



**KNOWLEDGE DIFFUSION INNOVATION IN THE CERAMIC
CLUSTER. SNA OF PATENT DATA**

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ABSTRACT: The intention of this work is to provide a study based on Patent Data from the Spanish National Association of Manufacturers of Frits, Glazes and Ceramic Colours, ANFFECC. The research makes use of the social network analysis (SNA) methodology in order to help us understand knowledge sharing within the innovation process. Following a summary of the basics of social network analysis, it is examined how and why innovation can benefit from knowledge exchange. The evidence shows the behavioural relationships between actors within organisations and the sharing of knowledge as a solid indicator of innovation. The main contribution is to detect, select and create networks of inventors for each group of companies within ANFFECC. The ancillary data is contrasted with the information of the patent data, and these results are then fed into special programs for social network analysis. The main objective is to understand how knowledge and innovation spread among the members of an organization. The most important node is connected with peripheral points and there is also knowledge flow among organizations. The results show that the larger and more diversified the company is, and the more inventors and patents are implicated in a wide range of projects, the greater the resulting level of innovation can be expected to be. The work concludes with a discussion of the implications of knowledge diffusion.

KEY WORDS: Social Network Analysis, Innovation, Ceramic tile industry, Social Capital, Industrial District DIS, SPTO, ANFFECC.

INTRODUCTION

Innovation is becoming ever more important for many enterprises. In fact, many companies have begun to rethink their services and products, as well as their company culture, in order to achieve improvements (Barlett and Ghoshal, 1990). Though the root of innovation can come both from inside or outside the organisation, firms are also more and more dependent on their environment as a source for knowledge and innovation (Patrucco, 2003). Regional clusters of industrial activity have long been understood to be potential spearheads of innovation and drivers effective economic progress (Cooke, 1996; Malerba, 2002; Becattini et al., 2009).

Generally, we can understand a social network as a grouping of nodes (people, organizations, etc.) connected by different types of relationships, e.g. personal, financial, etc. (Laumann, Galaskiewicz and Marsden, 1978).

The relevant development, since the 1960s, that this subsector has experienced inside Castellon's ceramic cluster benefited not only from the existence of certain raw materials in the area, the economical and qualified workforce available, and the great support by the Institute of Ceramic and Technology (ITC), but also, compared with other countries, from the scanty environmental restrictions in the past. The industrial district of Castellon is characterized by a great dynamism based on technological innovation, both in terms of product and process, the origins of which are to be found with its providers, the machinery industry and the frit, glaze and colours industry. Due to its innovative activity, the glaze industry is considered part of *Ceramic Innovation* cluster whose contribution is vital for the development of ceramics. Within this industry there is evidence of an intense innovation effort, both in the field of technology generation and dissemination of this technology, as glaze manufacturers not only provide their product, but also technical assistance, technology and design to its customers, ensuring greater added value.

Why is this work important, and why in particular these kinds of companies within the ceramic cluster? One of the reasons is that the production of frits, glazes and ceramic colours is also of great importance in the ceramic production process. Note

that in 2006, around 40% of the Spanish ceramic production were glazed products (see Table 8 in the Annex).

Manufacturers of glazes, frits and ceramic colours ceramic has been involved in an intense process of innovation, generating technology for the ceramic companies, both and in collaboration with machinery manufacturing companies. Therefore, the glazes and frits subsector holds a key position in relation to other actors within the ceramics industry (Gabaldon et al., 2008).

The evolution of the Spanish ceramic frits, glazes and colours producers from 1990 to 2006 is shown in Table 1, and (also see Table 9 in the Annex), in which it can be seen that exports rose eleven-fold during that period. The majority of the companies producing ceramic frits (twenty-three in total) belong to the ANFFECC and, as seen in the Table 1, twenty-two of these companies are located in the province of Castellon. Therefore, employment numbers, sales figures and foreign exports in the area depend heavily on this industry.

As we are dealing with an innovation-driven industry, it is of great interest to know how many inventors and how many patents each company has, and how is the structure of the network of inventors relates to the level of innovation of the respective company. This is, at least in part, due to the fact that they have relations with many other companies within the ceramics cluster that have diversified their products and services as well. It is thus worth attempting to relate the level of innovation of these companies in the current economic context with regional corporate resilience and the choice between diversification and specialization.

It is also important to gain a better understanding of the behaviour of inventors within organizations and their role in the innovation process and the diffusion of knowledge. Knowledge can spread within each group of companies, between organizations and even between different countries. Last but not least, it would be interesting to find out whether there is any connection between the structure of the network of inventors (range degree, betweenness and centrality) with the final results that is represented by the level of innovation (indicators such as Research and Development (R&D) projects, Alfa Gold Awards, etc).

Table 1. The evolution of the Spanish ceramic frits, glazes and colours

Empresa	Localidad	Facturación en miles de €	Empleados		
			Nº	%	% Ac.
Ferro Spain S.A. (a)	Almazora	174.566	734	18	18
Colorobbia España S.A.	Vilafames	120.738	387	10	28
Esmalglass S.A.	Vila-real	108.139	400	10	38
Torreced S.A.	L'Alcora	87.961	330	8	46
Itaca S.A.	Pobla Tornersa	71.899	217	5	51
Johnson Matthey Ceramics S.A. (b)	Castellón	61.259	183	5	56
Fritta S.L.	Onda	45.731	199	5	61
Quimicer S.A.	Onda	34.066	153	4	64
Colorificio Cerámico Bonet S.A.	Ribesalbes	33.774	153	4	68
Salquisa San Alf Químicas S.A. (a)	Cabanes	31.845	112	3	71
Esmaltes S.A.	L'Alcora	29.232	117	3	74
Colores Cerámicos de Tortosa S.A.	Tortosa	24.159	142	4	77
Coloronda S.L.	Onda	23.160	83	2	79
Vidres S.A.	Vila-real	23.684	125	3	83
Al-Farben S.A.	L'Alcora	22.158	89	2	85
Cerfrit S.A.	Nules	19.534	146	4	88
Vernis S.A.	Onda	15.897	70	2	90
Euroarce Color Esmalt S.A.	L'Alcora	14.610	87	2	92
Pemco Esmaltes S.L.	Vitoria	10.597	74	2	94
Wendel Email Ibérica S.A. (c)	Nules	10.370	53	1	95
Esmaldu S.A.	Sant Joan de Moro	9.894	37	1	96
Colores Cerámicos S.A.	Onda	9.648	51	1	98
Prodesco S.L.	Manises	4.344	41	1	99
Vitricol S.A. (d)	Onda	3.468	30	1	99
Colores Olucha S.L.	Onda	1.261	9	0	100
Colores Cerámicos Elcom S.L.	Manises	746	4	0	100
Colores Cerámicos Lahuerta S.L.	Manises	586	11	0	100
Total		993.326	4.037	100	

Source, D. Gabaldon et al. (2008)

The Alfa Gold Awards (*Alfa de Oro*) of the Spanish Society of Ceramics and Glass can be considered a reliable indicator of business innovation, as these awards recognize products, processes, machinery and equipment within the ceramics and glass sectors that stand out for their technological innovation. Between the years 1984-2014, some of the most successful companies according to the Alfa Gold prizes awarded, were the *Esmalglass Group* (Fritta S. L., Esmalglass S.A., Ithaca S.A.) with 10 awards, the *Torreced Group* (Torreced S.A., Al-Farben, S.A.) with 7 awards, and *Ferro Spain S.A.* with 2 awards.

According to the indicators mentioned above, in particular to the data from Alpha Gold awards such as indicators of innovation, projects and contracts or other implications with different entities (see Table III in the Annex), it can be concluded that companies such as the *Esmalglass Group* and the *Torreid Group* are among the leading companies for innovation in the sector.

The purpose of this work is to search and explain the innovation within an ANFECC, making explicit use of social network analysis methodology in order to gain insights into the innovation process and the structure of knowledge diffusion frameworks.

This work is structured as follows: Section 1 y 2 provides a theoretical framework, section 3 provides a very short introduction to network analysis which describes what it is, where it came from, the terminology used, and defines the concepts of structure and program used in SNA, and finally this section ends with the definition of the various measures offered by network analysis. Section 4 explains the methodology used for searching, collecting and selecting the data for this work. Section 5 explain method and findings presents the proposed aims and section 6 the results of the analysis, followed by section 7 the conclusion and suggestions of the research findings.

1. THEORETICAL FRAMEWORK

The aim is to analyse the innovation process in an industrial district. We are particularly interested in indicate the role of the Frit and Glaze firms within innovation system and confirming that this sub-sector is one of the key drivers of the innovation process in the industrial ceramic district.

1.1. INDUSTRIAL DISTRICT AND CLUSTER THEORY

1.1.1. INDUSTRIAL DISTRICTS

The concept of “industrial districts” was initially developed based on studies examining the ways in which production processes were organized when capitalism first emerged as early as the end of the 19th century (Marshall 1890; Marshall 1919), when the dominant model of production was so-called factory system, in which the entire production process takes place in the same location (Becattini 2002). These studies triggered research by authors such as Brusco (1990), Pyke et al. (1992), Porter (1998), and Becattini (2002), who adopted an operational point approach. As observed by Krugman (1991), the concentration of companies in one area gives them access to three types of economy: economies of specialization, economies of labour pooling, and

economies of knowledge spillover, all of which provide a competitive advantage. Marshall also notes the importance of an 'industrial atmosphere', in which knowledge and other non-physical resources are passed on between companies in an industrial district.

Since the 1970s, this approach has become particularly popular among scholars who focus on the innovative capacity of small and medium enterprises (cf. Becattini 2002). Supported by several case studies (e.g. Becattini 1973, 1979, 1986; Del Fabbro 1992), it is argued that smaller firms are more flexible and can thus adapt more easily to rapid changes caused by price fluctuations and changing customer demands than large enterprises, by exchanging knowledge and expertise with other firms in the same sector and the same geographical area, often complementing each other. According to Becattini (1990: 38), an industrial district is “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”.

The concept of the *industrial district* has traditionally been defined as “a socioeconomic entity which is characterised by the active presence of both a community of people and a population of firms in one naturally and historically bounded area” (Becattini, 1990: 39). An industrial district implies the existence of a population of firms specialised in one or more phases of the production process; it characteristically consists of a group of firms that work together, where the division of labour takes place on an intercompany, not an intracompany basis.

Becattini (1990) furthermore suggest that a ‘sense of belonging’ is an important sociological component that gives the members of an industrial district a certain sense of identity. While such a district is in constant flux, it can only be studied as a unit of analysis if its geographical and cognitive delimitations are clearly identified, and according to Becattini, it is the sense of belonging to a specific location, territory, culture, tradition and history that makes it possible to delimit the industrial district as a stable variable. This ‘sense of belonging’ is also an important factor that facilitates the creation and propagation of a strong brand image of an industrial area.

Industrial districts can also be defined as a “geographical concentrations of interconnected companies, specialized suppliers, services providers, firms in related industries, and associated institutions (for example, universities, standard agencies, and trade associations) in a particular field that compete but also cooperate” (Porter, 1998; 197-198).

Various types of economies of agglomeration are distinguished in the literature, including input-output linkages, labour market pooling, knowledge spillovers, sophisticated local demand, specialized institutions, and the organizational structure of business and social networks (Marshall, 1920; Porter, 1990, 1998; Swann, 1992; Saxenian, 1994; Storper, 1995; Markusen, 1996; among others). Such economies of agglomeration are characterised by clusters—geographic concentrations of related industries and associated institutions. Within regional clusters, companies and associated institutions (i.e. trade organizations, universities, and local government) can operate more efficiently and innovate faster due to the fact that they share common technologies, infrastructure, as well as skills and knowledge pools, in response to the demands of local customers. A regional cluster reflects specialization in a range of related industries, not specialization in a narrowly defined single industry (Porter, 1998, 2003; Feldman and Audretsch, 1999; Delgado et al., 2014).

1.1. 2. THE CLUSTERS

Porter (1990) proposes a basic conceptual framework for the description and definition of clusters, which he later defines as 'a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities. The geographic scope of a cluster can be a single city or state or a country or even a network of neighbouring countries' (Porter 1998: 199).

Clusters are concentrations of related industries and associated institutions within a single geographical area. The agglomeration of related economic activity is a central feature of economic geography (Marshall, 1920; Porter, 1990; Krugman, 1991; Ellison and Glaeser, 1997).

One of the advantages of the cluster concept is that it can explain why certain companies in certain countries are more successful than others, and what their competitive advantages are. A fundamental component of the concept, which has global validity and applicability, is identifying exactly how these competitive advantages, such as 'knowledge, relationships and motivation' are generated (Porter 1998: 78). According to Bathelt and Glückler (2014), it is difficult for companies that are located in distinct and distant areas from each other to create the same kind of business environment as that shared by firms that form part of the same cluster, which benefit from their proximity while and their close location also constitutes a barrier to 'outsiders'.

Marshall (1920) highlights three different drivers of agglomeration: input-output linkages, labour market pooling, and knowledge spillovers, all of which can give firms a

productivity advantage. Over time, the number of agglomeration drivers identified in the literature has increased; they now include local demand conditions, specialized institutions, the organizational structure of regional business, as well as social networks (cf. Porter, 1990, 1998; Saxenian, 1994; Storper, 1995; Markusen, 1996; Sorenson and Audia, 2000). Thus, clusters contain a mix of industries which are linked by knowledge, skills, inputs, demand, etc. and frequently share their supporting institutions.

Whilst formal definitions vary, most specialists agree that a cluster can be defined as geographic concentration of inter-connected companies and institutions working in a common industry.

Furthermore, clusters have a specialized infrastructure, consisting of collaborating and competing service providers and other enterprises, which support the working of the cluster's main industry.

Also, clusters draw upon a shared talent pool of specialized skilled labour. It is thus important to recognize that industry clusters are more than a group of firms within the same industry. The economic cluster model represents a synergy, a dynamic relationship and a network not only between the companies that make up a cluster, but also a successful partnership with the stakeholders. Government, educational institutions and other supporting organizations are vital to a region's economic success form part of this collaborative network.

The cluster notion is more recent than that of the industrial area, having emerged in the current era of globalization (Lazzeretti 2006). Despite its increasing popularity among academics and politicians (Ketels 2003), it has been criticised for its vagueness (Gordon and McCann 2000; Martin and Sunley 2003).

Industrial districts and clusters act a core basis for the economy of Spain in particular, but they are also relevant economic phenomena for other different countries, were they assume different configurations. A number of regions have been stated as industrial districts, mainly owing to the fact of their growth, competitiveness and agglomeration patterns and particular likeness to the model of industrial district provided by Marshall, or its Italianate variant (Piore and Sabel, 1984). The most widely known North-American examples are the regions of Hollywood, Silicon Valley and Orange County (Hall and Markusen, 1985) unexpectedly if many others have been studied (Porter, 1998). In UK academics have identified the area between London and Bristol; in France, Grenoble, Montpellier and Sophia-Antipolis; in Sweden the Gnösjo district; in Germany, Baden-Württemberg; some areas of Spain and Denmark and others outside Europe, similar as Ishikawa and others in Japan (Friedman, 1988), India, Brazil and Mexico (Schmitz, 1995; Rabellotti, 1997)

1.2. INNOVATION

It is extensively acknowledged that innovation is vital to the growth of production and productivity. Innovation means the conversion of knowledge into new products, services, or processes to be introduced to the market (or the introduction of significant changes to existing ones). It can be said that innovation, as well as companies' ability to innovate, depends on their capacity to join forces and exchange knowledge resources (Kogut and Zander 1992).

Innovation can also be understood as an implementation of one or more types of innovations, for instance product and process innovations, in accordance with the definition of technological product and process innovation used in the *Oslo Manual*, the most important international source of guidelines for the collection and use of data on innovation activities in industry.

According to the *Oslo Manual* (that is continuously being updated), innovation is defined as an implementation of a new or significantly improved product (goods or services), process, new marketing method, or new organizational method in business practices, workplace organisation or external relations (OECD / Eurostat, 2005).

It is important to bear in mind that an innovation is considered as such only when it implies a novelty and has been effectively introduced.

1.2.1. TYPES OF INNOVATION

The following four types of innovation can be distinguished (OECD / Eurostat, 2005):

- Product innovation: the introduction of goods or services that are new or significantly improved with respect to their features or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.
- Process innovation: the implementation of a significantly improved production or delivery method. This is achieved by significant changes in techniques, equipment and/or software.
- Marketing innovation: the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.
- Organisational innovation: the implementation of a new organizational method in a firm's business practices, workplace organisation or external relations.

1.2.2. SOURCES OF INNOVATION

There are different sources of innovation. It can occur as a result of a concerted effort by a range of agents, but it can also come about accidentally or as a result of a mistake.

According to Peter F. Drucker, The most common triggers for innovation are positive changes in industrial structure, in market structure, in local and global demographics, in human perception, mood and meaning, in the amount of already available scientific knowledge, etc., In particular, this author also gives us very important insights about innovation; in his work *Innovation and entrepreneurship* he suggests there are two different categories of innovations: those that are outside the company, (external) and those occurring within the organization (internal). On the other hand, the ability of the company to innovate depends on two factors: firstly on its providers, because in many cases the providers are key to delivering new technologies, and secondly on demand, i.e. the needs of its customers [36].

Innovation can be either radical or incremental. Radical innovation implies a change or introduction of a new product or service, while incremental innovation makes improvements to an existing product, thereby supplying added value.

1.2.3. MODELS OF INNOVATION

In the simplest, linear model of innovation, the traditionally recognized source is manufacturer innovation. This is where an agent (person or business) innovates in order to sell the innovation (see figure 1).

Fig.1. Linear model of three phases of the process



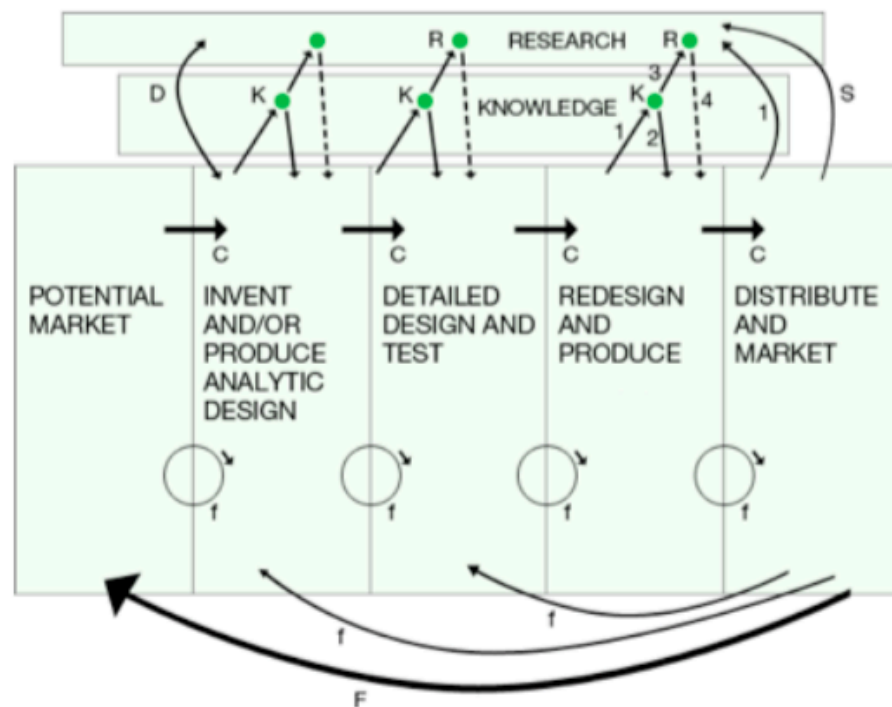
Source: Adapted from Eric Von Hippel, the original linear model of Innovation

Another source of innovation, only now becoming widely recognized, is end-user innovation. This is where an agent (person or company) develops an innovation for their own (personal or in-house) use because existing products do not meet their needs. In *The Sources of Innovation* (von Hippel, 1988), it is argued that end-user innovation is by far the most important and critical type of innovation.

Some authors, such as Engelberger (1982), claim that innovations require only three things: a recognized need, competent people with relevant technology, and financial support.

However, innovation processes usually involve (a) identifying customer needs, macro and micro trends, (b) developing competences, and (c) finding financial support. The chain-linked model developed by Kline and Rosenberg (1986), as illustrated in Figure 2, is an attempt to describe complexities in the innovation process. This model of innovation places emphasis on potential market needs as drivers of the innovation process, as well as describing the complex and often iterative feedback loops between marketing, design, manufacturing, and R&D.

Figure 2. Chain-linked model



Source: Chain-linked model by Kline and Rosenberg (1986).

Symbols on arrows: C = central-chain-of innovation; f = feedback loops, F = particularly important feedback.

K-R: Links through knowledge to research and return paths. If problem solved at node K, link 3 to R nor achieved. Return from research link 4) is problematic- therefore dashed line.

D: Direct link to and research from problems in invention and design.

I: Support of scientific research by instruments, machines, tools, and procedures of technology.

S: Support of research in sciences underlying product area to gain information directly and by monitoring outside work. The information obtained may apply anywhere along the chain.

Innovation by businesses can be achieved in many ways, especially with increased attention now given to formal research and development (R&D) for "breakthrough innovations". R&D helps to encourage the development of patents and other scientific innovations that lead to productive growth in areas such as industry, medicine, engineering, and government (Mark, Katz, Rahman, and Warren, 2008) Nevertheless, innovations can also be developed by practical, hands-on modifications of practice, by exchanging and combining professional experience, etc.. The most radical and revolutionary innovations tend to emerge from R&D, while more incremental innovations may emerge from practice – but there are numerous exceptions to this trend. The chain-linked model by Kline and Rosenberg (1986) shows the flow paths of information and cooperation (Figure 2).

1.3. NETWORK AND SOCIAL CAPITAL

A network is a group or system of interconnected people or things.

1.3.1. SOCIAL NETWORKS

A social network is a social structure consisting of a set of social actors (for example individuals or organizations), sets of dyadic ties (within the smallest possible social group, consisting of two people), and other social interactions between players. The social network approach identifies a set of processes for the analysis of the structure of social entities, and it also provides a variety of theories explaining the patterns observed in these structures. The function of social networks is to enable the circulation of information and trust both in terms of credit and relations between firms, "which in turn leads to economic consequences for development due to the exchanges that are fostered" (Gambetta, 1988).

1.3.2. SOCIAL CAPITAL

Broadly speaking, social capital can be understood to consist of the social relations that lead to economic benefits. The diversity of definitions found in the literature are due to the highly context-specific nature of social capital and the complexity of the way

it is conceptualized and operationalized. Social capital is the quantity of resources, real or virtual, that an individual or group of individuals has at its disposal by being part of a stable network of more or less institutionalized relations of familiarity and recognition (Bourdieu 1980; Wacquant 1992; Garcia and Benassi 2000).

There is not a single, undisputed definition of the term *social capital*, which is, at least in part, due to ideological reasons (Dolfsma and Dannreuther, 2003; Foley and Edwards 1997); the particular definition adopted in a study generally depends on the author's academic background and the type of research being carried out. (Robinson et al., 2002).

Social capital is about the value of social networks, bonding between similar people and bridging the gap between diverse people, in which reciprocity plays an important part (Dekker and Uslaner 2001; Uslaner 2001).

1.3.2.1. TYPES OF SOCIAL CAPITAL

According to the concepts proposed by Putnam (2000), we can distinguish two types of social networks. Putnam defines "bridging social capital" as bonds of connectedness that are formed across diverse social groups, whereas "bonding social capital" cements only homogenous groups. Bridging social capital has a positive effect on growth, whereas bonding social capital has a negative effect on the degree of sociability outside the closed social circle, as observed by Fukuyama (1995), who notes that the strength of the family bond implies a certain weakness in ties between individuals not related to each other. According to the OECD, social capital can be split into three main groups:

- (a) Bonds: Links to people based on a sense of common identity ("people like us")
 - such as family, close friends and people who share our culture or ethnicity.
- (b) Bridges: Links that stretch beyond a shared sense of identity, for example to distant friends, colleagues and associates.
- (c) Linkages: Links to people or groups further up or lower down the social ladder.

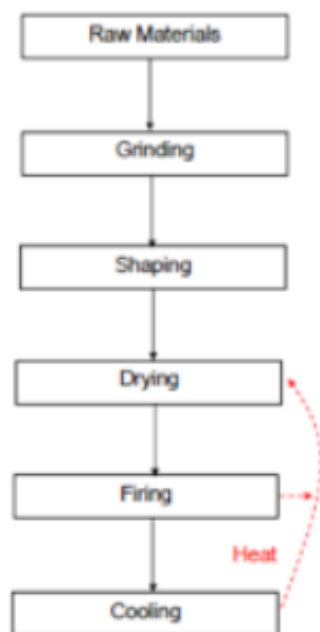
The potential benefit of social capital can be seen by looking at social bonds. Friends and families can help us in lots of ways – emotionally, socially and economically.

2. THE CERAMICS INDUSTRY

2.1. IMPORTANCE OF THE SECTOR IN SOCIETY

Ceramics are “non-metallic inorganic materials that lend themselves to permanent hardening by high temperatures” (Peterson, 2003: 11) and are a very diverse group of products, ranging from computer chips and electrical insulators to bathroom fixtures and tableware. Some typical features are their strength, texture, longevity, chemical inertness and electrical resistance. Their most distinguishing characteristic is that they are “more resistant to heat than any other material on the face of the earth” (Peterson, 2003: 11).

Figure 6. Typical ceramics production process



Source: Adapted from Valencian Institute of Business Competitiveness (IVACE)

According to Cérame-Unie (2007), the world ceramics market is worth around €120 billion. Manufacturers have, in recent years, significantly improved efficiency in the highly energy-consuming production process; the energy is mainly needed for drying and firing at extremely high temperatures of up to 2000°C (EC, 2007a). Figure 6 below shows the stages in a typical ceramics production process (techniques vary and are product-specific).

2.2. CERAMIC SPECIFIC PRODUCTS

2.2.1. WALL AND FLOOR TILES

Ceramic tiles are used to cover walls and floors and are typically produced from clay and a range of other raw materials. Wall and floor tiles can be shaped, sized, styled and finished (glazed) in a variety of ways to enhance the final product; they are physically strong, long-lasting, and they can also have a decorative function. The demand for wall and floor tiles is closely related to the demand for construction, which in turn is influenced by the number of new-builds as well as the demand for renovations and upgrading. Demand, is also closely influenced by changing consumer preferences and fashions.

2.2.2. BRICKS AND ROOF TILES

The market for bricks, blocks and roof tiles is mostly regional, mainly due to the comparatively high costs involved in transporting raw materials from their source, as well as finished products to the construction site. This is compounded by varying local conditions, such as different building traditions and climate requirements. The member companies of the Spanish Association of Ceramic Frit and Glaze Manufacturers (ANFFEECC) are suppliers of the of the global tile industry, providing products for the manufacturing of ceramic tiles. The products manufactured by these companies, i.e. frits, glazes, ceramic inks and pigments, give ceramic tiles their characteristic colour and look.

According to the website of the ANFFEECC and their website, there are several products and I will specify them below .

2.3.3. FRITS

A frit is a ceramic composition that has been fused in a special fusing oven, quenched to form a glass, and granulated. Frits are an important part of the batches used in compounding enamels and ceramic glazes; the purpose of this pre-fusion is to render any soluble and/or toxic components insoluble by causing them to combine with silica and other added oxides. In simple words, frits are vitreous materials that result from a molten process at high temperature (1350°C-1550°C) in a fusion furnace.

The main use of ceramic frits is the production of ceramic glazes. When glazes are applied onto the surface of the ceramic tile and then fired, they give an impermeable, protective and decorative layer to the tile.

2.3.4. GLAZES

Ceramic glaze is an impervious layer or coating of a vitreous substance, which has been fused to a ceramic body through firing. Glaze can serve to colour, decorate or waterproof an item. Glazing renders earthenware vessels suitable for holding liquids, sealing the inherent porosity of terracotta, the term we now use for basic unglazed earthenware. It also hardens the surface, and it can be used on stoneware and porcelain.

2.3.5. CERAMIC COLOURS

Ceramic colours are preparations made of frits, ceramic pigments and inorganic raw materials. Together with enamels, colours are the main components of the ceramic tile surface. They are usually supplied as a fine colour dust, with a particle size that depends on the desired decorative effect. They are made of oxides of different chemical elements, such as aluminium, antimony, cadmium, zinc, cobalt, chromium, tin, iron, manganese, nickel, silica, vanadium.

2.3.6. CERAMIC INKS

Inkjet technology and ceramic inks are a new product that has been introduced into the ceramic industry around the world since 2010. These inks were developed by Spanish enamel and machinery companies, that had invested in research, development and innovation. The mechanism is very similar to the one of a paper inkjet printer, printing on the tile without direct contact. This makes it possible to decorate any kind of tiles and low reliefs, minimizing the percentage of broken pieces; the entire tile can be decorated before entering the furnace.

This new, more versatile technology allows for a wider variety of decorative effects, and even the creation of completely different products. The quality and definition achieved with this technology is also superior to that of the previously used traditional methods.

The process is completely computer-assisted and monitored, which accelerates the change from one model to the other, since they go directly from the digital image to the printing machine, providing a wider product variety while saving time and money. The technology is also very environmentally friendly, as it makes the most of the product with no need for additives and without producing additional waste, which is beneficial to the environment as well as the work force.

2.3. EVOLUTION AND DEVELOPMENT OF THE CERAMIC TILE INDUSTRY

The Spanish ceramic tile manufacturing sector has a long history and it is important to present some historical data about this field. Its origins date back to the early eighteenth century, and though it is difficult to pinpoint the exact date ceramic tiles first appeared in architecture, we do know that they were used by the Egyptians more than 4,600 years ago. Glazed ceramic tiles came to Europe following the Muslim conquest of much of the Iberian Peninsula. Floor tiles known as *azzulezhi* (from which the Spanish word for tiles, *azulejos*, is derived) were used in Andalusia as early as the 13th century. They were characterised by their rich tones and replaced coloured marble. Glazed clay became common in Spain during the 13th and 14th centuries, as reflected in the examples of *Mudéjar* architecture that can be seen in the city of Teruel. Equally significant was the start of work on the Alhambra in the 13th century in Granada, a city which boasts a rich heritage in ceramic tiles.

The ceramics industry flourished in the region of Valencia as early as the 14th and 15th centuries, when the pressure exerted by the *Reconquista* forced a large manufactory of ceramic tiles to move from Malaga to Manises, near Valencia. The Valencian tile makers exported their goods as far afield as Venice, Egypt, Syria and Turkey, although Italy was their largest market. Manises became the supplier of floor tiles to the Vatican, decorating the papal palace in the 15th century.

In the 16th century, itinerant ceramic craftsmen brought their innovative technical discoveries (including polychromy) from Italy, together with the ornamental skills now associated with the Renaissance. This effectively put an end to the medieval ceramic tile trade in Manises, which was based on a single blue tone. From this period onwards, the centre of tile production was based in Valencia, although the factories were set up by master craftsmen from Andalusia or Talavera. This marked the start of Valencia's magnificent Baroque, Rococo and Classic tiles, which would remain fashionable until the mid 19th century.

In the area of Castellon, the *Royal Factory of China & Porcelain* was built in 1727 in Alcora. In the nineteenth century, industrialization began in the town of Onda, which became one of the major industrial centres of the Valencian Community in the first decade of the 20th century, with the factories "La Campana" and "El León" producing over 90,000 pieces of ceramics per month. The main export market for these products was Barcelona, followed by Andalusia, the Americas and North Africa, with the ports of Casablanca and Larache receiving a huge amount of mosaics. (Sarhou, 1913: 793-794). A training centre has been operating in Onda since 1925.

The introduction of natural gas as a source of energy in ceramics production in 1981 brought about one of the greatest technological changes in the sector. Natural gas produces comparatively clean combustion gases, which means it can be in direct contact with the products during firing. This, together with new transport systems for the materials in the kilns, meant that firing times could be reduced, with the corresponding savings in energy and increase in production rates. It was now possible to produce larger format tiles; the first cogeneration plants were created, and the glaze industry achieved a worldwide reputation. In addition, the consolidation of the cluster brought spectacular growth, turning it into Europe's biggest producer and the second in the world, leading the field with Italy in ceramic tile design, quality and trade.

According to Membrado (2001), in the early 80s a "second industrial restructuring" took place, whose main feature was the introduction of innovations such as mono-firing systems, increasing productivity due to a reduction of production time.

Another major advance in the industry was its segmentation and specialization, with innovations in the production process leading to a variety of specialised products, ranging from pavement tiles to coatings and sockets, but also developing a more traditional market with old and artisan ceramics. Another change was the diversification of production, with the emergence of related and complementary industries such as glazes, moulds, designs and even furniture.

On the other hand, large business groups emerged, bringing together all the processes of the chain of production; the cost advantage gained from the economy of scale allowed for reinvestment in development and innovation.

At the present time, the cluster of the wall and floor tiles industry identified by Ybarra (1991) is the driving force of the economy of the province of Castellon, accounting for more than 90% of production in Spain. It comprises 25 municipalities with 109 manufacturing companies in a 30-km-radius. The towns of Alcora and Onda alone have 33 and 27 companies respectively, producing 55% of all floor tiles. They also have the highest concentration of companies providing services for the ceramics industry. In this region, we find not only a concentration of industrial producers of ceramic products, but also of associated companies, technology centres and institutional innovation centres.

2.3.1. RELEVANT DATA ABOUT THE CERAMIC DISTRICT

The Spanish ceramic tile manufacturing industry is renowned for being one of the most innovative and dynamic in the world; it is at the forefront of the international market, in terms of technological development as well as the design and quality of its materials and services. According to the Spanish Association of Manufacturers of Ceramic Tiles (ASCER) in 2015, the Spanish ceramic sector produced 440 million square metres of tiles, with sales amounting to 3,095 million Euros. Spain has been one of the world's leading producers of ceramic tiles, but also the largest per capita consumer of the product. The ceramic tile cluster located in this area provides about 14,500 direct jobs; of the industrial sectors generating a positive trade balance in Spain it is the third most important. According to the Association of Spanish Ceramic Tile Industry (ASCER), more than 300 companies belonging to a variety of sectors are involved in the production and distribution of ceramic tiles: ceramic tile manufacturers, glaze, pigment and clay producers, suppliers of mechanical machinery for the ceramics production, transport businesses, distributors, etc.

In the following table we can see the evolution of the industry in both production and sales.

Table 2: Production and sales in the ceramic sector

	2011	2012	2013	2014	2015
Production	392	404	420	425	440
Domestic market sales	705	575	557	574	643
Export	1892	2082	2240	2328	2452
Total sales	2597	2656	2793	2902	3095

** Sales are reflected in million Euros and production in million square metres*

Source: Compiled from data by ASCER (2011-2015)

To better understand the figures in Table 2, it is important to understand the effects of the economic recession that began in 2007, at a time when, according to the ASCER trade association, 90% of Spanish floor tiles were manufactured in the province of Castellon. Tiles were exported to 177 countries, with a total production of 584.7 million square meters. Whilst these are, at first sight, quite impressive figures, they actually imply a drop of almost 10% of production compared to previous years. In Table 3, the effect of the crisis is clearly visible.

Table 3: Data in the ceramic tile sector

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Production	605,7	583,4	595,5	609,2	608,4	584,7	468,2	324,4	
Domestic market sales	1584	1379	1500	1609	1799	1871	1460	918	1747
Export	2582	1939	1977	2041	2183	2295	2211	1673	801
Total sales	4.166	3318	3477	3650	3982	4166	3671	2591	2548

Source: Gathered from data by ASCER

As can be seen, the economic recession has had a considerable effect on the industry. It is necessary to bear in mind that the main consumer of ceramic tiles is the construction sector, the one hit hardest by this recession.

According to National Statistical Institute data, since the beginning of the recession more than 40,000 construction companies as well as 30,000 developers have gone bankrupt, as reflected in Table 4.

Table 4: Number of companies by economic sectors

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total	590.756	732.767	746.644	685.688	740.544	708.159	647.394	632.178	608.924	603.853
Industrial	242.310	244.359	245.588	243.729	230.301	220.935	214.992	206.585	200.835	198.004
Construction	448.446	488.408	501.056	441.959	510.243	487.224	432.402	425.593	408.089	405.849

Source: Organised from data by ASCER years (2006-2015)

As we can see, there is a sharp drop in the number of companies engaged in industrial activity. Some have had to cease trading, while others have had to relocate to other countries in order to reduce cost.

The ceramics industry in the District of Castellon has not been subject to relocation pressure, at least in part due to the very existence of the district, since being located within it is a competitive advantage for companies that would lose the contact and the proximity which lead to tacit learning and innovation, as shown previous sections.

The Spanish ceramics sector exports to 186 countries; as seen in the Table 4, exports have been increasing since 2011, amounting to €3,095 million in 2015, which accounts for 80% of global turnover, while the remaining 20% are sold domestically.

According to the information provided by ASCER, the most important destination countries are the ones shown in Table 5.

Table 5: Spanish exports by geographical areas and countries

Areas	Fee
Europe	44,60
	%
European Union – EU28	36,50
	%
o EU 15	30,50
	%
o Eurozone	24,60
	%
Eastern Europe	6,80%
Middle East	21,70
	%
America	12,70
	%
✓ North America	7,90%
✓ Central America	2,50%
✓ South America	2,20%
	25,40
Asia	%
✓ East and Southeast Asia	3,20%
	16,40
Africa	%
✓ Maghreb	10,70
	%
Oceania	0,90%

Source: Organised from data by ASCER (February 2015)

The main recipient countries are in Europe, primarily France and Germany; exports to these countries have increased by 4.5% and 1.4% compared to previous years. Markets where exports have reduced the most have been the Middle East and Asia, mostly due to the socio-political situation. Compared to previous years, there is an overall increase of 10.7%.

Table 6: Spanish exports by geographical areas and countries

Areas	2012	2013	2014	2015
Europe	1.029,10 €	1.041,50 €	1.078,40 €	1.088,7 0 €
✓ European Union – EU28	734,20 €	734,50 €	742,00 €	890,00 €
o EU 15	627,70 €	618,30 €	664,10 €	737,40 €
o Eurozone	544,00 €	530,00 €	552,20 €	601,70 €
✓ Este de Europa	262,20 €	277,40 €	248,60 €	167,00 €
Middle East	465,40 €	493,50 €	484,70 €	530,00 €
America	213,00 €	230,40 €	246,00 €	309,10 €
✓ North America	120,70 €	135,90 €	149,60 €	193,10 €
✓ Central America	37,80 €	41,40 €	45,50 €	61,30 €
✓ South America	54,60 €	53,10 €	51,00 €	54,60 €
Asia	536,50 €	574,90 €	565,50 €	620,30 €
✓ East and Southeast Asia	59,80 €	67,30 €	70,30 €	78,60 €
Africa	289,10 €	379,20 €	421,00 €	400,10 €
✓ Maghreb	190,20 €	263,30 €	284,10 €	261,00 €
Oceania	13,70 €	13,70 €	17,40 €	23,10 €

Source: Organised from data by ASCER (February, 2015 balance sheet)

According to the information provided by the *Asociación Nacional de Fabricantes de Fritas, Esmaltes y Colores Cerámicos* (ANFFECC), Spanish ceramic frits, glazes, inks and pigments producers are globally ahead of their competitors, thanks to their investment in research and development, the quality of their products, their design innovation and the quality of their customer service. Their prestige is recognised around the globe. Right now, more than 70% of the production is sold abroad, from Europe to Latin-America, Africa and the Middle and Far East.

In recent years, the companies of the ceramic sector have been investing heavily in machinery and capital goods, leading to an increasing degree of mechanization. As a result of this, and of the new technologies applied in the sector, the overall cost of labour has been seen a reduction over the past years. The constant evolution of the sector has led the companies to develop new production flows, new technologies, and especially to diversify their range of products. Given that the global market requires constant innovation regarding design and quality, the manufacturers in the Castellon Ceramics District are continuously improving their products, based on specialization

and innovative research and development (RDI), with the support of research institutions such as the Institute of Ceramic Technology (ITC).

A particularly research-intensive task is the improvement of technology for the manufacture of frits, enamels and ceramic colours. The companies working in this area therefore employ a considerable number of specialists who work in RDI, as innovation in this field can provide a distinctive feature to ceramic tiles and floors. In particular, the ongoing development of ceramic inks and the digital inkjet technology is the sector with the greatest potential for the future.

It can be said that the Spanish enamel industry emerged after civil war, in the 1940s, after separating from the tile factories and becoming more specialised. The companies in this sector are now joined together in the ANFFECC, an association open to all Spanish producers of ceramic frits, glazes and ceramic pigments. Its members are global suppliers to the tile industry, who use these products in the manufacturing of ceramic tiles.

Thanks to its ongoing commitment to innovation and the development of new products and applications, Spain's ceramic tile industry is one of the most competitive in the world. Below are just a few figures that give some idea of the sector's outstanding degree of competitiveness. Spain is the world's third biggest exporter of ceramic tiles, with international trade rates of between 15 and 18%. Average annual turnover of the sector over the last ten years stands at almost 3.5 billion Euros. A comparison of exports and imports reveals that the average coverage rate for the sector's trade balance over the last decade is more than 2,300%, placing it at the forefront of Spain's major industrial sectors.

Today, export accounts for around 65-70% of the sector's total sales, with the remaining 30-35% going to the Spanish market. Less than 10% of the ceramic tiles sold in Spain come from abroad, which goes to show that the domestic market, which is the world's biggest consumer of ceramic tiles per capita, prefers domestically produced tiles, be it for their quality and diversity, which far exceeds that of other countries, or be it because of lower transportation costs. Over the past ten years, sales on the domestic market have been over one billion Euros annually.

The Spanish ceramic tile sector owes its prime position on the global market to its firm commitment to RDI. This is due in particular to individual corporate investments and joint ventures in which organizations such as the Institute of Ceramic Technology (ITC) and ASCER play a key role. What is more, the sector is continually broadening its horizons, embarking on innovative research projects to develop new materials for

architecture and the living environment. This has resulted in a wealth of highly innovative and specific solutions combining technology and ceramic materials, based on principles such as sustainability, adaptable technology and personalization of the end product.

2.4. SPANISH CERAMIC TILE DISTRICT INNOVATION SYSTEM (DIS)

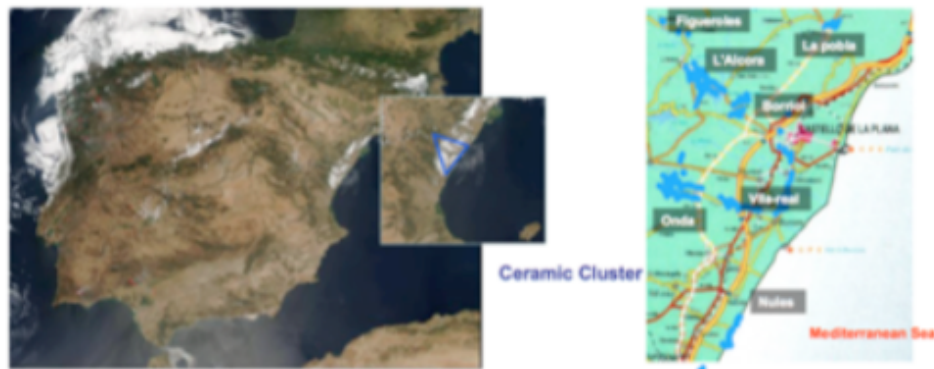
The ceramic tile industry includes the production of floor and wall ceramic tiles, decorative pieces, frit and glaze, machinery and equipment as well as other activities related to the ceramic process. It is an industry that is, all over the world, generally located in geographically concentrated industrial districts in countries such as China, Spain, Italy, Brazil and Portugal.

The Spanish ceramics district is located in the Region of Valencia that is situated on the eastern Mediterranean coast, constituting a part of the so-called Mediterranean Arch, an axis which has experienced one of the fastest economic growth rates in the European Union. In order to give more geographical information, the district is situated in the province of Castellon, specifically in the counties Plana Alta, Plana Baixa and L'Alcalaten. More than 90% of the Spanish ceramic tile production is concentrated there within a radius of no more than 20 kilometres (see figure 4 below). Spain is the leading European producer and the second worldwide, outperformed only by China, in terms of square metres of ceramic tiles produced. With respect to the international market share (21.2%) Spain ranks in second place after Italy (ASCER, 2015). Within the Castellon tile DIS, several institutions, firms and promoters offer their permanent support to the Spanish floor and wall ceramic tiles industry (Molina-Morales, 2002). In figure 5 the participants of the sector are shown, inside their own environment, following the model developed in studies analysing the Valencian Innovation System (Fernández and CONESA, 1996). Like in any system, the interrelation and cooperation between and within the different elements of the different environments is considered to be of critical relevance for innovation processes. Therefore, the Castellon tile DSI will be defined for the grouping of the elements in their environments and, in particular, for the relationships of the elements of a same environment and with elements of different ones. The productive environment of the DIS includes not only the floor and wall ceramic tiles producers, but also the producers of special pieces, as well as a range of producers of semi-finished products such as unglazed tiles and atomized clay. The technological and advanced services environment of the DIS includes any institution able to offer and deliver technological knowledge that can be transformed into

innovations. This includes technologically new machinery, materials, counselling and services.

It is important to highlight that the elements of this environment are the nexus between the requirements of the productive environment and the potential capacities of the scientific environment.

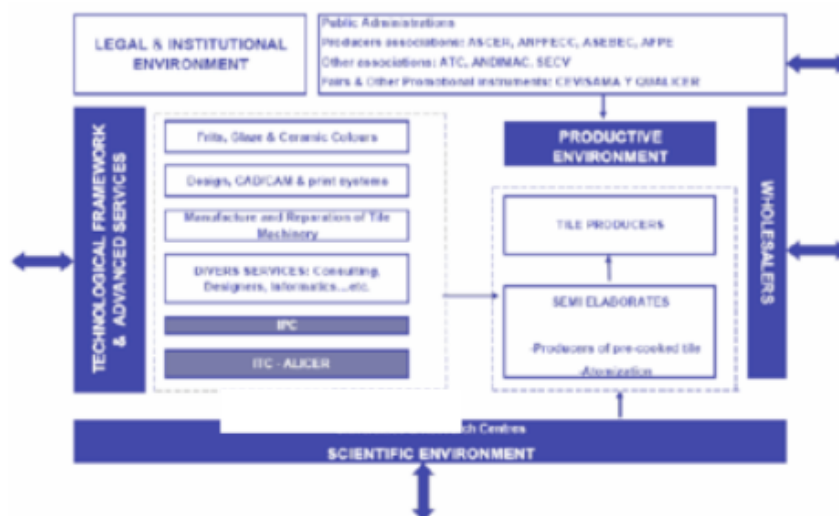
Figure 4: The Spanish Ceramics Cluster



Source: Adapted from Instituto Interuniversitario de Desarrollo Local, Economy Department. UJI

As is shown in figure 5, the agents in the technological and advanced services environment provide novel or improved technological solutions and disseminate them within the sector; examples are producers of frit, glaze and colour, of machinery, as well as providers of varied services, such as design, CAD/CAM, serigraphy, etc. (cf. Fernández I. and Conesa F., 1996)

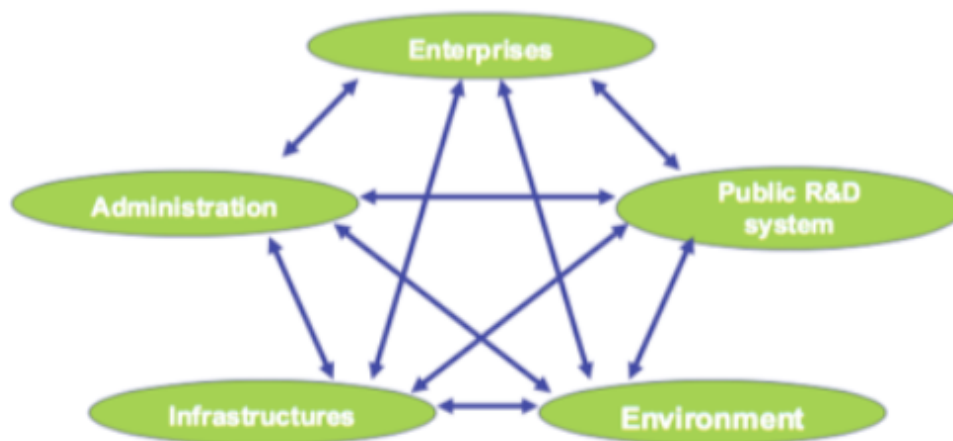
Figure 5. The District Innovation System (DIS) of ceramic tile in Castellon



Source: Adapted from Fernández and Conesa, 1996

The geographic area in which this cluster is located has, in the last ten years, become the area with the greatest economic growth of the entire Autonomous Region, mainly owing to the extraordinary dynamism of the cluster. This striking economic development has led to a substantial rise in family incomes and a sharp drop in unemployment. Other factors contributing to the success of the ceramic sector in Castellon include high sector cohesion, adaptability, i.e. the capacity of responding to changing demands, highly skilled human resources, an optimal use of technological resources, as well as the existence of public and private institutions supporting innovation within the sector. Innovation and technological development are the result of a complex set of relationships among actors in the system, which includes enterprises, universities, government and research institutes (Figure 6).

Fig.6. The District Innovation System (DIS) of tile in Castellon



Source: Adapted from Cluster building: the importance of regional networks,

EPP/ CoR Seminar – Open Days, Brussels, 9th October 2007

UNITS OF ANALYSIS

3. NETWORK ANALYSIS

3.1. TERMINOLOGY

A network consists of a set of nodes connected by a series of ties. The nodes can be individuals, teams, organisations, concepts, patents, etc.; in social networks,

the nodes represent individuals. Networks consisting of only one type of nodes are homogeneous, while networks with different types of nodes are heterogeneous. Ties linking pairs of nodes and can be directed (i.e. unidirectional, as in giving advice to someone) or undirected (with information flow in both directions); they can be dichotomous (presence or absence of a feature, as in whether two people are friends or not) or weighted (measured on a scale, as in strength of friendship). For a network analysis, it is fundamental that all ties are assigned a weight or value. Dichotomous relations have binary values (either the tie exists and is assigned a value of 1 or it doesn't, so it is assigned a value of 0). When we focus on a single node, we name that node the *ego* and call the set of nodes that ego has ties with *alters*. The data regarding ties between a set of nodes is referred to as relational data. Relational data can be pictured in a matrix or in graphic form. Table 7, below, summarises this terminology.

Network analysis is very different from other methodologies, though some aspects taken from other methods of analysis can be incorporated into network analysis. Actions are valid at the node-level, the group or local-level and at the network-level, and the selection of the appropriate measurements depends, in part, on what the network analyst intends to examine.

Table 7. Important terms and definitions

<i>Network Analysis Terms</i>	<i>Definitions</i>
Node	The basic element of a network
Tie / Edge	A set of two nodes. Ties can be dichotomous (unweighted) or weighted/valued, directed or not (undirected)
Directed Tie	An ordered set of two nodes, i.e., with an initial/source and a terminal/destination node
Network	A set of nodes connected by a set of ties
Valued Network	A network whose ties/edges are associated with a measure of magnitude or strength
Ego	A node which receives particular focus
Alters	The set of nodes that has ties with the ego but not including the ego itself
Network Size	The total number of nodes of a network
Relational data	The set of ties of a network

Source: Fabrice Coulon, Lund University, Sweden, 2005

3.2. STRUCTURE

Social network analysis departs from the premise that a fundamental distinction can be drawn between information about the social actors on the one hand, and information about the social structures within which these players act on the other. According to Wellman (1988) “behavior is interpreted in terms of structural constraints on activity rather than in terms of inner forces within [actors].” (Wellman, 1988: 20). For some social network analysts (Doreian, 2001: 83), the “rather than” can be substituted by “in addition to.” In other words, social network analysts distinguish two perspectives: they either focus only on structure to interpret behaviour, or they focus on both structure and actor-diversity to understand behaviour. The nodes of the networks in their studies are often individuals or members of a social group.

The first approach deals with the relationships between network structure, i.e. a set of established ties linking the members of a population, e.g. that of a firm, a school, or a political organization, and the corresponding social structure, according to which differences between individuals can be determined on the basis of their membership in distinct social groups or roles. The social network is made up of a combination of network structure. Essentially, the primary aim of this approach is to extract information about socially separate groups from purely relational data, by measuring the social “distance” between nodes, or by grouping nodes in the network. According to this view, networks are the signature of social identity or role – the relational patterns between individuals reflect these individuals’ underlying preferences and characteristics (Watts, 2003: 48).

The second approach is of a more technical or mechanical type. The network is understood as a set of paths along which information spreads and power is exerted, and an individual’s position in the overall pattern of relations determines what data that actor has access to and whom they can command. A person’s social identity and role therefore depends not only on the group the individual belongs to, but also on that individual’s position inside the group. In a way similar to the first approach, a number of metrics, i.e. measures of social “distance”, are applied to quantify individuals’ network position in relation to others and to explain observable differences in individual performance (Watts, 2003: 48-49).

3.3. DESCRIPTIVE MEASURES

This part begins by briefly presenting the different measures that have been encountered while carrying out this study. Some or all of them are part of any network analysis and it is essential to appreciate what they are in order to understand this study. Therefore, a short explanation of each of these measures is included.

The four most significant concepts used in network analysis are network density, centrality, betweenness and centralization. These terms cover a number of indicators, each of which has advantages and disadvantages regarding its use. Moreover, there are four measures of network performance: robustness, efficiency, effectiveness and diversity. Whereas the first set of measures concerns structure, the second set concerns the dynamics and thus depends on a theory explaining why certain agents do certain things (e.g. access to information). Many of the definitions are adopted from Scott (2000) and Burt (1992).

3.3.1. NETWORK DENSITY

Density can be considered a measure of the connectedness within a network. It is defined as the existing number of ties contained in a network, expressed as a proportion of the maximum possible number of ties. Its value lies between 0 and 1.0. When density is close to 1.0, the network is said to be dense; the closer to 0, the sparser it is. When dealing with directed ties, the maximum possible number of pairs is used instead. The problem regarding the measurement of density is that it is sensitive to the number of network nodes, which means that it cannot be used to compare networks that vary significantly in size (Scott, 2000: 76).

3.3.2. CENTRALITY

The concept of centrality encompasses a local and a global level. The higher number of ties with other nodes, the more central a node is. Local centrality only takes into account direct ties (directly connected to that node) whereas global centrality also includes indirect ties (not directly connected to that node). For instance, in a network with a “star” structure, in which all nodes have ties with one central node, local centrality of the central node is equal to 1.0.

Whilst local centrality measures are expressed in terms of the number of nodes which a specific node is connected with, global centrality is expressed in terms of the distances between the various nodes. Two nodes are linked by a path if they are

connected by a series of distinct ties, and the number of ties is determines the length of this path (Scott, 2000: 86). The shortest path between any pair of nodes in a network is termed *geodesic*, like the shortest distance between two points on the surface of the earth. A node is globally central if it lies at short distance from a large number of other nodes. Such a node is said to be “close” to many of the other nodes in the network, which is why global centrality is also referred to as closeness.

Local and global centrality depends, among other things, on the size of the network, and therefore comparability is not given when networks differ significantly in size. There is, however, a relative measure of centrality in which the actual number of ties is related to the maximum number that the node can support.

3.3.3. BETWEENNESS

Betweenness develops the concept of centrality further. It measures to what extent a node lies “between” the other nodes within the network. This is important because a node with few ties may, nevertheless, play an important role as an intermediary and thus be very central to the network. The betweenness of a node reflects the extent to which an agent (represented by a node) can function as a broker or gatekeeper, giving him potential for control over others. Burt (1992) describes the same concept as “structural holes”; a structural hole exists where two nodes are connected at distance 2 but not at distance 1. Methodologically, betweenness is the most complex of the measures of centrality to calculate and it also has the same disadvantages as local and global centrality; however, it is intuitively meaningful.

3.3.4. CENTRALIZATION

Centralization provides a measure on the extent to which a whole network has a centralized structure. Whereas density describes the general level of connectedness in a network; centralization describes the extent to which this connectedness is organized around particular focal nodes. Centralization and density, therefore, are important complementary measures. The general procedure involved in any measure of network centralization is to look at the differences between centrality scores of the most central node and those of all other nodes. Centralization is then the ratio of the actual sum of differences to the maximum possible sum of differences (Scott, 2000: 90).

2.3.5. ROBUSTNESS

Social network analysts have highlighted that its robustness depends on the structure of a network. Robustness can be determined by examining how it becomes fragmented as an increasing fraction of nodes is removed. Robustness is measured based on the tendency of individuals in networks to form local groups or clusters of individuals with whom they share similar characteristics, i.e. clustering. For example, if individuals A, B, and C are all experts in a particular field of knowledge, and if A knows B and B knows C, then it is very probable that A knows C. The higher the clustering of individuals in a network, the more robust that network is; within a cluster where everyone knows each other, it is unlikely that a given person will serve as a unique keystone in the network, potentially destroying connectivity within the network by leaving.

2.3.6. EFFICIENCY

The efficiency of a network depends on how many nodes (individuals or firms) can instantly access instantly a large number of other nodes, such as sources of knowledge, through a relatively small number of ties. Burt (1992) calls these nodes non-redundant contacts. The more non-redundant contacts a network contains, the greater benefits, whereas a new redundant contact is of little use, which means that time and energy would be better spent developing new non-redundant contacts (Burt, 1992: 20). Social network analysts measure efficiency by the number of non-redundant contacts and the average number of ties an ego has to pass through in order to reach any alter; this number is the *average path length*. The shorter the average path length in comparison to the network size, and the lower the number of redundant contacts, the more efficient the network will be.

2.3.7. EFFECTIVENESS

While efficiency focuses on the reduction of effort spent on redundant contacts, for example by eliminating ties with redundant contacts, effectiveness is concerned with the cluster of nodes that can be reached through non-redundant contacts. Each cluster of contacts can be considered an independent source of information, and according to Burt (1992), a cluster around a non-redundant node, no matter how many members it has, only functions as one source of information because people connected to one another tend to have the same knowledge at approximately the same time. For example, network effectiveness is greater when the information benefit provided by multiple clusters of contacts is broader, thereby ensuring that the central node will

receive relevant information. Moreover, because non-redundant contacts are connected only via the central node, this node is unavoidably the first to become aware of new opportunities that arise from needs in one group, which could benefit from skills offered by another group (Burt, 1992: 23).

2.3.8. DIVERSITY

While efficiency is concerned with the number of (non-redundant) nodes that can be reached, the diversity of nodes, not to be confused with network heterogeneity explained above, is critical for performance; the nodes within a network should be diverse in nature, which also implies that the history of each individual node within the network is important. This aspect, which is a matter of intense discussion among social network analysts (Doreian, 2001: 83), lends itself to being explored in case studies (Yin, 2003). The starting point of this debate is Wellman (1988), who notes that “structural methods supplement and supplant individualistic methods” (Wellman 1988: 38), which seems to suggest that social scientists should preferably use network analysis according to the first strand of thought developed by social network analysts like Wellman, rather than actor-attribute-oriented accounts based on the diversity of individual nodes.

3.4. RESEARCH METHODOLOGY

For this research, it has used a sample of Spanish Industrial firms located in the Valencia Region. Therefore, the selection will include the companies located in Castellon. For this aim, it has been decided to use the analysis of individual networks.

Collecting data. In order to obtain a characterization of the belonging ANNFFEC (Spanish National Association of Manufacturers of Frits, Glazes and Ceramic Colours) companies, the identification drew on ANNFFEC database and also was set out use data from SPTO (Spanish Patent and Trademark Office). So forth for illustrate how the SNA technique could be used and to prove and understand the evidence about the behavioural relationship between actors within organization and sharing of knowledge as a solid indicator of innovation. The main objective is to understand how knowledge and innovation spread among the member organizations.

3.5. RESULTS

For this research, data from the companies belonging to the representative producers associations has been used. Therefore, the selection includes the companies located in Castellon that are associated with the ANFFECC, in order to obtain a characterisation of the companies. The sample is not representative, but based on the data provided by this association. Patents registered between 1989 and 2004 were selected for each of the companies examined.

The Patent Data information was obtained from the SPTO and further verified with Google Patent Search. For each company, a selection of patents was made, and a network of patent inventors was created.

Social network analysis (SNA) is an interdisciplinary methodology, developed by sociologists and researchers in social psychology in the 1960s and 1970s. Subsequently, these foundations were amended in collaboration with mathematics, statistics, and computing, which led to a rapid development of formal methods of analysis, making it an attractive tool for other disciplines like economics, marketing and industrial engineering (Scott, 2000). SNA is based on the premise that relationships among interacting units or nodes are significant. Examining and interpreting the links or relations between different nodes is a fundamental part of SNA (Scott, 2000).

For each of the companies (see Table 8), the patents were selected and a network of patents and inventors was created. For this purpose, the Social Network Analysis program UCInet, a software package for the analysis of social network data developed by Lin Freeman, Martin Everett and Steve Borgatti, was used.

UCInet is a software that it is used for many purpose, for instance, for mapping, for edit, and also to analyze social networks. It was developed by Lin Freeman, Martin Everett and Steve Borgatti. The analysis of Social Networks has irrupido in many social sciences in the last twenty years as a new tool of analysis of social reality. SNA methodology allows as to identify patterns of relationships than can be related to be a consequence of social mechanisms that can help us to identify better our research objectives and possible explanatory models. (Giuliani, 2007; Boschma and ter Wal, 2007; Morrison, 2008).

3.6. ANALYSIS OF RESULTS OF NETWORKS

First off all, the graphic representation of the networks, shown in Figures 7-10 below, was obtained.

From a counterfoil Authors X Patents in every company has been made counterfoil constructed Authors X Authors by UCINET (affiliations 2 mode has been transformed into affiliations 1 mode. For every company the density and / or the average degree have been calculated, as well as the number of components.

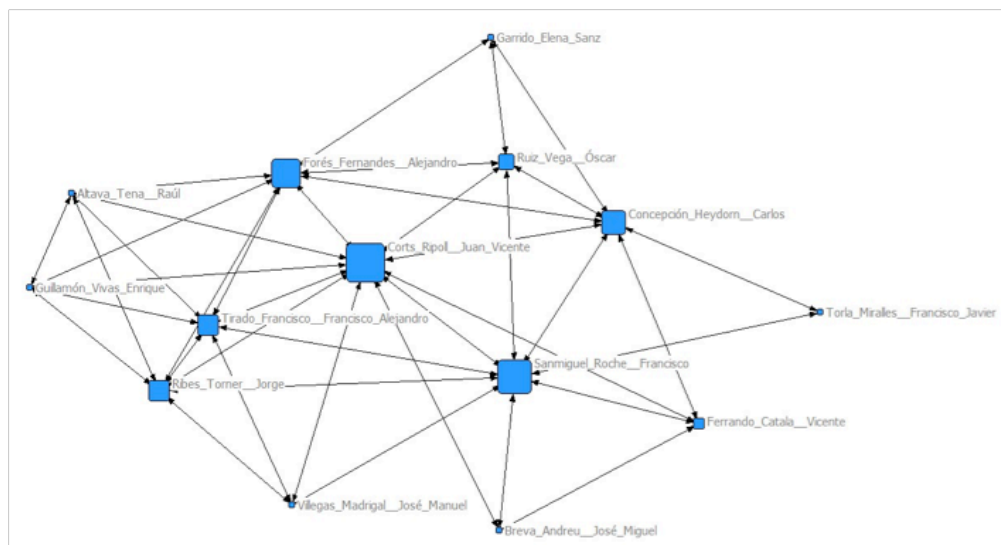
As a result: Fewer components and more density / average degree can be interpreted as a major internal cooperation in the company and major distribution of the knowledge.

Talking about the graphics, these networks generally have a picture of the relationships that exist within each company (network-company-group). At first glance we can see that there are individuals (inventors) more connected than others, that there are subgroups within each network, etc. We can set ideas about relationships, in particular about diffusion knowledge among actors.

For example, we may assume that people who are involved in more than one patent relate more to each other than not listed as connected. We can assume that: first, there are subgroups within our network as well as people with more connections than others, second, those who are in more of a patent, knew each other and share knowledge, third, it is more difficult to talk about sharing knowledge between the inventors appearing in various patents.

Figure 7, Graphic network of inventors, Torrecid S.A.

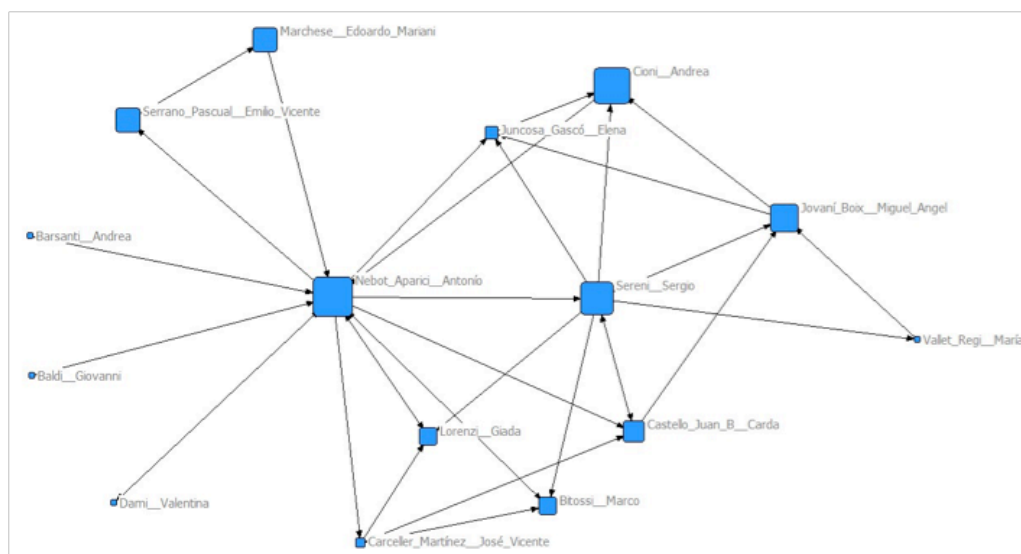
- 1 Avg Degree 5.714
- 3 Density 0.440
- 4 Components 1



(Own source, based on UCINET Program)

Figure 8, Graphic network of inventors, COLOROBBIA

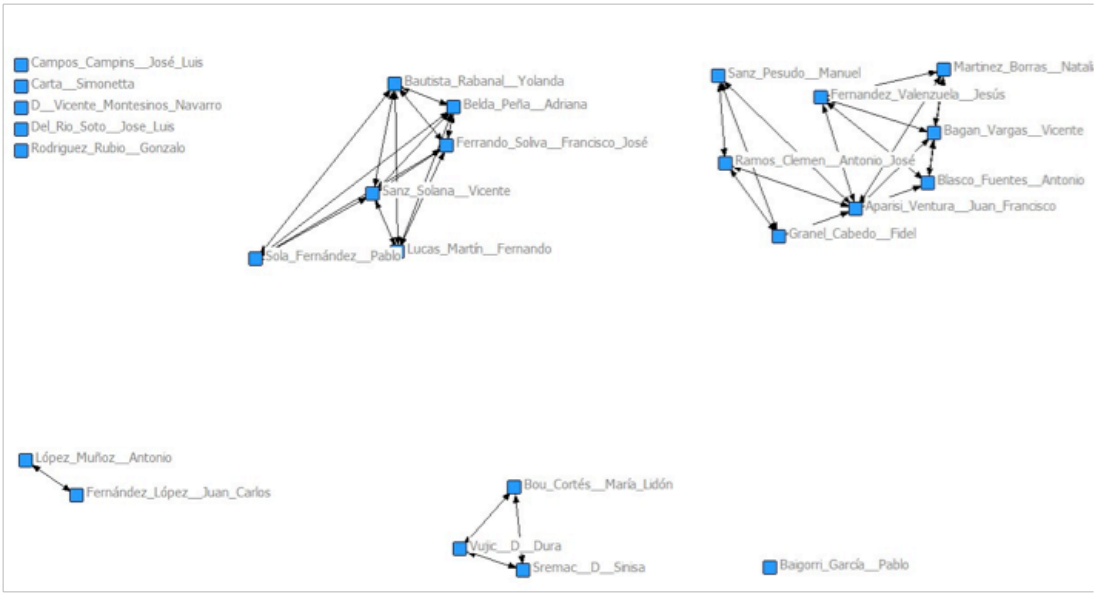
- 1 Avg Degree 2.333
- 3 Density 0.167
- 4 Components 1



(Own source, based on UCInet Program)

Figure 9, Graphic network of inventors, ESMALGLASS

- 1 Avg Degree 2.800
- 3 Density 0.117
- 4 Components 10



(Own source, based on UCInet Program)

Figure 10, Graphic network of inventors, FERROSPAIN

- 1 Avg Degree 1.167
- 3 Density 0.233
- 4 Components 3



(Own SOURCE, based on UCInet Program)

The work presented here has certain limitations, as a company's creativity and innovation can also be reflected in ways other than the registration of patents for their products or services. However, for the sake of transparency and accountability, this study limits its analysis to patents as a reflection of a company's degree of innovation.

3.7. CONCLUSIONS

In this work, it has been attempted to answer some questions about social network analysis (SNA): What it is? How has it been used, in the analysis of innovation, to achieve the proposed aims? What is the purpose of carrying out such an analysis?

Social network analysis is a methodology, not a theory. In some ways, it is closely related to descriptive statistics, as measurements are based on the data gathered at node-level. As a result, dichotomous ties are easier to incorporate in the calculation, and directed ties are required in order to research any sort of flow (e.g. knowledge flow) taking place between the nodes. The main types of network nodes are organisations and patents, which make it possible to reveal features of the entire network, such as its degree of density and centralization.

There is no a clear relation between the average degree of the internal network and its innovation ranking (see table 11 in the Annex); however, there is a clear connection between the number of implied persons and the ranking of innovation, which seems to be logical. The most interesting finding is that there are two network structures that lead to almost the same result. The structure identified for the *Esmalglass Group*, with little internal cohesion but many patents, on the one hand, and

on the other hand the network structure of *Torrecid*, with a far greater degree of cohesion and many patents.

I consider that this work is a contribution to further our understanding of innovation and, as social networks have been shown to constitute an important factor in the generation of innovation. More specifically, it provides insights into how knowledge is shared and leads to innovation in the Valencian Community, by means of an analysis of social networks that has permitted us to determine the capacity of a network and of the all components that it consists of. Nevertheless, this work is limited due to the fact that it is a regional case study, and further research will be required to verify whether these findings can be generalised, ultimately leading to the formulation of specific recommendations regarding the promotion of innovation. Only with a profound understanding of the structure and features of the relevant social networks is it possible to implement improvements that will allow companies to draw the greatest benefit from this research.

The work presented here has certain limitations, as a company's creativity and innovation can also be reflected in ways other than the registration of patents for their products or services. However, for the sake of transparency and accountability, this study limits its analysis to patents as a reflection of a company's degree of innovation.

A. ANNEX

TABLE 8: Ceramics, evolution of the typology in Spain

	2000	2001	2002	2003	2004	2005	2006
Extruidos*	19.867	19.482	19.073	18.955	19.482	19.800	19.924
% sobre producción total	3,44	3,28	3,15	3,25	3,27	3,25	3,27
Gres Porcelánico*	32.264	39.716	48.187	59.527	73.964	94.675	113.534
% sobre producción total	5,58	6,69	7,96	10,2	12,42	15,54	18,66
Azulejos*	232.041	233.874	236.324	233.356	234.989	238.132	242.054
% sobre producción total	40,16	39,4	39,02	40	39,46	39,09	39,79
Pavimentos Esmaltado*	293.628	300.527	302.116	271.562	267.066	256.593	232.887
% sobre producción total	50,82	50,63	49,88	46,55	44,85	42,12	38,28

Source: D. Gabaldon et al., V., 47, 2, 57-80 (2008), based on ASCER, 2004 and 2008

TABLE 9: Frits, producers companies (2000-2002)

Empresa	2000	2001	2002
Ferro Italia	66,1	64,4	106,3
Colorobbia Italia	91	105,1	104
Johnson Matthey Italia	63,1	66,3	66,3
Cerdec Italia	66,1	59,2	n.d.
Smalticeram Unicer	33,8	38,1	43
Colorobbia	35,7	32	33,5
Colorveggia Reine	24,5	24,1	24,5
Esmalglass	18,8	18,4	19,1
Inco	13,5	13,6	18,5
Cover	19,7	18,6	16,3
Ramacolor	16,4	18,2	15,9
Intercolor	7,9	9,4	15,7
Sicer	14,2	13,6	15,2
Torreacid	10,4	12,4	13,5
Reimbold & Strick Italia	11,4	10,8	11,7
Vetriceramics	8,6	9,6	11,6
Cer.Ser	9,2	8,4	10
Coloritalia	9	7,5	9,8
Garcolor	8,5	7,3	8,1
Smaltitalia	8,7	8	7,5
Torriana	7,9	6,9	7,1
Def di Doni	7,7	7	n.d.
Smalti per Ceramiche S.P.A.	5,5	6,3	6,9
A.S.	8,1	6,2	n.d.
Eurocolor	3,8	3,9	4,5
Sicer Internacional	0	3,7	n.d.
Ceramvetro Gold	3,2	2,5	2,8
Fritta Italia	2	1,9	2,3
Vernis Italia	1,6	1,7	2,1
Decograf	1,3	1,6	1,6
Cerev	3	2,4	1,5
Mph	0,5	0,4	0,3
Total	581,2	589,5	n.d.

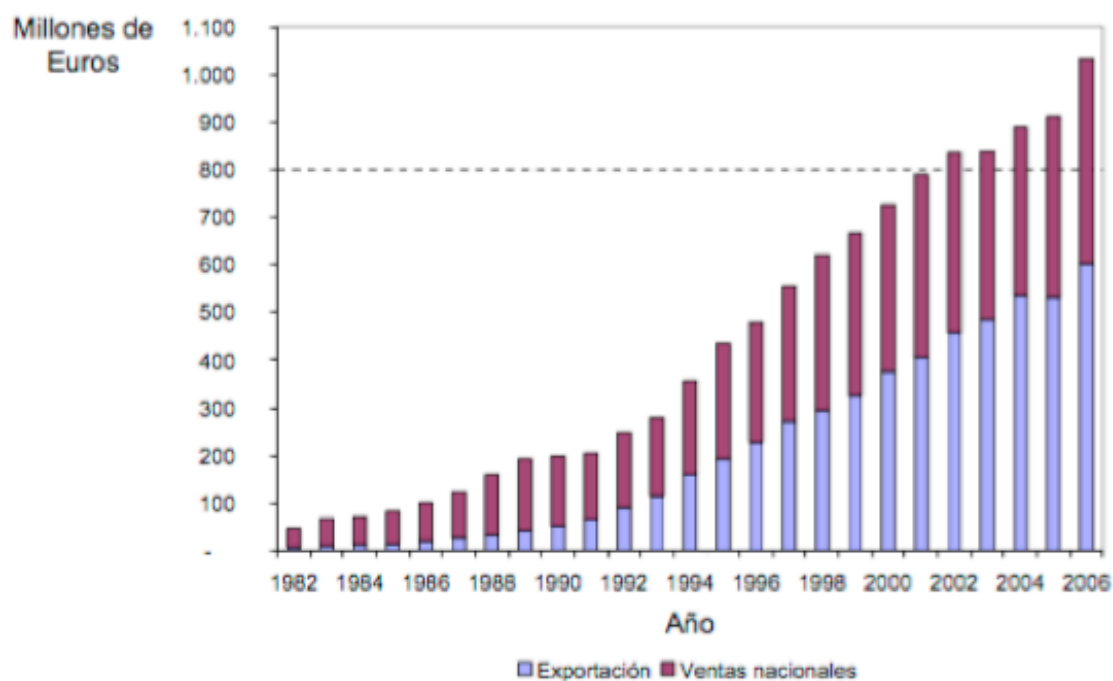
(Production in bln., euros.) Source adapted by Sezzi, 2003.

TABLE 10: ACTIONS CONTRACTED WITH THE INSTITUTE OF CERAMICS AND GLASS. Period 1999-2004.

Empresa	Acciones	Importe (€)	%
TORRECID, S.A.	7	807.760	71,0
ESMALTES, S.A.	1	228.393	20,1
FRITTA, S.L.	2	58.898	5,2
FERRO ENAMEL ESPAÑOLA, S.A.	3	41.879	3,7
Total	13	1.136.930	100

Source, D. Gabaldon et al., V., 47, 2, 57-80 (2008)

Figure 11: FRITS, SALES TRENDS (1982-2006).



(Source. ANFFECC internal document)

Table 11. Relation between the average degree of the internal network and the ranking innovation

Organizations	Ranking Innovation	Average network degree
Esmalglass Group	with 10 awards,	2,8
Torrecid Group, S.A.	with 7 awards,	5,74
Ferro Spain S.A.	with 2 awards,	1,16
Colorobbia S.A.	no found results	2, 33

Own source based on data from ALFA Gold Awards

Table 12. Ratio between number of published patents and enterprises within ANFFECC.

AL-FARBEN, S.A.(grupo TORRECID)	3 patents
CERFRIT, S.A.	no found results
COLOR ESMALT S.A.	no found results
Colores Cerámicos de Tortosa S.A.	no found results
COLORES CERAMICOS ELCOM S.L.	no found results
COLORES OLUCHA SL	no found results
COLOROBBIA ESPAÑA, S.A.	15 results
COLORONDA, S.L.	2 patents
ENDEKA CERAMICS GROUP HEAD OFFICE	no found results
ESMALDUR S.A.	no found results
ESMALGLASS S.A	13 results
Esmaltes S.A.	no found results
FERRO SPAIN S.A.	6 results
ITACA S.A.	1 results
KERAFRIT, S.A	4 results
TORRECID S.A.	24 results

(Own source, based on Spanish Patent and Trademark Organization data)

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