How does diversity affect district innovation systems? Findings from a comparative study of European ceramics*

¿Cómo afecta la diversidad a los sistemas distritales de innovación? Hallazgos de un estudio comparativo de la cerámica europea

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Abstract: This research applies Nelson's (1993) primary typology of enterprises to understand why the propensity for innovation varies across ceramics district innovation systems in Europe. We use innovation systems and industrial district theories to explore the innovation capacity of the two most important ceramic tile industrial districts in Europe—Emilia Romagna in Italy and Castellon in Spain. Our analysis shows that, in both districts, innovation plays a decisive role in allowing companies to maintain competitiveness in a globalizing market. However, by comparing the composition of their district innovation systems, our analysis shows that: (i) although levels of competition in both districts are similar, cooperation is stronger in Italy; (ii) scarce technology and advanced service providers in Spain make it predominantly a follower in the adoption of innovation; (iii) higher innovation intensity in Italy is due to diffusion of technology from firms in neighbouring districts specialized in other industry sectors. We provide strong evidence indicating that differences in the industry mix shape both national and district innovation systems.

Keywords: ceramic tile industry, district innovation system, industrial district, industrial mix.

Resumen: esta investigación aplica la tipología de empresas de Nelson (1993) para entender por qué la propensión a la innovación varía entre los sistemas de innovación de distritos cerámicos en Europa. Usamos las teorías de sistemas de innovación y distritos industriales para explicar la capacidad de innovar de dos de los distritos industriales de producción de baldosas cerámicas en Europa: Emilia Romagna en Italia y Castellón en España. Nuestro análisis mostró que en ambos distritos la innovación juega un papel determinante para permitir a las empresas mantener la competitividad en un mercado cada vez más globalizado. Sin embargo, al comparar la estructura de sus sistemas de innovación, nuestra investigación comprobó que: (i) aunque los niveles de competencia en ambos distritos son similares, la cooperación es más fuerte en Italia; (ii) la escasez de tecnología y proveedores de servicios avanzados en España hacen que este país sea predominantemente un seguidor en la adopción de innovaciones; y (iii) la mayor intensidad de innovación en Italia se debe a la difusión de tecnología desde firmas en distritos vecinos especializadas en otros sectores industriales. Finalmente, proporcionamos evidencia sólida que indica que las diferencias en la composición de la industria dan forma a los sistemas de innovación, tanto nacionales como distritales.

Palabras clave: industria de baldosas cerámicas, sistema de innovación, distrito industrial, composición comercial.

INTRODUCTION

A considerable amount of manufacturing activity in Europe is performed by Small and Medium-sized Enterprises (SMEs). According to Eurostat,[1] in 2014, 43.8% of manufacturing companies in the EU -28 were SMEs, and this percentage rises to 66.7% and 57.3% for Italy and Spain, respectively. In those countries, many SMEs are structured into productive agglomerates such as clusters or industrial districts[2] (Boix et al. 2015; Sforzi and Boix, 2016), which applies to the case of ceramic wall and floor tiles manufacturing (Meyer-Stamer et al., 2004; Studies–ENTR, 2008). Awareness of the relevance of industrial districts has resulted in specific policy instruments such as technology districts in Italy (Bertamino et al., 2016).

Europe used to be the world leader in the production of ceramic tiles, but it was overtaken during the 1990s to 2000s. Currently, although China Brazil and India dominate the world production of ceramic tiles (Baraldi, 2016), Italy and Spain are the world leaders in ceramic wall and floor tiles innovation and they export over 80% of their production despite comparative disadvantages in production costs.

However, the innovative behaviours of Italy and Spain in ceramic wall and floor tiles are not equivalent. Their innovativeness seems to be linked to the industry mix in the focal and neighbouring districts.

In Section 1, we present the theory underlying our exploration of the intersection between systems of innovation and industrial districts. In Section 2 (Methods), we discuss our choice of comparative case study and the differences and similarities between the chosen cases. Section 3 presents a brief description of the industrial districts and the results of our analysis. Section 5 discusses our findings and their contribution to theory and practice. Section 6 discusses some limitations of our study and suggests some directions for future research.

Systems of innovation

Most systemic approaches understand innovation as a collective and interactive process, in which a variety of institutions and organizations participate. An innovation system includes 'all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovation' (Edquist, 2004, p. 182).

This theoretical approach to innovation considers that relationships and networks are key aspects of the processes of innovation and production (Edquist, 1997). The importance of the concept of innovation systems has increased (Doloreux and Porto, 2017) and technological change is not considered an exogenous factor explaining economic growth. Although the concept of innovation system derives from evolutionary economics, its influence has spread to other disciplines such as evolutionary economic geography (Kogler, 2015). In our view, the characteristics of our case are fitted to a sectoral innovation system framework.

Although the concept of sectoral system is linked to the perspective of traditional or econometric industrial organizational analysis (such as identification of sectors based on their products and demand, and an emphasis on basic technologies), it shows some differences (Malerba, 2002; 1999). For instance, it emphasizes the importance and heterogeneity of a knowledge base in agents' learning processes, sectoral institutions and organizations other than companies; the importance of dynamic complementarities; their emphasis on the processes of change; and the dynamics and coevolution of the sectoral system. The analysis of sectoral systems builds on evolutionary studies and

[1] Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Manufacturing_statistics_-_NACE_Rev._2#Sectoral_analysis

[2] Although the use of the concepts "industrial district" and "cluster" in the literature is inconsistent and inaccurate, the Porterian cluster is acknowledged to be the foundation of the Theory of the Firm (firm boundaries, firm heterogeneity and firm performance), whereas the "industrial district" concept takes equal account of social and economic issues (Ortega-Colomer et al. 2016).

innovation systems, although it focuses on sectors rather than technologies or countries.

Malerba (2004) considers that innovation in a given sector is affected by three main factors: (1) knowledge and technology, (2) actors and networks and (3) institutions. Drawing on the evolutionary literature and adopting a sectoral perspective, knowledge can be seen at the base of technological change. Nevertheless, it is highly idiosyncratic at the company level and not freely and automatically disseminated among companies but rather absorbed by firms based on their accumulated capabilities. López-Bazo and Motellón (2017) found that the regional context moderates the effect of internal determinants—particularly, firms' absorptive capacity—and showed that the relevant interactions operate only for small and medium-sized enterprises and are negligible for large firms.

In sectors where innovation is rapid, knowledge and technology frontiers change continuously. The links and complementarities between artefacts and activities are relevant to establish the limits of the sectoral system. Dynamic complementarities take into account interdependencies and feedback at both levels, demand and production, which are the main sources of transformation and growth of sectoral systems that can promote virtuous cycles of innovation and change. For their part, actors or agents can be individuals, organizations (companies, universities, financial organizations, unions, etc.), sub-organizations (such as R&D departments) or groups of organizations (e.g. business associations). Agents, together with companies and non-business organizations, include both suppliers and customers. Depending on the type of industry, each of them plays a more or less fundamental role. These heterogeneous agents, which are characterized by learning processes, abilities, beliefs, objectives, structures and particular behaviours, are linked through market and non-market relations. The types of networks and relationships vary among sectors depending on the characteristics of their knowledge bases, their learning processes, their basic technologies, the characteristics of demand and dynamic complementarities.

On the other hand, agents' knowledge develops according to relevant institutions, norms, routines, habits, practices, rules, laws, standards, etc., which are imposed or consensual, obligatory or optional, formal or informal, national and sectoral. Finally, according to Malerba (2004), demand within a sectoral system comes from individual consumers, companies and agencies, each characterized by their particular knowledge, learning processes, competences and objectives, and subject to social factors and institutions. Thus, buyers are not homogenous, but rather heterogeneous agents whose interactions with producers conform to institutions.

From a sectoral perspective, knowledge, learning processes and technologies are important. Regarding the latter, Malerba (2004) indicates that in some industry sectors more than one technology may be important, while the same technology can be relevant to more than one sector. A matrix linking technologies and products would be useful to differentiate sectors.

The foregoing suggests that, in a given sector, there can be companies that use more than one technology but, particularly in the case of large companies, there may be some differences between their technological diversification profiles.

In terms of knowledge, the sectoral perspective is in line with evolutionary theory, which highlights significant differences among sectors and technologies in terms of knowledge bases.

Malerba (2004) also notes other dimensions of knowledge useful to understand innovation activity in a sectoral system, and builds on Nelson and Winter (1982) and the notion of technological regime. One dimension refers to the appropriability or accessibility of knowledge. Knowledge can be internal or external to the company; the more internal knowledge implies higher possibilities for its appropriation (more difficult for competitors to imitate products and processes). Access to knowledge that is external to the sector is related to the level and sources of scientific and technological opportunities; external factors include human capital or scientific and technological knowledge developed in non-business organizations.

Second, sources of technological opportunities differ markedly among sectors as pointed out by Freeman (1982) and Rosenberg (1982) and, in some sectors, they represent technological opportunities linked to scientific advances in universities; in others, development of the firm's R&D activities. In certain sectors, opportunities to innovate come from suppliers (based on acquisition of equipment) or customers. Whether external knowledge is assimilated and applied in a specific industry depends on its accessibility and the possibilities for it to be transferred. If both are at a high level, innovation will also be high. However, if advanced capabilities are required to assimilate the knowledge, the industry will be more inclined to configure itself around large previously-established companies.

In addition, knowledge can be more or less cumulative depending on its source—cognitive, organizational or feedback from the market. Cognitive sources are learning processes. Knowledge obtained through learning can limit the acquisition of new information, but it can also generate new knowledge. Organizational capacity is specific to companies and generates path-dependent type of knowledge, which defines what the firm learns and can expect to learn in the future. Market feedback refers to opportunities for successful innovators to reinvest the returns from innovation in the development of new innovations and initiate a virtuous circle. Accumulation of knowledge can occur at different levels of analysis: technological, corporate (when appropriability is high), sectoral (when appropriability is low) or local (more feasible when appropriability is low and spill overs are located in an area).

According to Malerba and Orsenigo (1993), there is evidence that certain types of learning regimes are associated to basic innovative behaviours. Therefore, technological opportunities are more easily associated with radical innovations, accumulation is facilitated by innovative behaviour and the appropriability or accessibility of knowledge, by imitation.

Based on Malerba (1999), we can summarize the main elements of this perspective:

- The sectoral perspective focuses on knowledge and its structure. Knowledge bases differ among sectors and affect innovation activities, their organization and the behaviour of companies (or the appropriate unit of analysis).
- In relation to companies (or the appropriate unit of analysis), the sectoral perspective is interested in their learning processes, competencies, behaviour and organization, and emphasizes agents' heterogeneity and the variety of their behaviours and organization.
- Interdependencies and complementarities represent true sectoral frontiers, which may be at the input or demand level and may affect innovation, distribution or production.
- The role of non-business organizations and institutions is emphasized.
- The relationships between agents, whether market or non-market, are considered.
- The focus is on the dynamics and transformation of sectoral systems.
- Both tacit and codified knowledge play a fundamental role in innovation and production. The knowledge base underlying the firm's activities is idiosyncratic, does not spread automatically or without cost, and must be absorbed by companies through acquired skills.

- A multitude of links and complementarities that extend beyond the sector border are defined in terms of demand or basic technologies. These links can be static; dynamic complementarities include interdependencies and feedback at both the demand and production levels. Both affect firm strategy, organization and performance, speed and direction of technological change, type of competition and firm networks.
- The sectoral perspective emphasizes the diversity among agents in terms of knowledge and skills, importance of trust, and degree of informal interactions and relationships between agents. It suggests that in contexts of uncertainty and change 'networks do not arise as a consequence of the similarity of their agents, but because they are different. In this sense, networks can integrate complementarities in knowledge, skills and specialization' (Malerba, 1999, p. 17).

Industrial districts

Districts are geographically defined production systems, characterized by large numbers of companies that deal with different phases and forms in the production of a homogeneous product. Originally formulated by Alfred Marshall in 1870, the concept of a Marshallian Industrial District (MID) was resurrected more than a century later by Becattini (2002, p. 484): *to emphasize the dynamic linkages between the socio-cultural features of a productive community and the rate of growth of both its productivity and innovativeness* and is defined traditionally as a

A socio-territorial entity which is characterized by the active presence of both a community of people and a population of firms in one naturally and historically bounded area. In the district, unlike in other environments, such as manufacturing towns, community and firms tend to merge (Becattini 1990, p. 38).

The MID theory assumes the existence of a population of companies, usually small or very small, that specialize in one or more phases of the production process. A group of companies characterized by working together within a division of labour between companies rather than inside companies. This concentration and specialization increase the tension and need to innovate which, in turn, reinforces the integration and links among companies (Galetto, 2008). Furthermore, MID are conceived as social and economic wholes

> *where the main industry and the local community of families and collective institutions overlap in the sense that the values, attitudes and investment decisions of the community are guided by the presence of the industry, and strategic industrial factors are linked to the socio-economic relationships developed in the community.* (Bellandi, 1996, p. 2)

The foregoing implies that there is a close interrelation between the social, political and economic spheres and that the operation of one (e.g. the economic) is determined by the workings and organization of the others. Therefore, economic success depends not only on the economic field but also on the broader social and institutional aspects (Dei Ottati, 2006).

In fact, in MID there is an institutional, public and private network that offers real services (Brusco, 1990).

One of the central aspects of the MID theory is the existence of external economies; that is, a large number of small producers specialized in particular phases of the production process in the same district, which allows maximum economic and efficient performance. A MID makes it profitable to investment capital in subsidiary industries that provide special elements required for each specific phase, that collect and distribute the relevant materials, or collect and distribute the products of their activity (Becattini, 1979).

A MID is characterized by: trained, specialized and flexible labour supply for the phases of the production process (Galetto, 2008); faster circulation of ideas (Becattini, 1979) via a large population of workers thinking about, reflecting on and experimenting within an interconnected community (or, as Marshall described it, an industrial atmosphere), which allows knowledge to flow through the district, boosting innovation and productivity (technological efficiency and cost reduction); and physical, social and cognitive proximity among district agents make the processes of diffusion and absorption of innovations faster and more efficient—in MIDs, this rarely occurs through alliances or direct cooperation between companies (Boix, 2008). At MIDs, knowledge diffusion is based on the combination of several phenomena: 1) informal exchange of information in public and private spaces; 2) mobility of the workfoce; 3) chain of specialized suppliers articulated around the demands of the final integrator; 4) innovations in the supplier phases; and 5) imitation. Competition and moderate rivalry provide an incentive to take risks and innovate (Bellandi, 1996).

MID participants include final companies, suppliers of different intermediate products and services, and a wide range of other organizations (universities, business associations, industrial policy agents and other local or regional institutions). In MIDs, technological and organizational innovations take the form

> *of a continuous process, with an accumulation and interdependence on the effects of a large number of technological changes, each of which is small, and consequently on the connotations of an incremental process of innovation (à la Rosenberg; [1983]), rather than through great leaps. (Schumpeter, [1946])* (Garofoli, 1989, pp. 81).

In MIDs, practical knowledge generated through the

> *learning by practice or learning through use, requires a large number of interconnected actors to meet the demands of continuous exchange (learning through interaction). Therefore, most innovations are not generated in R&D departments but are derived from spontaneous creativity* (Boix, 2008, pp. 7) or are decentralized (Bellandi, 1996).

MIDs are characterized by bottom-up processes of innovation or decentralized industrial creativity (decentralization of the sources of new knowledge about the production process and the activities of use of products, which is beyond the control of R&D), which favours gradual change understood as (a) limited variation in markets, factors or technology and (b) a flow of continuous variations that accompany the processes of sustained growth (Bellandi, 1996).

Specialization in different activities or foci causes different particular knowhows and approaches to production and innovation, whose interaction favours the emergence of original combinations of products, processes and markets, allowing small businesses to focus on niche high-end markets.

Internal accessibility to the MID makes appropriation difficult as it elicits the imitation and development of new companies within the district network, and therefore favours incremental innovations.

From an evolutionary perspective, MIDs are *multicellular economic organisms immersed in processes of economic selection that see themselves in the need to change their traits through innovation in order to survive the process of destructive creation* (Boix, 2008, p. 7) in which the spin-off and the fragmentation of the production chain are facilitators of the innovative process.

The MID structure makes it difficult to adapt to more radical changes due to the tendency to inertia and its decentralized organization, which can hinder strategic investments to open new markets or set standards. Also, its diverse nature can favour the use of another of the subunits that make up the MID, thus ensuring its survival—even if its orientation changes—and the role of collective institutions or actual provision of real services in a MID, which can reduce the difficulties derived from decentralization (Bellandi, 1996).

Face-to-face contact and physical proximity among companies facilitate interaction and transmission of resources and knowledge, which can be difficult in long-distance relationships.

All things considered, the critical value of districts is more linked to social or relational resources than to tangible externalities or physical infrastructures.

District innovation system

Given the main contributions of both abovementioned perspectives, in this section we consider some of the traits of District Innovation Systems (DIS) (Gabaldón-Estevan et al. 2012). From a DIS perspective, the type of networks established can favour different types of knowledge transfer, allowing frequent contact among companies that can be positive for the development of incremental innovation, which requires deep knowledge in a certain area. However, these types of strong links seem not to be favourable to the development of breakthrough innovations because they provide information which, given the frequency of contacts, tends to be redundant, and because those same networks can lead to path dependency or a lock-in (Østergaard and Park, 2015) derived from a shared perception of reality (group thinking). For this reason, participating in networks with weak links is recommended for companies that want to preserve the ability to change their orientation (Fagerberg, 2003). An example here is the case of development of Inkjet printing in European ceramics (Hervás-Oliver et al. 2017).

Each innovation consists of a new combination of previously existing factors—such as ideas, capabilities and resources—which is why the degree of openness to new ideas and solutions is considered essential for innovation, particularly in its early stages (Fagerberg, 2003). Consequently, the greater the variety of these factors, the greater the chance of achieving a more sophisticated innovation.

It might seem that bigger systems (companies, regions, nations, etc.) have more advantageous starting positions because their constituent elements are richer; however, smaller systems (such as a DIS) do also require constant monitoring of competitors, surveillance systems and external sources of knowledge (Evans and Bosua, 2017). Thus, the greater the number of companies able to interact with external sources of knowledge, the greater the pressure on the remaining companies to do the same. And this drives the innovative capacity of both companies and the systems to which they belong (regional, national, or district) and is particularly relevant to SMEs, which need to compensate for limited internal resources through good capacity for interrelation with the outside world. Nevertheless, the growing complexity of the knowledge bases required for innovation means that even large companies increasingly depend on external sources for their innovation activities (Fagerberg, 2003).

Kline and Rosenberg (1986) underline that innovation should not be understood as a well-defined and homogeneous 'something' that appears or is available at a precise moment; in most cases, innovations involve drastic changes in their economic significance. Many improvements following the first introduction of an invention produce much more important economic consequences than the initial invention. For instance, Nelson and Rosenberg (1993) indicate that the innovative Schumpeterian company, which brings the product to market, is generally not the one that ultimately collects most of the profit associated with the innovation. A successful innovation depends less on invention and more on design. Innovative activity, therefore, depends on the interactions among the set of institutions that make up the DIS and neighbouring industries, through what has been described as *cross-industry innovation capability* (Hauge et al. 2017).

The systemic vision includes a series of conditions. First, it implies that agents and institutions are considered in terms of their contribution to innovation. A fundamental aspect of improving the innovation process involves reviewing and redesigning the links between the parts of the system. This vision assumes certain imperfections in the market for innovations, which require political intervention. Competences are distributed unequally among companies; good innovation practices are not immediately disseminated among companies and market mistakes may include failures of institutions to coordinate, connect and meet the needs of the system. On the other hand, it is assumed that the institutional framework differs from one territory to another, and that certain phases of the process are more suited to the companies in a specific territory or country. In short, innovation systems must ensure the flow of information through interfaces between companies, research centres, entrepreneurs, investors, consultancies, patent agencies, local institutions and other intermediaries (Lundvall and Borrás, 2005).

In a generic way, from the perspective of the DIS, innovation is conceived as an interactive process in which a multitude of different kinds of agents participate, they include clients, companies and other organizations such as universities, research centres, public administrations and financial institutions. The networks that connect the different elements of the system, information exchange mechanisms, feedback and knowledge stock are paramount, since companies do not innovate in isolation but in interaction with other companies and organizations and elements of the system. Cainelli and Zoboli (2004) suggest that economies of localization can favour intra-industry spill overs (exchanges of information among firms belonging to the same sector), whereas inter-industry spill overs associated to a variety of sectors in a local environment can foster the cross fertilization of ideas.

In contrast to the sectoral perspective—which is distinguished by the notion of industrial sector (defined in terms of product) as the scope of analysis and, consequently, of interest to those companies, agents and institutions that are linked to the sectoral activity regardless of its location—in a DIS the emphasis is on the types of relationships that are generated in the same territorial area. Malerba suggests several connections along these lines: *'high accumulation of knowledge in specific spatial locations is more likely to be associated with conditions of low appropriation and spill overs of spatially localized knowledge'* (Malerba, 1999, pp. 9), which coincides with the district scope of our approach. On the other hand, he indicates that the analysis of the agents that intervene in a system may be different (superior or inferior) to sector analysis (Malerba, 1999, pp. 15). Malerba also suggests that in some sectors networks can constitute local (regional) systems of innovation and production (Malerba, 1999, pp. 17), and recognizes that:

a tradition close to sectoral systems is the study of regional or local systems: in fact, often a local system coincides with a sector (see for example the studies on industrial districts and the machinery industry) (Malerba, 1999, p. 30).

The main ideas in MID theory are based on the rejection of the sectoral unit of analysis, due to its inadequacy to explain the main phenomena that affect the development of local production systems. According to Becattini, Marshall suggests that the industrial district is the indivisible unit, the atom, on which industrial research must be based. In addition, spatial location and the multi-sectoral nature of MIDs provide them with greater stability in the face of intense changes than any industry, sector or technology. The more transitions MIDs experience, the more their identity is reinforced (Becattini, 1979).

Also, from the systemic perspective, the emphasis is on the way the interconnections that facilitate interactions and synergies among companies without large resources can make up for the lack of those resources. Hobday (1991) describes the main mechanisms that help these companies: (1) small business groups can maintain cutting-edge technologies by relying on other organizations in the network; (2) accumulation of skills and collective learning within the network benefits all participants; (3) the network promotes the flow of key individuals between companies; (4) competencies can be combined and recombined to overcome bottlenecks; (5) the time and costs of innovating are reduced; (6) the network allows new innovative companies to enter the industry; and (7) companies operate in the network with great flexibility and at reduced costs.

These characteristics coincide with the so-called competitive advantages of district economies, which are derived from a strongly interconnected set of economies external to the companies, but internal to the district (Dei Ottati, 2006). Such advantages are summarized as: (1) efficiency in the use of resources, particularly work and intermediate inputs; and (2) innovation as a result of the accumulation of specialized human capital, competitive dynamics and rapid dissemination of information.

Thus, we use the notion of DIS, which requires the unit of analysis to be expanded to include not only the companies and institutions that make up the industrial district but also those elements of its sectoral system (conceived as both a technological system and a product) with which such unit interacts based on the location in the same national or regional innovation system, or outside of it, which applies to the case of the ceramic tile districts in Italy and Spain (Fernández et al, 2005, Molina-Morales, 2008a,b). Therefore, what defines which agents and institutions fall within the unit of analysis of the DIS is their contribution to innovation in the district being analysed. Thus, we avoid delimiting industry activity based on a product (in our case the ceramic tile), which would neglect other relevant activities (e.g. frits, glazes and ceramic colours). We also try to avoid the classification of industry activity based solely on technology, since its contribution is relatively conjunctural to the development of the industry (Becattini, 1979; Ybarra, 2007). On the other hand, as Becattini (1979) points out, the sense of belonging to an industry (as an element of collective psychology), which is at the basis of the definition of MID, can be useful for limiting our unit of analysis.

Consequently, it is clear that we are not proposing a radically new concept to analyse innovation in industrial conglomerates (closer to the original source) but rather a synthesis of two perspectives on industrial development using different yet complementary tools and levels of analysis.

METHOD

We carried out a comparative analysis to study the ceramic tile industries in Castellon (east Spain) and Emilia Romagna in Italy. We believe that a comparative study helps to identify the specific factors of each of these European ceramic tile industrial districts.

Both the Spanish and Italian ceramic tile industries have strong production capabilities and led sales in the international market until the 1990s and early 2000s, when they were overtaken by emergent economies. However, according to Baraldi (2016), in 2015 they were ranked 2nd and 3rd after China in the share of world exports (China 39.8%, Spain 13.8%, Italy 11.6%), and 4th and 6th in world production (China 48.3%, Brazil 7.3%, India 6.9%, Spain 3.6%, Vietnam 3.6%, Italy 3.3%). As a result of the competition of new producers, there is a need for continuous improvement and innovation in Italy and Spain, which face similar internal market problems due to the recent financial crisis, as well as quality and environmental regulations (Gabaldón-Estevan and Hekkert, 2013; Gabaldón-Estevan et al., 2014; Monfort et al., 2014).

Despite their similar context, there are substantial differences between the Spanish and Italian ceramic tile districts. The most of important dissimilarities are bigger companies and a stronger component of metal mechanics in the Italian DIS, which is also surrounded by other industrial districts (Meyer-Stamer, et al. 2004; Molina-Morales, 2002). Conversely, the Spanish DIS is characterized by smaller companies with a higher proportion of frits, glaze and colour companies, more geographically isolated from other industrial districts.

Based on a qualitative interpretive research design, empirical evidence was gathered through 36 semi-structured personal interviews with representatives from these districts. Such strategy builds on previous work on these districts.

Interviewees (see Table 1) in Italy and Spain include managers from the ceramics, electro-mechanical and glaze companies; representatives of employers' and workers' associations; representatives of public institutions specialized in technology or trade; directors of research institutes responsible for R&D for the industry; and academics researching the area. The interviews were designed to obtain information on various aspects of the innovation process. Specifically, we are interested in understanding the achievement and dissemination of innovation in the market, and the role of the various agents that participate in the innovation process. During the interviews, in addition to general questions, we asked about sector evolution, global production trends, new competitors and trade. This information, combined with statistics, was used to study the innovation capacity of European ceramics.

Table 1. Description of the informants' interviews

Ceramic tile	Frits, glazes & colours	Machinery and equipment	Scientific environment	Other
Sassuolo (Italy)				
G.M. (Assopriatrelle)*		P.G. (ACIMAC)*	C.P. (CCB)	P.G. (CWR)
G.M. (Cooperativa Cerámica d'Imola)		I.L. (LB Officine Meccaniche)	M.R. (UMRE)	G.S. (Tile Edizioni)
		F.S. (SYSTEM)	G.S. (UMRE)	
		G.V. (CIMES)		
Castellon (Spain)				
P.R. (ASCER)*	JL.B. (ANFFECC)*	F.O. (ASEBEC)*	E.C. (ICV-CSIC)	F.C. (QPT)
M.T. (ASCER)*	C.G. (ANFFECC)*	S.C. (Cretaprint)	C.F. (ITC)	E.D. (COCIN Castellon)
R.B. (Gres de Nules - Keraben)	C.G (Vernis)	J.R. (Plasma)	JA.H. (UJI)	J.R. (ATC)
J.C. (Zirconio)	M.R. (Ferro)		M.M. (ITC)	J.B. (SECV)
J.P. (Tau)			G.M. (UJI)	JM. S. (Ayto. Onda)
J.R. (Tierra Atomizada)			D.G. (ALICER)	
S.L. (Silvano Lassi)				

* Representatives.

Source: Authors' own elaboration.

It should be noted that, although the group of experts interviewed provided information on different production activities of the value chain and from public and private institutions not involved in productive activities, the interviews focused on questions related to the main productive activity, that is, ceramic tile production.

Finally, to understand why the propensity for innovation varies across ceramics district innovation systems in Europe, this research applies Nelson's (1993) primary typology of enterprises. Nelson distinguishes three types of industries based on the characterization of their technical change process. We classify the enterprises in the two ceramics districts studied in this paper as follows. Type A enterprises (correspond to Nelson's *bulk commodities*) group the producers of ceramic tiles (Type A - Tile producers) based on minimal product and process innovation; they exploit equipment and input suppliers as the sources of innovation. Type B enterprises are providers of technology and advanced services (i.e., mechanics, electronics, design ventures) and include *complex systems* producers (Type B1 - Machinery and Equipment producers) and *chemical products* producers

(Type B2 - Glaze and Colour producers), which are responsible for most innovation in the ceramic tile districts. The technical advances of complex systems producers tend to be incremental improvements to components and system designs; chemical products producers innovate mainly through the introduction of new products. Consequently, input suppliers—such as component and material producers and system designers—play an important role in the innovation processes of Type B1 enterprises, but are less important for the innovation processes of B2 enterprises, whose products do not involve complex systems. It follows that the producers of chemical goods are more dependent on in-house R&D and close relations with clients, while complex systems producers are more dependent on the innovative performance of their input suppliers.

RESULTS

In this section, we present the results of our analysis starting with a brief description of both industrial districts in the European ceramics innovation system. We identify the elements of the analysis and compare the cases based on the characteristics of their productive, scientific and technological environments.

The technological progress and competitiveness of an industry heavily depend on institutions and supporting organizations. National institutions have a strong regional influence on district firms. A comparative analysis of the Spanish and Italian ceramic tile DIS shows that, at the institutional level, the Spanish tile sector is more fragmented than the Italian. In Italy, the tile manufacturers' association (Assopiastrelle) and the association of manufacturers of machinery and equipment (ACIMAC) dominate the district, while in the Spanish sector several institutions are important, especially the manufacturers' association (ASCER). The other institutions are associations of frits and glaze manufacturers (ANFFECC), manufacturers of machinery and equipment (ASEBEC), ceramics technicians (ATC), and ceramic and building materials distributors (ANDIMAC). This diversity in Spain reduces the influence of each entity on the tile district. In Italy, ceramic and technological fairs (respectively Cersaie and Tecnargilla) are more important than their Spanish equivalents (Cevisama and Qualicer). In neither case do the districts benefit from direct policies, although the institutional environment in Spain is more sympathetic to the Spanish tile industrial district.

At the scientific level, we can distinguish between education and research activities. In Spain, Jaume I University (Castellon) offers high quality degrees in chemistry oriented towards the ceramics process; however, there is very little provision of good quality training in management, commerce and industrial engineering. In Italy, the degree courses offered by the University of Modena and Reggio Emilia have only recently included chemistry; their main strengths are in business administration and industrial engineering. More research is conducted in the Castellon district, supported by Jaume I University and two research centres—Instituto de Cerámica y Vidrio and Instituto de Tecnología Cerámica (ITC). The Centro Ceramico di Bologna (CCB) is responsible for most ceramics research in Emilia Romagna district.

Technological and services innovation is driven by the glaze sub-sector in cooperation with the ITC in the Castellon's ceramics district, and by machinery providers and design studios in the Italian ceramics district. The CCB's capabilities are less sophisticated than those in the Spanish industrial district. In Spain, the ITC stands out for its contribution to training (80% of the teaching staff in chemical engineering are specialized in ceramics technology) and R&D. The Emilia Romagna district has design, management and commercialization strengths, but not the support of a technical association similar to the Spanish ATC.

To summarize, first, leadership is weaker and more fragmented in the Castellon ceramics district, which negatively affects its direction and visibility. Second, the strength of this district is in the glaze sub-sector (Type B2) and in chemistry (training and R&D), while Emilia Romagna's are in R&D conducted by machinery providers (Type B1) and training in business administration and industrial engineering (Gabaldon-Estevan, 2016).

The district productive environments differ in several ways. First, Spanish enterprises are younger and smaller (see Table 2), more flexible and more dynamic than their Italian counterparts, with limited capacity for independent research. The older age of Italian firms means they are more experienced in management based on the expertise of firms' owners and main shareholders, which results in more business-like organization and involvement of shareholders in strategic decision-making through participation in firms' boards. Generally, Spanish enterprises are not specialized, but produce several different types of products; they are involved in subcontracting and do not collaborate with other firms. Italian companies are specialized in products, which increases their impact on the innovation system. The share of Castellon's tile products in the high market segment is small, while Emilia Romagna is the leader in all the major market segments.

Table 2. Tile producers: number of firms and employees in 2008 and estimated size of the industrial district

	Italy	Spain
Firms	195	201
Employees	26.364	22.300
Mean	135.2	110,9
ID km^2	35 - 40	20 -25

Source: KPMG, 2010.

The recent introduction of robots in different phases of the production process, the development of porous single-firing and porcelain stoneware are notable. The production of porcelain tiles—a type of ceramic tile that requires more pressing and cooking at higher temperatures—was developed in Italy by Italian machinery manufacturers and, although the production of this type of good is greater in the country of origin, it has increased in Spain.

Italian machinery companies have been responsible for most process innovations and, especially, innovations from nearby districts. For instance, the atomizing machine that was adapted from equipment used to manufacture milk powder and the roller furnace—an adaptation from the biscuit manufacturing industry—both belong to the agri-food sector in Emilia-Romagna (Russo, 1996).

The most recent innovations, except for *Laminam*3, are directly linked to design. If we decompose a ceramic piece into its three basic properties—size, texture and decoration/colour—we can follow the main innovations in each area. Innovations in size have been developed by Spanish ceramists in collaboration with Italian equipment companies and constitute a product differentiation strategy. Italian ceramic producers, in close collaboration with Italian equipment companies, have developed a variety of textures that mimic all types of natural stone and wood surfaces. The response from the Spanish frits, glaze and colour companies was to develop the Inkjet printing technology with partners outside the European ceramics sector (Tortajada et al. 2008; Hervás-Oliver et al. 2017) where a frit, glaze and colour company has developed several patents in association with British and Japanese partners. Finally, regarding decoration and colour, in Spain this activity is carried out by the frits, glaze and colour companies in collaboration with ceramic companies, while in Italy it is performed by designers. See Table 3 for a summary of the comparative evidence collected.

[3] *Laminam was developed by the leading Italian machinery producer System, and it has revolutionized the tile industry. Sinterflex, Laminam's production process, is fully automated, from pouring the clay into the line to storage. The product requires only a third of the material inputs for conventional tiles including energy and water. It is 3mm thick and is a third of the weight of a conventional tile. It can be produced in bigger sizes, 1m x3m, which can be cut in different shapes. However, only 5 enterprises are producing it, due to the reluctance of tile producers to adopt this new technology*. (Gabaldón-Estevan, 2012, p.97)

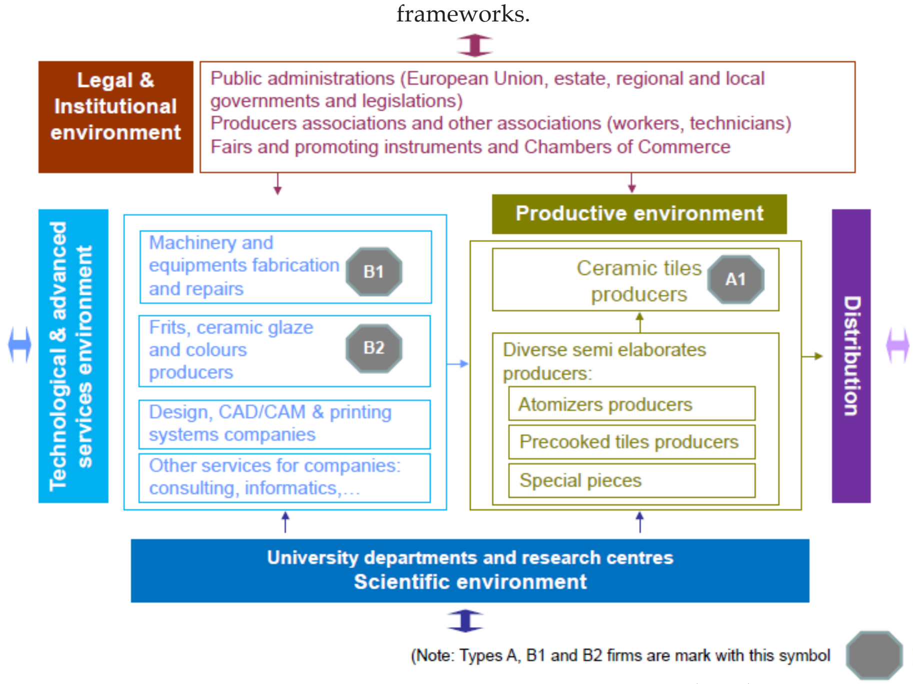
Table 3. Summary of comparative evidence collected

Spain	Italy
Institutional Environment	
The associative level is fragmented (ASCER, ANFFECC, ASEBEC, ANDIMAC, AFPE and ATC) and although ASCER is the most important actor, it is not as predominant as its Italian counterparts, Assopiastrelle.	The associative level is concentrated mainly around Assopiastrelle and ACIMAC.
Relevance of Cevisama and QUALICER as international events.	Leader position of Cersaie and Tecnargilla.
There are no direct policies to support the sector, although good institutional disposition is observed.	There are no direct policies to support the sector and the institutional disposition is weaker.
Scientific Environment	
Important role of the Jaume I University (UJI) training Chemist and Chemist Engineers. Deficient commercial and management training. Inadequate Industrial Engineering training.	The Modena and Reggio Emilia University only recently offers degrees on Chemistry and Ceramic Engineering, being more experienced on Business Administration and on Industrial Engineering training.
Research is developed by the ICV (Ceramic and Glass Institute), the ITC (Technological Institute of Ceramics) and the UJI (Jaume I University).	Less research is done in the Italian scientific environment, and it is carried by the CCB (Ceramic Centre of Bologna).
Environment of the Providers of Technological and Advanced Services	
Technological innovation is driven by the glaze sub sector and assisted by the ITC (Technological Institute of Ceramics).	Technological innovation is driven and supported by the capital goods sub sector and design studios.
Central role of the ITC in education and process innovations.	The role of the CCB (Ceramic Centre of Bologna), although important, is not as central as its Spanish counterpart.
Education on chemistry and cooperation from the ATC (Ceramic Technicians Association) is remarkable.	Excellence in design, business administration and commercialization.
Production Environment	
Small and Medium Enterprises, flexible and dynamic.	Bigger ceramic holdings, less dynamic than their Spanish counterparts.
Low specialisation, most companies undertake all product types.	Higher product specialisation.
Relative vertical integration within companies.	Weak vertical integration within companies.
Family-founded firms; decisions are still adopted by the owner or main shareholder.	Decisions are adopted by shareholders in boards, adopting a more management-like approach.
Small inter-firm collaboration in R&D projects. Subcontracting is considerable.	Stronger involvement of tile firms in the Sectoral Innovation System articulation.

Spain	Italy
Weakness in the high market segment positioning.	Leadership in main markets.
Environmental Interactions	
Information flows between the UJI, the ITC, the glaze companies, and the ceramic companies, and it is reinforced by the mobility of and relationship between graduates.	Dense network of actors invigorated by capital goods companies.
The internationalization of the Spanish district with the Italian one is realized through the relationship between Spanish ceramists and Italian capital goods providers.	The internationalization of the Italian district with the Spanish one is realized through the relation of Italian ceramists with Spanish glaze providers.
Predominant role of the institutional actors.	Predominant role of business associations.
Innovation within the district	
Few relevant innovations both of product and process, more frequent in design and carried out by glaze firms.	Frequent product and process innovations driven by their leading position in capital goods.
Too much dependent on capital goods providers and glaze firms.	They try not to be excessively dependent on providers.
Lower innovative tension than their Italian counterparts.	Continuous search for new tile uses

Source: Authors' own elaboration.

Figure 1. Depicts the context of the tile innovation systems in Spain and Italy. It shows three regionally bounded (productive, scientific and technological) environments that are influenced by their legal and institutional frameworks.



Source: Adapted from Fernández-de-Lucio, et al. (2005).

DISCUSSION

To contribute to the debate over the role of conglomerates to influence innovative capacity, we formalize our propositions following Nelson's (1993) primary typology of enterprises in light of the evidence presented in the Section 3.

Our first proposition (P1) states that innovation in a given industrial district strongly depends on the district structure in terms of the types of enterprises included. This dependence is positive: the more Type B enterprises included in the district, the higher the district's innovation capacity. As a result, the composition of these firms (in terms of number of B1 and B2 companies) will influence the predominant type of innovation.

The second proposition (P2) claims that the innovation capacity of a district depends on the strength of the relations between Type B district enterprises and Type B enterprises in neighbouring districts specialized in other industry sectors. This is especially important if Type B1 firms are more dependent on input suppliers than Type B2 firms. In other words, innovation in a given industrial district might be more influenced by innovations developed in neighbouring districts specialized in other industrial sectors, if the process is facilitated by the relations among other Type B1 enterprises.

Our assumptions are that district innovation capacity is affected positively by: a) (P1) the presence, magnitude and composition of Type B firms in a given district; and b) (P2) the strength of the relationships among these companies and Type B enterprises in neighbouring districts specialized in other industrial sectors.

Proposition 1 states that innovation in a given industrial district is dependent on the district structure in terms of the types of enterprises it includes. We suggest that there is a positive relationship between the number of Type B enterprises and the district innovation capacity. We also observe that the different compositions of Type B enterprises will influence the type of innovation that predominates. Proposition 2 claims that the strength of the relationships between Type B1 tile enterprises and Type B1 enterprises in neighbouring districts will influence the innovation activity in a given district.

Our analysis suggests that Type A enterprises in the Spanish industry are relatively smaller than Italian ceramic tile firms (see Table 2), which could limit the former's capacity for innovation. Also, the Spanish ceramic tile district seems to have an insufficient critical mass of technology suppliers (Type B1) to produce innovations other than those specifically related to glaze production and application; they have a weaker set of advanced service purveyors specialized in design. In Spain, firms are mainly focused on the production of the commodity (Type A) and much less on the production of components. The consequences of being specialized only in the production of the traded good include isolation and low levels of cooperation among the actors in the value chain. Since inclusion and high levels of cooperation are prerequisites for innovation in an industrial district, the evidence provides tentative support for P1. Also, considering the major role of knowledge in innovation in an industry context, the absence of providers of knowledge-intensive processes—such as advanced services and technology (Type B1)—has an impact on the relations with universities.

Tile making includes the important component of glaze, which is a complex and highly scientifically-dependent input. In the Spanish tile district, the glaze makers (Type B2) provide services such as technical assistance and design, which in part compensates for the lack of specific service providers. The presence of glaze producers in the district fosters cooperation with the chemistry departments of universities in the region. This cooperation promotes innovation mainly, but not exclusively, in aspects related to the chemistry of glazing. The existence of ties with university departments is strongly related to the efforts made by enterprises in the ceramic tile sector to recruit employees with specialist training and a degree in chemistry. This has two important consequences for sector performance. First, there is a strong relationship between education and social capital (Putnam, 1996; Cainelli and Zoboli, 2004; Hadjimanolis, 2003), especially tertiary education; and social capital implies cooperation among the agents in the system. The experience of studying at the same university and the rotation of workers among enterprises acts as 'glue' that enables successful cooperation and mutual assistance among technicians in the region. Second, the qualified human capital in the district facilitates the absorption and development of innovation (Fagerberg, 2003).

The Emilia Romagna district is a technology leader specialized in the commercialization and design of products. It is famous for fashion, design and technology advances in bioengineering, electronics and automobile engineering. Our analysis shows that, in addition to excellent performance in tile production, Emilia Romagna companies perform most of the complementary activities in the product value chain. The Italian district includes technology (Type B1), advanced services and components providers. This is important for several reasons. First, the fact that the producers of the commodity and the providers of capital goods are located in the same geographical space probably boosts confidence and facilitates information transfer, and may foster cooperation for innovation. Our evidence shows that most process innovations are developed by Italian capital goods producers, while developments in Spain are related only to the glazing process. This provides further support for P1. Second, the location of advanced services providers from different industries in the same geographical space probably facilitates greater transfer of knowledge. Evidence supporting P2 can be found in the cases of atomization and furnace tunnel technologies: providers of capital goods for tile manufacturing (Type B1) developed these technologies in close collaboration with the providers of capital goods for the agro-food industry (also Type B1) firms in neighbouring industrial districts. Nelson (1993) points out the fact that differences in the industry mix have a strong influence on the shape of the national innovation system. Our results suggest that this applies also to industrial districts.

CONCLUSIONS

The objective of this study was to understand the links between innovation and cooperation involving the various elements in a given industrial district and the presence of enterprises and providers of technology and horizontal advanced services supporting several different types of industrial districts.

There are several conclusions relevant to our propositions that emerge from our comparative analysis of the tile industry districts in Castellon and Emilia Romagna. 1) We observed a strong role of competition in the Spanish district, which is not accompanied by similarly strong cooperation. Our interviews show that the level of competition in the Spanish and Italian districts is similar, but there is less active cooperation in the Spanish district. 2) The scarcity of technology and advanced services providers (Type B) in the Spanish district suggests that the important process and product innovations are introduced in Italy, with Spain adopting a follower role in most areas. 3) The existence of horizontal technology enterprises increases competition in innovation due to technology diffusion across neighbouring districts specialized in other sectors, which is favoured by the mobility of qualified workers. Findings 1) and 2) provide support for P1; finding 3) provides support for P2. Therefore, we can conclude that innovation positively depends on the relative level of technology and the presence of advanced service providers in a district, as well as the strength of the cooperation between these firms and similar firms in neighbouring districts. Our analysis also suggests that the districts in both countries would benefit from stronger links with universities, which would increase the possibilities of developing radical innovations. As Coenen et al. (2015) point out, infusion of radical emergent technology is necessary, but not sufficient for new regional industrial path development. In our case, several radical innovations, such as self-cleaning tiles, were neither developed in Italy nor Spain despite their leading positions in tile production. The threat to European ceramics emerged in the 1990s with the entry of new countries and it grew during the 2008 crisis, which affected the economies of all southern Europe (Donatiello and Ramella, 2017). The providers of technology and advanced services, in addition to being more competitive, are better positioned to diversify their activities to new sectors.

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