complementary assets to commercially exploit the innovation[3] (Teece, 1986), such as commercial networks. Network orchestration and the socially-tied controlled networks, in the

[3] Following Teece (1986) we refer to the non-generic ones, that is, specialized or co-specialized ones, referring to them just as specialized.

case of MIDs may act as *specialized complementary assets* favouring the incumbents and constraining new firms from new industries.

The role and performance of incumbents facing radical innovation, therefore, is determined by their specialized complementary assets: whether they are necessary or not for the new knowledge to be applied. Hence, complementary assets are an advantage of incumbents over newcomers (Hill and Rothaermel, 2003). In MIDs the socio-economic cooperation and competition with other actors in a social and trust-based relationship confers advantages to leading incumbents, counteracting newcomers' access to those networks. The reason is based on the fact that leading firms orchestrate those networks of small firms. In MIDs, therefore, these leading firms are more interested in the creation of less disruptive technology-related knowledge (Glasmeier, 1991). Thus, the prominence of trust-based relationships, values, reciprocity and informal norms fuelled by the intense existent social capital articulated in formal and informal networks (Becattini, 1990; Saxenian, 1994) make the orchestration of local networks one of the most important institutions in MIDs and also one of the key incumbents' specialized complementary assets that prevent newcomers from accessing MIDs. Therefore, new firms participating in the creative destruction process need to access those local networks through leading local firms that orchestrate them. Our argumentation is based on the idea that the diffusion of radical innovations in MIDS requires accessing those established networks, shaped by trust, norms of cooperation, common language and shared beliefs that facilitate communication (e.g. Becattini, 1990). Thus, *cooperation* or partnerships between incumbents and newcomers or district outsiders are vital so that radical innovation occurs, due to the overwhelming role played by local networks. Both incumbents and new (district outsiders) firms seek each other's specialized complementary assets: while incumbents want to access the new technology-distant knowledge in order to recombine their capabilities, newcomers need to access existing networks to diffuse their new paradigms. This mutual interest may even foster alliances (Rosenkopf and Nerkar, 2001) between newcomers and the local networks in MIDs.

2.3 Syntheses of expectations.

To sum up, after intersecting MID and radical innovation perspectives, we argue that for radical innovation to occur in MIDs often implies the creation or adoption of technology-distant (to the district) knowledge from other industries that need to be combined with local knowledge, a fact already stated (see Russo, 1996; 1998; Gabaldon-Estevan, 2016). Creative destruction or radical innovation, however, is usually constrained from local firms' cognitive inertia and lock-in and especially from the pressure by leading firms that orchestrate local networks and see new disruptions as a threat to their centrality. MID rejuvenation through the creation of adoption of new radical knowledge also requires new (to the district) firms renewing networks. As these new firms need to access local networks, given the fact that strongly-tied local networks act as leading incumbents' specialized complementary assets, the cooperation or partnerships between leading incumbents and newcomers is also expected. Table 1 summarizes points. See table 1.

Insert table 1 here

3- Research setting: Castellon and Sassuolo MIDs in Europe

The Castellon (Valencia Region, Spain) ceramic tiles ID is a typical Marshallian industrial district (Hervas-Oliver and Albors-Garrigos, 2009; 2008; 2007), well endowed with world-class public R&D and educational organisations, all of which are focused on ceramic tiles (see Belussi and Hervas-Oliver, 20017; Hervas-Oliver et al., 2017; Hervas-Oliver et al., 2011)[4]. It includes all the activities necessary for the ceramics value chain: clay processing, ceramic tile production, frit and glaze decoration based on high-tech chemistry and ceramic equipment production and services such as logistics, design, and other related activities. It is significant to state that the industries in the ID providing key knowledge and innovation are the frit and glaze (chemistry for tile surface decoration) and the ceramic equipment manufacturers (kilns, production lines, presses, etc.), following a supplier-driven innovation pattern in the sense of Pavit (1984).

In addition, along with Castellon, Italy also has one of the largest ceramic tile industries in the world. Around 80% of Italy's ceramic tile production is concentrated in the Emilia–Romagna region, around Sassuolo district, deeply embedded in the Emilia-Romagna regional innovation system, containing a strong ceramic tile equipment manufacturing sector. Both IDs (Castellon and Sassuolo) are mentioned in Porter's (1990) seminal contribution[5]. These machine manufacturing firms lead the ceramic tile equipment world and are present in Castellon as

[4] The cluster provides around 16,000 direct jobs (in 2014) and there are around 300 firms in related industries (Ascer 2014), see www.ascer.es (industry statistics)
[5] The agglomeration indices for the Castellon and Sassuolo ceramic tiles industries are reported to be around 4.5 (450%) in both cases. ISTAT, 2006

subsidiaries. Similarly, the Spanish (chemical) frit and glaze industry is the most powerful auxiliary industry in the Castellon cluster and is the absolute world leader[6] in the frit and glaze activity for tiles, having extensive operations in other clusters worldwide, including Sassuolo. Both IDs form a network of clusters, channeling information back and forth through their multinational companies in their respective industries co-located in both IDs (Meyer-Stamer et al., 2004; Hervas-Oliver and Boix, 2013) and making the best world-leader inter-cluster connection for ceramic tile innovation.

4- Methods and data sources

For our research we have used the approach of a case study, a key instrument for capturing complex information (e.g., Eisenhardt, 1989), with secondary data analysis being utilised alongside in-depth semi-structured interviews in order to decipher *how* and *why* radical change occurred.

Our focus and unit of analysis is on district firms that were involved in the disruption that took place in the tile industry. We identified all active firms from rosters provided by industry associations in both districts. In all, more than 300 firms in the two IDs were explored for their relationship with the new technology inception and adoption, selecting those which directly took part. As a robustness check, we also tracked all patents related to the new event. Interviews (62 respondents) were conducted over the years 2011, 2012, 2013 and 2014. In the first round (2011 and 2012), 50 interviewed respondents included the inventors, competitors and the subsequent adopters of the new technology in Castellon.

5- Data analysis

5-1 Radical innovation: inkjet printing tile decoration technology in Castellon

5.1.1 Overall explanation of the disruption

[6] In 2014, 26 Castellon frit firms exported around 66% of their total production valued at 1.2 billion Euros, and employed around 3,400 workers (ANFFECC, 2014). Five of them account for 75% of those exports, the leading group. See www.anffecc.es (http://www.anffecc.com/es/cifras-del-sector)

Our focus is the analysis of ceramic tile decoration, which dramatically changed from a mechanical process to a digital inkjet-based one, constituting a radical innovation that made the existing tile decoration process obsolete in view of the new digital decoration process. To summarize, ceramic tile production is composed of three main activities: *tile production* (using clay, processes and equipment), *tile decoration* (designing and coloring tile surfaces) and the *baking process* (in the kiln). It was a process of creative destruction that incorporated new radical knowledge and technology (digital inkjet-based knowledge into ceramic tile decoration) that existing value of incumbents in that particular activity (tile decoration) was destroyed, affecting all parts of the value chain (machinery, chemical and production process). Disruption occurred in the tile decoration process by (i) replacing traditional mechanical decoration processes and equipment by digital (computer-assisted inkjet, based on images and files and not in chemical formulas and color combinations) ones and, (ii) replacing traditional frits and glazes (chemical compounds to color and decorate tiles) by new *inks* (new frits suitable for the digital processes with the new head printers, based on the inkjet system). This radical inkjet innovation was led and orchestrated by Castellon firms that eventually overcame inertia and shift, leapfrogging their Italian counterparts, who suffered a severe inertia process. In Appendix I, additional information in order to fully understand the case is provided. See Appendix I. For the sake of clarity, our core research question is: how does radical innovation occur in MIDs?

5.1.2 Technology-distant new knowledge and new firms entering the tile industry

In 1994, the leading incumbent *System* from Sassuolo introduced the *Rotocolor* technology[7] as the new dominant design in Castellon and Sassuolo, functioning as a mechanical process spreading (chemical) frits and colors onto the ceramic tiles by rolling on their surface. Later on, in 1998, a new local Castellon equipment firm, *Kerajet*, began exploring new possibilities to decorate ceramic tiles based on digital technologies that would ultimately substitute Rotocolor gradually from 2006. The entrepreneurs at Kerajet, all of them with extensive experience in the industry, challenged the entire industry and dreamed of a digitized process in order to decorate tiles by inkjet printing, as was being done in other industries such as graphic design. The necessary knowledge was not available in Castellon nor in Sassuolo. The CEO from Kerajet reported: (clarifications in brackets):

[7] This technology decorates ceramic tiles by means of engraved silicon cylinders which reproduce high definition images, abandoning serigraphy. Similar to the rotogravure press, designs are transferred to the silicon cylinders by laser engraving.

“We knew exactly what we were looking for....and the solution was not part of traditional ceramics knowledge among people in the (Castellon) ID...nor among the Italians [Sassuolo ID]. For this reason, we visited the Cambridge printing cluster [Xaar] and also Japan [Seiko], searching for printing technology...Such distant [to ceramics] knowledge proved to be good, but insufficient. Micro-milling processes were also necessary, from other industries, along with other different technologies…… ”

Kerajet was searching for knowledge outside the ID and throughout many industries, meeting the firm Xaar, located in the (UK) Cambridge inkjet printing cluster. In 1998 they co-developed a first prototype based on inkjet printing, their main aim being to digitize the decoration process for ceramic tiles. So far, the decoration process was dominated by the Sassuolo mechanical process (Rotocolor). The advantage for the new firm, Kerajet, was that it was located in Castellon, far away from the cognitive mechanical framework existent in Sassuolo and better supported by the world-class chemical decoration process available in Castellon. The new technology involved a dramatic change in the knowledge base, moving from *mechanistic* decoration to *digital inkjet* (printing) decoration, pioneering a radical innovation. See Tortajada-Esparza et al., (2008b) to learn more. The main problems, however, were (i) transferring that new digital knowledge to the tile industry and, (ii) convincing an entire MID to abandon the existent decoration process based on mechanical Rotocolor (fully efficient and known). New firms entering the industry, or at least trying to at that time, were those from the inkjet industry, offering the new tech to be adapted to the ceramic tile process.

5.1.3 Cognitive inertia: reluctance to change and the power of leading incumbents

The new technology was not ready to be used and the tile producers were very comfortable receiving technical assistance on the existent (Rotocolor-based) decoration process from the powerful Castellon-based leading chemical incumbents. Nobody was eager to change and the leading Castellon chemical and the Sassuolo mechanical firms were both constraining the development of the new technology by not recommending change to tile producers. The powerful influence that those leading firms exerted on those networks of small tile producers, the latter receiving innovation and technical support from those leading firms, made change in Castellon almost impossible. Meanwhile, in Sassuolo, nobody was aware of or interested in that nascent technology from Castellon, as it radically confronted Sassuolo’s established paradigm concerning the mechanical decoration process.

As one of the interviewees pointed out (clarifications in brackets):

"…*the new technology included new machinery, new inks (substituting frits) and new processes….but the most problematic thing was to change our production processes well established around large batches, traditional* (non-digitized) *design….We had in stock more than 7,000 references for colours to be blended…..and now with only four colours* (based on CMYC, four-color printing, based on cyan, magenta, yellow and black combinations) *the job is done by the computer….and the decorating personnel was old and not used to working with computers…..At that time none of us wanted that change…..At the present moment we know how good this new technology is ….*"

The main problem was not to develop the new technology but to convince all firms in the Castellon MID to change and overcome the established status quo or cognitive inertia concerning the Rotocolor established paradigm. As the CEO at Kerajet reported,

"….*technology adoption was crucial and problematic…..the ceramic tile producers incorporate knowledge and innovation from leading frit and equipment companies……networks in the cluster are really closed and tied around leading firms and we knew that the leading established companies were the key to opening the market….but they were all reluctant…except Ferro which was allowing us to test the prototype with some of its key customers…..*".

As one manager from a leading chemical firm asserted:

"We were all reluctant to take on something new which could cannibalize our own products, no matter how good it was. At that time it was risky to shift focus towards a new thing which in turn could be oppose our interests…".

During the first three years, the district was reluctant to adopt the new technology, which was far from ready to fully substitute the dominant Rotocolor. Even though the new inkjet application (software, print heads and equipment) was developed, the new issue became the chemical compounds (frits) products, which were not optimized. Traditional chemical decoration (frits) for Rotocolor did not work with the new digital technology. In short, at that time (2001-2004) two major problems constrained the release of the new technology: one was the collective reluctance to change, led and reinforced by leading incumbents; and the other one was the lack of proper chemical decoration frits for the new technology. In addition, new firms entering the Castellon cluster with digital (inkjet) technology to facilitate the transition could not access the local networks, as the latter were orchestrated by local leading chemical firms from Castellon, based on extensive trust and social ties.

As managers of ceramic tile firms manifested:

"Personal ties are more important than formal inter-firm agreements….my friends mostly work for the industry and we regularly meet for a meal…of course we share issues…you have to live and socialize here to keep learning…..In general, most ceramic tile firms do exactly what their key suppliers [frits and equipment firms] advise them to do, because the latter are the ones supplying innovation, support and knowledge"

"Some of my rivals' managers are also my friends and we were all trained in the same school…It does not mean we share everything….but we respect each other's views and opinions about current affairs….None of them recommended the change to digital, not at least up until 2006. When we did all recognize its value [digital

printing] we were all interested in the new technology. Yes, our suppliers [frits firms] started trial and error with some of us, suggesting that the new technology looked interesting…not all of them suggested change, only two of them in 2005-06 [Ferro and Torrecid]...the rest came later……".

All in all, we identified a collective (inertia) reluctance to adoption, orchestrated by leading chemical and equipment companies controlling networks of tile producers that restricted the entrance of technology-distant (to the district and to the industry) knowledge (from the printing digital industry) and; new entrants, mostly from the inkjet industry (e.g. Xaar, Seiko) threatening the rules of the game and the current paradigm established in the Castellon ID, although they could not access those local networks.

Meanwhile, in Italy no company was participating in the development of the new technology for inkjet tile decoration. The reason was based on the prevailing mechanical cognitive framework for producing tiles and the fact that leading equipment firms were reluctant to diffuse that knowledge to their local networks around Sassuolo. The latter is explained by the fact that radical innovation could render leading tile equipment firms' knowledge obsolete, as it directly confronted the well-established (equipment, processes, jobs, etc.) mechanical paradigm. In part, this explains Sassuolo's late adoption of inkjet.

5.1.4 New firms and leading incumbents' alliances

Around 2003-04 the leading chemical firms in Castellon understood their key position in the new situation: they were controlling the networks of local ceramic tile producers, deciding whether or not to advise switching and thus blocking technology shift; additionally, leading chemical firms were the ones with enough technical capabilities and investment capability to pursue the development of the necessary new inks for the new digital technology. That power and control of networks is perfectly described at Tortajada-Esparza et al., (2008ab; 2009).

Three leading frits incumbents from Castellon (named *Ferro, Esmalglass* and *Torrecid*) started a race in order to secure the inks for the new technology, in an attempt to seek prominence and maintain their status quo in a potentially possible new dominant design post-Rotocolor, forging alliances with new firms focused on digital inkjet technology in order to combine capabilities and develop inkjet for tiles: Ferro was the first firm to support Kerajet; Esmalglass established a co-operation agreement for inkjet development with Xennia in the Cambridge cluster (a spinoff spawned by Xaar, the provider of the print heads for Kerajet); while Torrecid, another frit incumbent did the same with Durst, a diversifier from the printing industry. Three out of the five most powerful frit incumbents (absolute world leaders[8]) struggled to lead the new frits development of the new technology. In 2005 the new organic pigmented inks and the inkjet technology became fully established and accepted, a chemical innovation that all three incumbents found simultaneously[9]. This opened the way for the inkjet to be fully applied in the MID. All in all, from 2006 Castellon began to transfer to the new tech led by powerful local Castellon chemical firms. Those three leading firms turned from rejection to encouragement to shift, orchestrating local networks to the new technology paradigm.

5.1.5 Sassuolo cluster reluctance to transfer: why?

Why was the innovation diffusion uneven in both intertwined MIDs, Castellon and Sassuolo? Why was Sassuolo MID a laggard in the transition toward the new digital decoration? Following our findings, the reason was based on the persistent reluctance to change caused by the prevailing and dominant *mechanical* cognitive framework for producing tiles existent in Sassuolo, fuelled by the powerful and leading equipment firms that understood the change as a threat and a potential loss of local networks' control and orchestration. Additionally, the lack of decoration tile technology existent in Sassuolo, heavily dependent on the Castellon firms that were first and foremost more oriented to advising transition to their Castellon local networks that are their natural *living lab*. As an R&D manager in a leading frit company reported (clarifications in brackets):

"…the problem for the Italians (Sassuolo) in this case was that the new paradigm was heavily dependent on decoration based on new frits (inks) and that knowledge was only available in Castellon […] and System and the rest (Barbieri, Sacmi, among others) are heavily present here (Castellon) but their R&D facilities are in the Italian cluster….; there is no doubt that if the new technology had been based on mechanical technologies, instead of decoration, we would have been followers….".

During the early years (2000-05), Kerajet, the pioneer firm, dominated the market completely with printer sales going to leading customers on a trial and error basis. Meanwhile, System, the Rotocolor manufacturer, was so constrained by its own technology that it kept developing the Rotocolor technology along with the new inkjet technology, producing a kind of "hybrid technology" (mixing both Rotocolor and digital) which consumed most of its R&D resources, failed and led to engaging ultimately with Kerajet as a licensee of the inkjet printing

[8] Torrecid, Esmalglass, Ferro, Colorobbia and Endeka, all of them with 100% of R&D activities in the Castellon cluster. These multinational companies are present in more than 20 countries and are responsible for almost 70% of the world share of exports of frits and glaze for the ceramic tile industry. Interviews and Tortajada-Esparaza et al., 2008ab; 2009

[9] Torrecid patented it

technology. SACMI, another leading equipment company from Sassuolo did the same. As revealed during interviews by the frit trade association board (ANFFECC, June 2012):

"….System was incapable of fighting this battle […] all its commitments, networks and technologies had been embedded in the mechanical rolling decoration technology since the launch of the Rocket version in the 1970s […] they were developing new Rotocolor-based versions of inkjet printing which did not work…..".

Patent analysis, see Appendix II for technical details, also supports the first factor about the cognitive inertia in Sassulo firms due to their *mechanical architectural knowledge*. Leading incumbents from Sassuolo, a cluster deeply embedded in its extraordinary mechanical capacity confirmed in the interviews and as evidenced in the patent analysis, was unable to escape from past paradigms: both firms had their manufacturing facilities and R&D labs in Sassuolo, albeit both had affiliates for selling products (not manufacturing) in Castellon. They ended up entering as latecomers and their proportion of inkjet decoration capabilities market share is residual with 2016 data. Their embedded mechanical knowledge was a core rigidity that prevented transition.

Summing up, in the Italian case, patents were hybrid versions (*System* and *Sacmi*) of the Rotocolor or just latecomers (e.g. Projecta): lock-in was pervasive. In this specific case of Sassuolo, a pervasive process of inertia or resistance to abandoning old technologies was observed, corroborating past studies (e.g. Glasmeier, 1991; Grabher, 1993; Sull, 2001).

5.1.6 Concluding the case.

Overall, findings confirmed that the new tile inkjet technology is entirely a Castellon produced technology, without Italian participation, adapting inkjet technology from the Cambridge printing cluster (*Xaar, Xennia*, etc.) or Seiko (Japan) to the specific case of tile decoration using inkjet. The technology was adapted to the tile process by local Castellon firms (Kerajet and the leading chemical companies). The adaptation and full adoption was possible in Castellon because that MID was fully embedded in tile decoration and the powerful leading chemical firms facilitated the new inks and fostered the transition after a first period of reluctance and inertia.

Overall, Castellon had the necessary ecosystem for advancing the decoration process and turning it from a mechanical (Italian equipment based) into a digital one. Then, the main difference between Castellon and Sassuolo was based on the fact that the former is highly specialized in tile decoration and chemical knowledge is its core asset. Castellon's main strengths concerning tile decoration technology include a world-class research transfer office fully devoted to tile decoration with over 100 researchers (ITC), along with the presence of all leading chemical firms for tile decoration, all indigenous to Castellon with their R&D labs located there, and the local university (UJI) offering industrial engineering with focus on tile decoration; all this ecosystem of innovation was the seedbed for tile decoration disruption, combining decoration processes with the new inkjet technology. In Sassuolo, decoration is led by the Castellon firms and the MID is entirely devoted to tile production based exclusively on mechanical knowledge based, far from the decoration emphasis from Castellon. Thus, the cognitive inertia in Sassuolo was more difficult to overcome.

Also, it is important to remark that the new inkjet technology provided significant productivity improvements shown in Appendix III. For the sake of clarity, a time diagram is also provided in Appendix IV.

Regarding the Cambridge and Castellon co-operation, mixing inkjet printing and tile decoration, the unexpected results were impressive. First, the inter-industry co-operation brought radical discontinuities to both sides, opening up new possibilities. Thus, Cambridge firms accessed the most powerful innovation center for tiles, Castellon, using it as a springboard for new markets in the global ceramic tile industry, which were very promising and profitable in Europe and Asia (China, India, Indonesia, etc.) and Latin America (Brazil or Mexico). Second, subsequently, companies from Silicon Valley (e.g. EFI), like those from Cambridge, have also established a foothold in Castellon, opening up new markets and technology for both sides, yielding unexpected positive returns and rejuvenating MIDs.

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