EXPLAINING TECHNOLOGICAL INNOVATION OF THE CLUSTERED FIRMS: INTERNAL AND RELATIONAL FACTORS

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ABSTRACT

The objective of this research is to investigate the combinations of internal and external factors that lead cluster companies to innovate. The study follows a complex causality approach using Qualitative Comparative Analysis (QCA) with a sample of 166 companies that belong to the ceramic tile cluster, differentiating between end-product firms and specialized industrial firms. The results show how the two groups benefit from different factors when it comes to technological innovations. End-product focused firms benefit from vertical relationships with suppliers and the interaction with supporting organizations like universities, among others. Specialized industrial firms benefit, above all, from a high R&D investment.

Key words

Technological innovation, vertical and horizontal relationships, clustered firms, fsQCA

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1. INTRODUCTION

Research on innovation in industrial clusters have been the focus of an extensive part of the academic literature, which describes these contexts as competitive and innovative industrial environments, often under a regional economy perspective (Porter, 1990, 1998). The influence of cluster external and internal firm factors on innovation has been one of the most devoted topics. However, previous efforts narrowly focus on the individual effects of such resources in isolation (Frenken, Cefis, and Stam, 2015; Hervas-Oliver, Sempere-Ripoll, Rojas Alvarado, and Estelles-Miguel, 2018; Pouder and St. John, 1996). The lack of understanding of the interaction mechanisms and conjoint effects of these well studied factors constitutes a significant gap in our view. In fact, the orchestration of these resources is more likely to broaden the options for clusters firms to innovate than concentrating on single effects (Chadwick, Super, and Kwon, 2015; Haddoud, Jones, and Newbery, 2020; Hughes, Hodgkinson, Elliott, and Hughes, 2018).

Earlier research has been quite extensive in analysing the individual net effect of several antecedents such as the role of institutions (McDonald, Tsagdis, and Huang, 2006; Suchman, 1995), vertical and horizontal relationships (Boari, Odorici, and Zamarian, 2003; Martínez-Cháfer, Molina-Morales, and Peiró-Palomino, 2018; Tomlinson, 2010), and internal resources such as absorptive capacity (Barney, 1991; Cohen and Levinthal, 1994; Zahra and George, 2002). In some cases, double interactions (Boari, Molina-Morales, and Martínez-Cháfer, 2017) and even triple interactions (Tomás-Miquel, Molina-Morales, and Expósito-Langa, 2019) have also been analysed despite the fact that their interpretation can sometimes be complex.

Notwithstanding the amount of research on the topic, conflicting results are common. In the case of internal resources, while some authors assume an intrinsic homogeneity in clusters firms (Pouder and St. John, 1996), others highlight the role of these types of resources on firms performance (Shipilov, 2009; Zaheer and Bell, 2005). The same applies to the relevance of external resources. For example, some studies point to the negative or non-relevant effects of external resources (Alberti, 2006; Glasmeier, 1991, 1994) while others contradict this view (Molina-Morales and Martínez-Cháfer, 2016; Suchman, 1995). As a consequence, the understanding of the effect of the aforementioned resources on innovation remains unclear.

In this research article we take a different perspective. Our work focuses on the simultaneous effects that external linkages and firms' capabilities have on technological innovations. Consequently, we intend to reconcile previous partial and contradictory contributions by considering the conjoint effect of both internal and external resources as drivers of cluster innovation. Indeed, there are probably multiple pathways for cluster firms to innovate, between which internal and external resources have asymmetrical roles in terms of necessity and sufficiency (Denk and Lehtinen, 2014; Fiss, 2007).

Hence, our accompanying research question is: ‘What configurations of horizontal and vertical interorganizational relationships, including supporting organizations, together with internal absorptive capacity are associated with high firm-level innovation?’ In order to do so, we follow a complex causality (Meyer, Tsui, and Hinings, 1993) approach using the Qualitative Comparative Analysis (QCA) technique (Ragin, 1987, 2008; Woodside, 2016) applied to a sample of 166 companies that belong to the Spanish ceramic tile cluster. Particularly, the ceramic cluster is dedicated to the manufacture of wall and floor tiles together with other related activities like machinery, technical assistance or the production of raw materials. This specific location has been identified previously in the literature as an appropriate and relevant environment to perform this type of research work (Boix and Galletto, 2006; Molina-Morales and Martínez-Cháfer, 2016; Ybarra, 1991).

Our research effort contributes to the existing literature about clusters. Indeed, the results obtained refer to the existence of multiple paths for cluster firms to innovate. In fact, this research moves away from the excessive homogeneity promulgated by the classic literature on clusters as reflected in the diversity of innovation strategies detected. As a consequence, our results support the importance of external and internal resources on innovation (Cassiman and Veugelers, 2006) together with the relevance of developing appropriate individual business strategies and maintaining optimal levels of internal capacities (Molina-Morales and Martínez-Fernández, 2009; Tallman, Jenkins, Henry, and Pinch, 2004). Consequently, this paper also provides food for thoughts for both policymakers and practitioners as our results can be inspiring for enhancing the innovation performance of cluster firms. Indeed, the representative cases associated to each path can be an interesting source of benchmarking that practitioners can use in order to enhance their innovation development strategies.

2. THEORETICAL BACKGROUND

Clusters have been widely considered as industrial agglomerations that are very well suited to be analysed under the network model as they are populated by firms, institutions, research centres, administration entities and labour resources in constant interaction (Boschma and Ter Wal, 2007; Branston, Rubini, Sugden, and Wilson, 2005; John and Pouder, 2006; van Dijk and Rabellotti, 2005). Figure 1 shows the theoretical model that we follow in this paper and serves as a reference to the theoretical background described in the following subsections.

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Figure 1

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2.1. External Sources of Knowledge

Regarding the relational activity and depending on the position that companies occupy in the cluster value system, we can differentiate between vertical and horizontal knowledge exchanges. These two modes of knowledge flows have been treated under different theoretical reasoning in the literature (Boari et al., 2017). Vertical relationships within a cluster value system involve the participation of customers and suppliers, which in turn affect firms' innovation and competitiveness (Dyer and Nobeoka, 2000; Lorenzoni and Lipparini, 1999; Von Hippel, 1977; Yli-Renko, Autio, and Sapienza, 2001).

Literature exploring the connection between firms' linkages and innovation contains a great deal of evidence about the role of vertical relationships, both upwards (suppliers) and downwards (customers), on firms' innovation capacity. Vertical knowledge acquisition through the relationships between companies and their customers can generate positive effects related to innovation. These effects include reductions in the number of stages of the innovative process or new innovative combinations, among others (Von Hippel, 1977; Yli-Renko et al., 2001). For instance, Dyer and Nobeoka (2000) found that, for Japanese manufacturers, heavy interaction with suppliers improved the development of products through coordination enhancement. In the same line, Lorenzoni and Lipparini (1999) found positive effects derived from the interaction with suppliers on firms' innovativeness.

More specifically and in the industrial cluster context, firms occupy different stages of the cluster value chain or *filieres* (Molina-Morales, Martínez-Cháfer, and Belso-Martínez, 2018). These shape a whole ecosystem of industrial customers and suppliers that exchange technical and organizational knowledge enabling interaction among companies that perform different industrial activities. Vertical relationships, involving customers and suppliers in clusters, have been identified by previous literature as relevant elements in accelerating the firm's access to knowledge and technology (Lorenzoni and Lipparini, 1999), improve innovation processes (Von Hippel, 1977; Yli-Renko et al., 2001) and enhance product development (Dyer and Nobeoka, 2000).

Following the aforementioned arguments about the benefits associated with the diversity of knowledge that characterizes vertical relationships and considering its combination with other kinds of exchanges and internal factors, we want to evaluate if companies that have vertical relationships, along with other exchanges and/or important internal capacities, enable the development of technological innovations in the organization.

Horizontal relationships, on the other hand, primarily involve relationships established with actors occupying the same positions in the cluster value system, which in turn means relational activity with competitors. Some authors (Tomlinson, 2010), consider horizontal relationships to be less important than vertical relationships. In fact, there are some potential limitations related to horizontal relationships. These limitations emanate from the fact that proximity facilitates imitation and prevents companies from establishing horizontal relationships as they tend to protect themselves from knowledge spillovers that may benefit their competitors. In the same line, the existing relational ecosystem involving firms and their suppliers, is also important. These interactions necessarily generate flows of knowledge that in some cases may end up in unintended imitations by competitors, so in this case vertical relationships might indirectly generate the same effects that characterize horizontal relationships (Boschma and Ter Wal, 2007).

However, rivalry plays a fundamental role in the dissemination of best practices and the enhancement of innovation within clusters. In fact, the main positive effects of clusters on the firms that populate them come from the association of proximity and rivalry. The mechanism through which proximity exerts an influence on rivalry relies on the ease with which firms can learn about competitors and identify the real depth of their knowledge base. In this context, rivalry is necessarily associated with a localized phenomenon where the closest competitors stand as such due to geographical proximity. But, at the same time, the amount of information available is increased, thus providing an incentive to get involved in the relationship (Boari et al., 2003). Relationships with competitors are another mechanism used by firms to access knowledge related to innovation. In consequence, we want to observe if companies that have horizontal relationships, along with other exchanges and/or important internal capacities, enable the development of technological innovations in the organization.

This study also analyses the conjoint impact of the involvement of supporting organizations together with other knowledge exchanges and/or internal capacities on firms' innovation performance. Regarding institutional support, beyond providing firms with services and benefits from other resources (Baum and Oliver, 1992), local supporting organizations can open the access to appealing knowledge bases that have the potential to generate and develop competitive capabilities and opportunities. In addition, previous research has provided evidence on this matter highlighting the impact of supporting organizations on firms' innovation in cluster contexts (Decarolis and Deeds, 1999; McEvily and Zaheer, 1999).

Industrial clusters, in addition to specialized companies, include a long list of local institutions and supporting organizations that act as bridges between external knowledge networks and the internal network of firms (McEvily and Zaheer, 1999). We can find some examples of these types of institutions in entities such as research centres, universities, training centres, business associations or centres that offer technical assistance, among others.

Supporting organizations interact with a large number of cluster companies and are therefore familiar with many of the business issues and organizational challenges. Based on this experience, local institutions, acting as intermediaries, build skills, routines, procedures and know-how in the cluster companies. Notably, local supporting institutions act as facilitators of business management innovation by providing access to valuable information and resources that allow companies to expand their knowledge bases and acquire new innovative capabilities (McEvily and Zaheer, 1999). These mechanisms, inherent to the intermediation processes, generate a reduction in search costs (Molina-Morales, 2005; Molina-Morales and Martínez-Cháfer, 2016) for the beneficiary companies. As a consequence, we can argue that the action of the local supporting organizations together with other types of exchanges and the appropriate level of internal capacities improves the innovative capabilities of cluster firms.

2.2. Internal Sources of Knowledge

Some academics highlight the relevance of internal firm characteristics that can act as enablers of the external potentialities (Shipilov, 2009; Zaheer and Bell, 2005). These characteristics include the size of the company, its age or market experience, its learning orientation or even attributes associated to the individual entrepreneurs (Mahto, McDowell, Kudlats, and Dunne, 2018). In particular, absorptive capacity (Cohen and Levinthal, 1990; Zahra and George, 2002) appears as a very important attribute that companies can deploy in order to either generate new knowledge internally or to take advantage of external flows containing novel information that leads to innovation (Boari et al., 2017; Expósito-Langa, Molina-Morales, and Capo-Vicedo, 2011).

Moreover, external and internal factors must be analysed together for a complete understanding of the determinants of clustered firms' performance (Zaheer and Bell, 2005). In fact, the two categories of factors (resources) can interact in different ways (Hitt, Bierman, Shimizu, and Kochhar, 2001; Park, Chen, and Gallagher, 2002). Consequently, we suggest that superior internal resources can allow better exploitation of external resources and enhance the performance of the firm.

According to previous research, particularly on SMEs, there are a number of internal firm attributes associated with innovation. For instance, Mahto et al. (2018) proposed internal factors like the learning orientation of the organizations and some characteristics of firm owners such as gender and satisfaction with their firm's past performance. There are some additional factors also considered in the literature like favourable entrepreneurship ecosystems (Liguori, Bendickson, Solomon, and McDowell, 2019), the intellectual capital (McDowell, Peake, Coder, and Harris, 2018) or entrepreneurial orientation (Peake, Barber III, McMilan, Bolton, and Coder, 2019). Furthermore, the actual size of the company or its market experience may also influence performance regarding innovation.

A positive relation between internal attributes, such as firms' capacities and firm innovation results, was supported by a large body of previous research. Among internal capacities related to innovation, absorptive capacity has received more attention by authors. According to Cohen and Levinthal (1990), a high absorptive capacity would develop higher organizational learning and better ability to apply external information and knowledge in organizations. It can be stated that absorptive capacity exerts a positive effect on innovation (Cassiman and Veugelers, 2006; Vega-Jurado, Gutiérrez-Gracia, Fernández-de-Lucio, and Manjarrés-Henríquez, 2008). In this same vein, other authors such as Zahra and George (2002) also highlight its benefits in terms of innovation and strategic flexibility. Furthermore, this list of positive effects also extends to the exploitation of external sources of knowledge (Cohen and Levinthal, 1994), the improvement of business performance (Barney, 1991; Wernerfelt, 1984) and the generation of competitive advantages (Teece, Pisano, and Shuen, 1997).

The absorption and exploitation of external knowledge resources coming from other companies or institutions is especially relevant for cluster firms (McCann and Folta, 2011). Individual firms have access to a series of capacities which are exclusive with respect to companies outside the cluster. The cluster creates mechanisms to identify changes and facilitate access to new ideas and opportunities. Moreover, in clusters the additive systemic absorptive capacity (Giuliani and Bell, 2005) that interacts with individual organization capacities amplifies the effect of these attributes on the access to and exploitation of the external resources.

Furthermore, in previous cluster research there is a common agreement in favour of a positive association between internal capacities and innovation. Belso-Martínez and Molina-Morales (2013) argued that, instead of continuous investment in internal resources, cluster firms should find an optimal balance since at certain levels costs would rise more than benefits, suggesting a curvilinear effect. In the same vein, Molina-Morales and Expósito-Langa (2011) indicate that the firm's cluster connectedness amplifies the curvilinear effect of the R&D effort on innovation. Thus, we can observe if companies that have a high absorptive capacity, along with other knowledge exchanges, enable the development of technological innovations in the organization.

2.3. Configurational model of external and internal sources and their effects on innovation

Considering all the theoretical background that we have previously exposed according to the type of approach that we have in this paper, in this section we develop the configurational model exposed in Figure 1. To this end, we have integrated the attributes referring to external and internal resources of the cluster companies so that we can better assess their joint effects. The model that we propose here follows the set-theoretic neo-configurational approach (Misangyi et al., 2017). We consider cases as combinations of conjoint attributes that are based on the principle that some variables can have a causal relation in some of the configurations but not in others (Fiss, 2007; Greckhamer and Gur, 2019; Meyer et al., 1993; Ragin, 2000).

The model is the result of the integration of the different interdependent attributes identified in the previous sections of the theoretical background taking into account the actual limitations of the number of cases under study (Marx and Dusa, 2011). As a final remark regarding our configurational model we need to consider that the inclusion of the individual attributes is largely supported by the literature. However, its intersection into knowledge configurations towards the development of technological innovations has not been sufficiently explored.

3. METHOD

Complex causality is the idea according to which a phenomenon is typically the result of the interaction among various forces (conjunction) and the result may be achieved from different configurations of elements (equifinality). This complexity framework also takes into consideration the fact that the interactions between the elements and an outcome in one case may not be the same in other cases (asymmetry) (Meyer et al., 1993). The qualitative Comparative Analysis offers researchers an approach that takes complex causality into account, thus providing a solid basis and correspondence between the results of the study and the reality they represent. fsQCA, the latest version of QCA, builds on Boolean logic to identify and test the combinations of conditions that are necessary or sufficient to cause an outcome of interest (Crilly, Zollo, and Hansen, 2012; Fiss, 2007, 2011; Ragin, 2008). Because of its applications in social science, fsQCA has received increasing attention from researchers from different areas such as management, innovation, marketing, etc. (Álvarez-Coque, Mas-Verdú, and Roig-Tierno, 2017; Gast et al., 2018; Roig-Tierno, Gonzalez-Cruz, and Llopis-Martinez, 2017). In fact, some scholars have referred to the newly acquired relevance of complex causality approaches as a neo-configurational perspective (Misangyi et al., 2017). Finally, and as Cooper and Glaesser (2016) point out, the fact that fsQCA was designed for small and medium N does not limit its applications to large sample data. Therefore, in this research effort we make use of this configurational approach by applying fsQCA.

3.1. Context of the research

This paper analyses a particular context, namely, the Spanish ceramic tile cluster located in the region of Valencia. This industrial concentration of ceramic companies produces 94% of the total Spanish production of wall and floor tiles (ASCER, 2016). Following the classification proposed by Brusco (1990), companies within industrial districts have three categories that correspond to the product they manufacture: End-product focused firms, stage-firms or specialised companies and integrated companies. The end-product focused firms are those that belong to the activity that defines the cluster, its end-product or service. The specialized companies are those firms that normally focus on one stage of production and act as manufacturers of supplies, components, inputs, raw materials, etc. The third group, integrated companies, are those firms that belong to a different industry from what defines the end-product product of the cluster. This is the case, for example, of companies dedicated to transport and financial services, among others. In sum, end-product focused firms, operate alongside other actors that complete the whole value system of the cluster. In the case of the ceramic industry, the cluster consists mainly of end-product (wall and floor tiles) focused firms that operate in constant interaction with other specialized companies such as: decorative pieces producers, chemical additives manufacturers, machinery and equipment producers, and ceramic glazes manufacturers. As already commented in the theoretical section, apart from companies we also find supporting organizations in the cluster. In this category we consider the following types of institutions and organizations: universities, research centres, policy agents, trade associations and so on. As reported by the main trade associations of the ceramic cluster, the business volume in 2016 was approximately €4800 million (ANFFECC, 2016; ASCER, 2016). In the last decade the cluster has introduced a major process innovation, the inkjet technology, that has reshaped the industry structure and leadership in some of the activities (Hervás-Oliver, Albors-Garrigos, Estelles-Miguel, and Boronat-Moll, 2017; Molina-Morales, Martínez-Cháfer, and Valiente-Bordanova, 2017).

3.2. Sample and Data

This study is based on primary data on the Spanish ceramic tile cluster collected between February and July 2011. In order to gather all the information needed we designed a questionnaire to be answered in a survey and complemented with interviews. The respondents were engineers in charge of the R&D departments, general managers or operations managers, depending on the availability. The questionnaires comprised several items and topics to be fulfilled with a special focus on knowledge exchange, social networks and innovation performance. The final sample of companies (166) was composed of the following: wall and floor tiles producers, manufacturers of glazes and frits, machinery and equipment, decorative pieces, atomized clay, and chemical additives (see Figure 2).

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Figure 2

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In order to perform our analysis, we distinguished between two categories of companies. On the one hand, we considered the end-product focused firms (83 firms) and, on the other, the rest of the sample, which comprises the specialized industrial activities (83 companies) such as the manufacture of glazes and frits, machinery and equipment, decorative pieces, atomized clay, and chemical additives. This subdivision of the sample is due to the fact that our analysis is focused, to some extent, on vertical and horizontal relationships. By subdividing the sample into these two categories, end-product focused firms and specialized manufacturers, we enhance the interpretation of the results concerning knowledge exchange. In fact, vertical relationships involve customers and suppliers which, in the case of the specialized companies, are both inside the cluster while end-product focused firms have their customers outside the cluster boundaries. This is a very relevant aspect for this research effort. The main benefit of these interactions with customers and suppliers relies on the direct feedback between actors. However, this feedback is very scarce for the end-product focused firms in the ceramic sector. Indeed, the tile distribution channels are composed of many intermediaries such as wholesalers and retailers. This increases the distance between the manufacturer and the final consumer, who in most cases remains unknown. Consequently, customer feedback for the end-product focused firms has many barriers that significantly reduce its value. Conversely, specialized firms obtain direct feedback from both customers and suppliers, which are basically all located in the same cluster area. As a result, splitting the sample into two allows us to obtain much richer insights from the results.

Table 1 shows the outcome and the conditions considered in this research effort along with their associated description and expected direction in the model. Additional information about how the casual conditions and the outcome were built can be found in the appendix.

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Table 1

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3.3. Calibration

Following Ragin (2008), the direct calibration method is employed. This method involves indicating whether a condition is fully in or fully out of the set and the point of maximum ambiguity. The software used for the calibration of the rest of the analysis is fsQCA 3.0 (Ragin and Davey, 2016). Table 2 shows the main descriptive statistics of the sample and the cut-off points established for the calibration. Because calibration is a critical step in QCA (Greckhamer et al., 2018), a full description of the calibration is presented in the appendix section.

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Table 2

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4. RESULTS

FsQCA explains complex causality in terms of necessity and sufficiency (Ragin, 2008). Thus, the first step consists in analysing whether there are necessary conditions for the outcome (Tec. Innovation) to take place; that is, whether the presence or absence of any of the conditions under study is necessary for the end-product focused firms or specialized companies to introduce technological innovations. The second step consists in analysing which conditions or patterns are sufficient for companies to perform technological innovations (Tec. Innovation).

4.1. Necessity analysis

Table 3 shows the necessity analysis, where (~) indicates the absence of the condition. For a condition to be considered necessary, its consistency must be higher than 0.9 (M. R. Schneider, Schulze-Bentrop, and Paunescu, 2010). As can be seen, the only condition that exceeds the 0.9 threshold is the absence of collaboration with competitors

(~Competitors). This situation occurs for both end-product focused firms and specialized companies. However, following Schneider and Wagemann (2012), in both cases the necessity of the absence of collaboration with competitors is a trivial condition because the RoN (Relevance of Necessity) values are 0.139 and 0.211 respectively.

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Table 3

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4.2. Sufficiency analysis

The step before the sufficiency analysis is to generate the truth table. The truth table contains all the possible logical combinations (Fiss, 2011; Ragin, 2008). Specifically, in our study, there are 256 possible configurations (2^8), where 8 is the number of conditions. The two truth tables (end-product focused firms and Specialized companies) have 218 and 223 logical remainders respectively.

The minimum consistency value selected for each solution is 0.806 and 0.823 respectively (end-product focused firms and specialized companies). These thresholds are greater than the minimum recommended value of 0.75 (Fiss, 2011; Ragin, 2008).

Table 4 and Table 6 show the sufficiency analysis for end-product focused firms and specialized companies respectively. Specifically, we used the notation proposed by Ragin (2008) and Fiss (2011), according to which black circles indicate the presence of a condition, white circles indicate the absence of the condition and blank spaces “don’t care”. Furthermore, big circles indicate core conditions and small circles indicate peripheral conditions.

Fiss (2011) points out that core conditions are essential for the outcome, whereas peripheral conditions are less important or even dispensable. The author indicates that core conditions are those that appear at the same time in the intermediate solution and in the most parsimonious solution.

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Table 4

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The sufficiency analysis for the end-product focused firms shows that there are seven causal configurations or recipes to achieve technological innovations in these companies. The total consistency is 0.82, which is above the 0.75 threshold (Fiss, 2011; Ragin, 2008).

The analysis suggests three clearly differentiated tendencies. On the one hand, configurations 1 and 6 refer to paths that rely exclusively on external sources of knowledge to develop technological innovations. Among these external sources of resources, we observe how vertical relationships with providers (path 1) and bonds with universities (path 6) are the core conditions to obtain the outcome. Most remarkably, we see how Path 1 is clearly dominant in comparison to the rest (raw/unique coverage = 0.51, 0.14). In fact, this particular path explains more than half of the innovation of this particular set of firms. Strong cases for this path are companies A and B that are very diverse in size and operating income but use the same type of collaboration with suppliers to develop their innovations (see table 5). These two paths (1 and 6) also show how horizontal relationships with competitors are absent as a peripheral condition in both cases. In the specific case of path 6, it can also be seen how the absence of the condition age is core together with the absence of links with buyers, in this last case as peripheral. Firms that belong to this option are characterized to be relatively young. Examples of these are Company G with a modest number of employees and total dependence on external resources for innovation or Company H with even less employees but the same lack of own R&D resources (see table 5). On the other hand, there are a series of paths that combine both sources of knowledge. This is the case of 3, 4, 5 and 7. Among these we see how the main internal resource that combines with other external factors is R&D investment, which appears as a core condition in paths 3 and 7. Other internal characteristics of the firm such as age and size are also present but always as peripheral. Regarding external resources, the most prominent kind of relationships are vertical (suppliers) and institutional (Technological centres and universities). Cases that represent paths 3, 4, 5 and 7 are described in table 5. Finally, there is a third kind of solution that involves just one path. This is the case of solution 2, which represents a case where companies rely solely on the combinations of internal factors to achieve the outcome. Again, the role of R&D investment, representing the firm's absorptive capacity, is more important than age (not present) or size (present as a peripheral condition). A representative case of this path is Company C, which is a well-known large company (more than 400 employees) whose main feature is having strong R&D activity both in process and product development (See table 5).

Our results display an interesting variety of configurations. The collection of paths shows how the joint action of different factors in various combinations can lead to the same outcome. This collection of paths also confirms all the expectations present in our theoretical background except the one related with the horizonal interactions as our results show how the relationships with competitors are not relevant in any of the paths obtained. In Table 5 we analyse each of the solutions obtained in more detail along with references that support them.

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Table 5

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Moving on to a more specific presentation of our solutions, we see how Path 1 is remarkably dominant in comparison to the rest (raw/unique coverage = 0.51, 0.14). The companies representing this particular configuration are well known companies leading the sector with robust experience and strong market share. This is very representative of the ceramic sector where leading companies that manufacture the end-product heavily rely on strong relationships with specialized suppliers in order to develop technological innovations.

In sum, end-product focused firms in the ceramic sector are characterized by a great dependency on specialized firms in terms of technological R&D (Gabaldón Estevan, Molina Morales, and Fernández de Lucio, 2008; Hervas-Oliver and Albors-Garrigos, 2014; Tortajada Esparza, Gabaldón Estevan, and Fernández de Lucio, 2008). In fact, this cluster has often been identified as a supplier-dominated case, according to the Pavitt taxonomy (Pavitt, 1984). In this vein, our results show this external dependency regarding technological innovation. Six out of seven configurations in the solution include external relationships either with suppliers or with supporting organizations. Nevertheless, we also see how some companies choose to intensify their efforts on R&D. This basically corresponds to the group of end-product focused firms that have a greater size and hence additional capacity to be more independent from external sources of knowledge and information regarding technological innovation.

In line with the above, there are also some remarkable features of the ceramic end-product focused firms that should be commented on. On the one hand, these companies rarely know or have strong links with the final customers that install their tiles. The normal distribution channel includes many intermediaries that have all the relationship with the consumers. Hence, their feedback regarding technological innovation loses a lot of importance. On the other hand, relationships with competitors are quite strong in the ceramic sector, but mainly concerning common business matters that are handled by the ASCER[1] trade association, which is made up of the majority of the end-product focused firms. As a consequence, relationships with competitors become quite irrelevant for the development of technological innovations in these firms.

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Table 6

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The analysis of sufficiency for specialized firms presents five configurations (table 6). In contrast with the results obtained for the end-product focused firms, specialized companies show a greater influence of the internal sources of information in most of the solutions. However, we still observe the importance of the combination of knowledge sources in several paths. There are two main groups of solutions. On the one hand, paths 1 and 2 represent combinations of factors based on internal characteristics. Like it happened with the end-product focused firms, path 1 is again the most dominant in comparison to the rest (raw/unique coverage = 0.58, 0.18) and it also explains more than half of the innovation of the specialized firms. A strong case that represents path 1 is company I that belongs to the frits and glazes subsector and is a clear technological leader. This particular company was born local decades ago and has developed a great international expansion through these years. Company I has more than 600 employees

[1] Asociación Española de Fabricantes de Azulejos y Pavimentos Cerámicos: www.ascer.es

and a great tradition on R&D efforts that have received a considerable number of awards and patents. In the case of path 2, a strong representative case is company L with just 50 employees approximately but decades of experience and internal strong R&D efforts (See table 7).

On the other hand, solutions 3, 4 and 5 show how combinations of external and internal sources can also lead to technological innovation. Finally, specialized firms do not show any combinations of factors that are exclusively dominated by external sources of knowledge and/or information. In Table 7 we show details of each individual path obtained and representative examples.

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Table 7

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Specialized firms in the ceramic sector are characterized by carrying out the bulk of the technological innovation development (Gabaldón Estevan et al., 2008; Hervas-Oliver and Albors-Garrigos, 2014; Molina-Morales and Martínez-Cháfer, 2016; Tortajada Esparza et al., 2008). This is mainly due to the importance of the machinery manufacturers and producers of frits and glazes. These specialized firms, in turn, provide end-product focused firms with their important technological developments as they are their main client. The configurations obtained in the sufficiency analysis clearly illustrate these dynamics. Four out of five configurations show the importance of R&D investment for specialized firms, although these efforts are also often accompanied by collaboration with the pool of relationships available in the clusters such as buyers or supporting institutions. Indeed, there is just one configuration that does not include the R&D efforts corresponding to the younger representatives of the sector that rely on the size and external collaborations in relation to technological innovation. This is the case of specialized firms dedicated mainly to the atomization of clays like the young company M, that does not perform internal R&D operations with around 100 employees and company N with the same characteristics as the previous one but with slightly higher operating income and even younger than the previous one. In the case of the specialized firms it is worth noting that customers (mainly end-product focused firms) play a relevant role (path 3) as they are the final implementers of the technological developments provided by specialized firms. Representatives of path 3 include Company J founded in the early nineties with a relatively low number of employees (around 30) dedicated to the machinery manufacturing and Company K which doubles the number of employees but as young as the previous one and also dedicated to machinery. Both companies J and K tailor their machinery solutions to the requirements of their main customers stablishing strong collaboration relationships with them. Finally, competition is very fierce among specialized firms in the ceramic sector, which explains their lack of relevance in every single configuration. However, there are also important trade associations among the specialized firms such as ASEBEC[2] and ANFFECC[3] but they are mainly focused on common business matters. In sum, like it happened in the case of the end-product focused firms, these results confirm the expectations regarding the conjoint positive role of internal and external sources of knowledge in the firms technological innovation with the sole exception of horizontal relationships.

[2] Asociacion Española de Fabricantes de Maquinaria y Bienes de Equipo para la Industria Cerámica. www.asebec.org
[3] Asociación Nacional de Fabricantes de Fritas, Esmaltes y Colores Cerámicos. www.anffecc.com

5. DISCUSSION AND CONCLUSIONS

In this paper we have tried to disentangle the combinations of internal and external factors that enable cluster firms to develop technological innovations. With this aim in mind we have applied a complex causality approach (Meyer et al., 1993) using the QCA technique (Garcia-Alvarez-Coque, Mas-Verdú, and Roig-Tierno, 2019; Ragin, 2008; Woodside, 2016) in a sample of 166 companies in the Spanish ceramic tile cluster. To better understand the conjoint effects of vertical and horizontal relationships, the influence of supporting organizations and the relevance of R&D investments, we divided our sample into two main groups that correspond to end-product focused firms and specialized industrial firms.

Our results show how both end-product focused firms and specialized companies benefit from different combinations of factors when it comes to technological innovations. First, both sets of firms are clearly dominated by their corresponding path 1 that explains more than half of the technological innovation of each set of firms. The analysis of both dominant recipes shows how end-product focused firms rely on specialized firms (providers) to develop their technological innovations while the specialized firms make a great internal R&D effort in order to do so. This result could be expected since specialized firms are the ones that are mainly responsible for technological advances in the cluster. In this vein, our result is aligned with some previous research (i.e. Tortajada Esparza et al., 2008) that reported that end-product focused firms (tile manufacturers) are more focused on market innovation in contrast to suppliers, which are more inclined to develop technological innovations. Furthermore, the ceramic cluster has been traditionally characterized as a supplier-dominated case (Gabaldón Estevan et al., 2008; Hervas-Oliver and Albors-Garrigos, 2014; Tortajada Esparza et al., 2008) under Pavitt's (1984) taxonomy. This last feature of the ceramic cluster can also be observed in our results and the aforementioned remarkable importance of the more dominant recipe on each set of firms (Path 1). Additionally, we also observe some interesting differences regarding the balance between external and internal factors depending on the type of company. While for the end-product focused firms the external resources show a great deal of importance, for specialized firms the main protagonists are internal firm features like the absorptive capacity, experience and size. Our results, in sum, are quite representative of the dynamics associated with the technological innovations development and knowledge exchanges in the ceramic cluster.

Second, and also regarding external sources of knowledge, it is notable that the difference in the types of buyers between the two groups seems to be relevant for technological innovation development. While end-product focused firms, whose main buyers are not members of the clusters, do not obtain any benefit, specialized firms, which have mainly end-product focused firms as their customers, obtain valuable results from these types of relationships, in particular, in sufficiency configurations. This fact seems to result from the inherent characteristics of the tile market. In the ceramic sector, the distribution channel separates the end customer from the manufacturer and therefore the value of its feedback is diluted.

Third, the companies in charge of manufacturing the end-product seem to be the ones that benefit most from the relationships established with universities and research centres. In fact, these two conditions appear in several of the configurations obtained in our sufficiency analysis. These results are in line with previous research (Molina-Morales and Mas-Verdu, 2008) emphasising the relevance of both the supporting and the research organizations in clusters. Conversely, the benefit for specialized firms is not so straightforward. In some configurations we observe how research centres can be beneficial while their absence is advisable in other configurations that consider the presence of suppliers. In relation with this specific question we must consider the different categories that populate the set of specialized firms. Indeed, the analysis of the companies that belong to the obtained paths show how firms dedicated to the frits and glazes activities are more reluctant to trust on external sources of knowledge that those dedicated to machinery development or atomization of clays. As commented in Table 7, this particularity stems from the lack of trust between frits and glazes companies and technological centres, which in turn derives from opportunistic behaviours in the past. Specialized firms, in any case, seem to be very sensitive to the R&D investment. Indeed, even though both typologies of cluster companies benefit from the high R&D investments, specialized companies seem to have a higher dependence on them as it appears as a core sufficiency condition in four out of five combinations and most notable on the dominant solution (path 1). Nevertheless, the same effect applies to end-product focused firms in three sufficiency configurations out of a total of seven identified in our model.

Finally, even though both groups of firms have diverse options in terms of conjunctural causation, the end-product focused firms show a little more versatility as they outnumber the path choice. This is perhaps due to the fact that end-product focused firms as a whole are more diverse regarding size and this enables different balances between external and internal factors.

Apart from the distinction between end-product and specialized firms, we also observe some other relevant questions in our results. First, the results regarding the role of horizontal relationships are quite clear. In fact, the absence or the negation of relationships with competitors are almost omnipresent conditions for both end-product focused firms and specialized companies. Our results are in line with part of the literature that considers these kinds of interactions to be less relevant than the vertical relationships (Tomlinson, 2010). Although previous research emphasized particularities of the competition in local and close contexts (Boari et al., 2003), there are still some interesting issues that have not been fully covered. In particular, those related to knowledge transfer between rivals or the learning effects of emulation or replication among neighbours. In any case, the ceramic sector shows an intense relational activity between competitors that is represented in the most popular business associations of the cluster: ASCER, ASEBEC and ANFFECC. However, these interactions are mainly focused on common business issues and that is a potential explanation of their lack of value when the outcome is technological innovation.

Second, our results also show interesting complementarities and/or substitution effects of some of the factors. This is the case of the relationships with suppliers and supporting institutions. While both of them seem to have a relevant role in combination with other conditions, they rarely combine together. This implies that when companies rely on suppliers, among other factors, they do not include supporting institutions and vice versa. In the case of the size of the company, this feature seems to be quite complementary to the R&D investments, on the one hand, but a substitute of vertical relationships, on the other. All of these particularities of our results are quite representative of the ceramic cluster reality as displayed in Tables 5 and 7. Finally, we also see a certain degree of substitution effect of the R&D investments and the collaboration with research centres that is probably based on the aforementioned latent conflicts between actors.

In sum, this research effort contributes to the existing literature about clusters and innovation by considering a conjoint effect of several external and internal resources already identified as innovation enablers. In this paper we aimed at reconciling previous partial and contradictory contributions on this matter. In this vein, our results clearly indicate the existence of multiple pathways for cluster firms to innovate, which go beyond individual net effects of already studied variables. In this sense, the results obtained confirm the majority of our expectations with the exemption of the external knowledge that comes from horizontal relationships. This particular source of external knowledge fails to provide the predicted positive effect together with other relevant sources of knowledge mainly due to the aforementioned reasons associated with the type of innovation under study. In conclusion, in spite of some previous incomplete analysis of these innovation factors, we support the importance of the role of internal and external relational resources for innovation (Cassiman and Veugelers, 2006) highlighting the potential that the conjoint effect has.

All things considered, this paper adds further evidence of the cluster diversity in terms of strategies to develop innovation, which is a long way from the excessive homogeneity proposed by some authors. Indeed, our results provide another supporting element to the advantages observed in territorial agglomerations from the point of view of individual business strategy and internal heterogeneity (Molina-Morales and Martínez-Fernández, 2009; Tallman et al., 2004).

In consequence, there are some important implications derived from this research effort that might be interesting for both policymakers and practitioners. On the one hand, the design of programmes of regional development may benefit from knowing the actual configurational options that companies have to innovate. Instead of focusing on individual or isolated factors, they can concentrate on particular recipes focusing on the complementarities and/or substitutions of fostering elements. Furthermore, in the hands of practitioners, these results can be inspiring as a means of finding out unknown alternatives for enhancing the innovation performance of firms. These alternatives can be outlined considering the illustrative examples of cases belonging to each solution (table

7). Indeed, these insights provide a benchmarking opportunity for managers that aim at enhancing their strategical options to innovate.

Specifically, in the case of the end-product focused firms, we observe how the strategies to develop technological innovations suit different typologies of companies. While the benefits of collaborating with specialized providers are quite popular regardless the internal resources, bigger companies are able to rely on internal R&D combining it or not with external resources. Finally, younger companies benefit from the collaboration with supporting institutions as an interesting option towards the development of technological innovations.

On the other hand, the specialized firms dedicated to the frits and glazes manufacturing rely intensively on R&D activities. However, other strategies are possible for this group of companies. This is the case of the machinery manufacturers, that according to the representative cases of some of the paths identified seem to opt for combining internal resources, such as R&D, with external relationships with customers. Lastly, and without considering R&D, large companies dedicated to atomization activities seem to optimize their external resources that come from the collaboration with supporting institutions.

Finally, this particular research work is not exempt of limitations. As a matter of fact, we purposefully limited our attention to the technological innovation of the companies. Yet, innovation has other interesting dimensions that could be considered such as marketing or organizational innovations, to name a few. Going beyond this particular focus on technological innovation, future research can also use a similar approach to shed some light on the configuration of knowledge sources that foster other specific kinds of innovations. Another contingency of this work stems from the fact that we are focusing on a very specific context such as the Spanish ceramic industry. Consequently, we have to be cautious about the generalization of the results as they cannot be extrapolated to other industrial contexts. Indeed, this also opens the door to a potential extension of this research to other industrial contexts and compare how the combinations of sources of knowledge vary among cluster that have diverse level of technological development or development trajectories (De Marchi, Gereffi, and Grandinetti, 2018; De Marchi and Grandinetti, 2014). Altogether, this study opens up new directions of research to explore new factors and combinations, as well as a different category of innovation outcomes in clusters.

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FIGURES AND TABLES

Figure 1. Theoretical Model

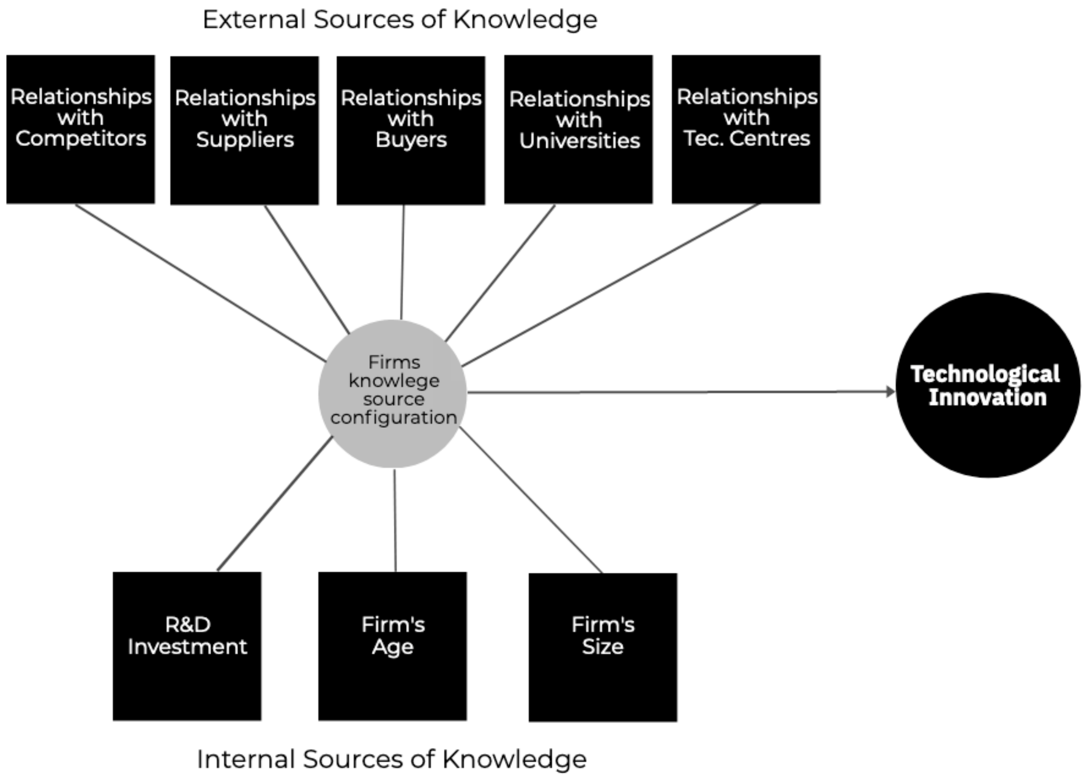

Figure 2. Sample

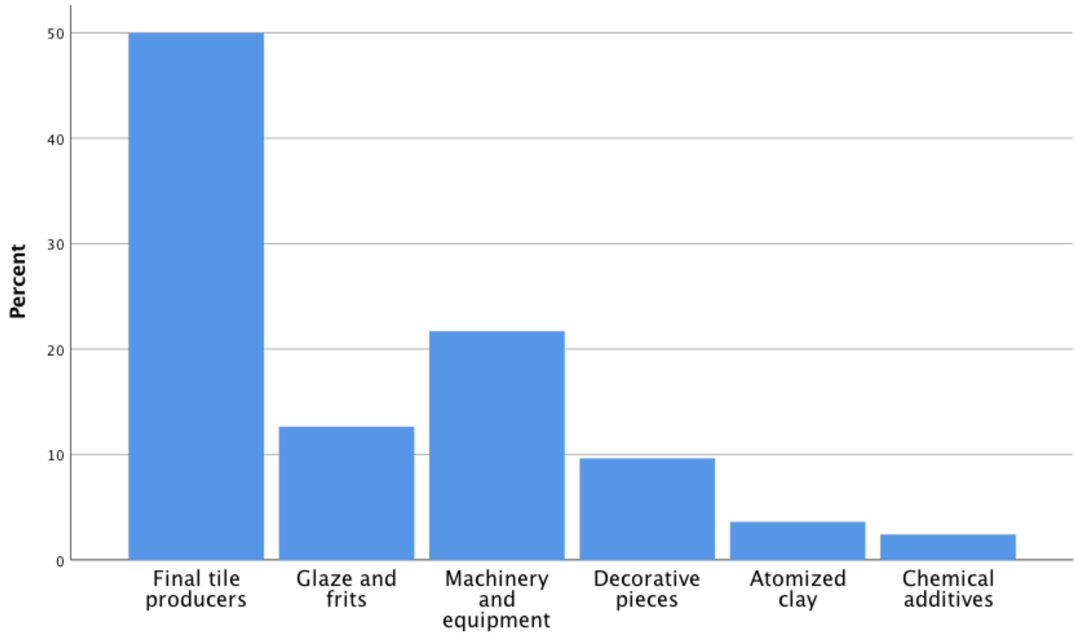

Table 1. Definition of the outcome and the conditions.

Type	Name and Code	Description	Relation outcome/condition	Direct Expectations
Outcome	Technological Innovation (Tec. Innovation)	Innovations of products or processes introduced by the companies		
Condition	Relationships with competitors (Competitors)	Existence of relationships with competitors reported by firms	(Boari et al., 2017, 2003; Tomlinson, 2010)	Absence
	Relationships with Universities (Rel. Universities)	Existence of relationships with universities reported by firms	(Capó-Vicedo, Molina-Morales, and Expósito-Langa, 2012; Ortega-Colomer, 2013)	Presence
	Relationships with Technological Centres (Tec. Centres)	Existence of relationships with technological centres reported by firms	(Bessant and Rush, 1995; Molina-Morales and Martínez-Cháfer, 2016)	Presence
	Relationships with buyers (Rel. Buyers)	Existence of relationships with customers reported by firms	(Bidault, Despres, and Butler, 1998; Gabaldón Estevan et al., 2008; Hervas-Oliver and Albors-Garrigos, 2014; Tortajada Esparza et al., 2008)	Presence for Specialized firms. Absence for end-product firms
	Relationships with suppliers (Rel. Suppliers)	Existence of relationships with suppliers reported by firms		Presence for end-product firms. Absence for Specialized firms
	Percentage of innovation expenditure during the previous year in relation to the company's turnover (R&D Investment)	Operationalization of the general absorptive capacity as the R&D investment performed by the firm	(Bilbao-Osorio and Rodríguez-Pose, 2004; Cerulli and Potì, 2012; Expósito-Langa et al., 2011)	Presence
	Firms' Age	Operationalization of the age of the company as the number of years that the firm has been operating. In other words, the experience of the company	(Hansen, 1992)	Presence
	Firms' Size	Calculated using the number of employees		Presence

Note: The scales used for calculating the variables are mostly based on the Spanish Community Innovation Survey (PITEC)

Table 2. Descriptive statistics and calibration points.

	Descriptive statistics			Calibration Anchors		
	Max	Min	Mean (S.D)	Fully-in	Crossover point	Fully-out
Tec. Innovation	5	0	3.01 (1.73)	5	2.5	1
Competitors	4	0	0.17 (0.60)	6	2	0
Rel. Universities	6	0	1.10 (1,53)	6	2	0
Tec. Centres	6	0	0.82 (1.45)	6	2	0
Rel. Buyers	4	0	0.80 (1.24)	6	2	0
Rel. Suppliers	6	0	1.24 (1.43)	6	2	0
R&D Investment	6	0	2.53 (1.53)	5	3	1
Age	63	3	26.99 (13.64)	50	25	10
Size	1028	1	108.63 (142.53)	250	50	10

Note: As in Crilly et al. (2012), values of 1.99 and 2.99 have been computed as 2 and 3 in the fsQCA software.

Table 3. Necessity analysis

	fs_TEC (End-product)		fs_TEC (Specialized)	
Conditions tested:	Consistency	Coverage	Consistency	Coverage
Competitors	0.146061	0.951960	0.096795	0.835822
~ Competitors	0.940085	0.620359	0.989510	0.579128
Rel. Universities	0.369060	0.841267	0.320402	0.652582
~ Rel. Universities	0.771674	0.627314	0.812280	0.609157
Tec. Centres	0.312337	0.853392	0.243563	0.687051
~ Tec. Centres	0.813574	0.624469	0.862536	0.586791
Rel. Buyers	0.271043	0.805993	0.316262	0.786051
~ Rel. Buyers	0.832962	0.625095	0.813956	0.572368
Rel. Suppliers	0.544044	0.836955	0.321100	0.805793
~ Rel. Suppliers	0.614958	0.603615	0.822834	0.577048
R&D Investment	0.452518	0.812563	0.637024	0.800436
~ R&D Investment	0.680956	0.612416	0.506296	0.492229
Age	0.644129	0.703136	0.463519	0.661868
~Age	0.498757	0.662590	0.724504	0.644516
Size	0.828061	0.765993	0.500375	0.717567
~Size	0.362486	0.616694	0.649462	0.576222

Note: (~) means absence of the condition.

Table 4. Sufficiency analysis. End-product focused firms.

	Solution						
	1	2	3	4	5	6	7
Competitors	○	○		○	○	○	○
Rel. Universities				●		⬤	●
Tec. Centres				⬤	⬤		⬤
Rel. Buyers		○	○		○	○	
Rel. Suppliers	⬤		⬤				
R&D Investment		⬤	⬤				⬤
Age				●	●	◯	
Size		●	●	●	●		●
Consistency	0.84	0.86	0.89	0.86	0.87	0.87	0.93
Raw Coverage	0.51	0.38	0.33	0.24	0.22	0.19	0.17
Unique Coverage	0.14	0.04	0.01	0.00	0.01	0.00	0.00
Overall Solution Consistency		**0.82**					
Overall Solution Coverage		**0.65**					

Note: As per Fiss (2011) black circles "●" indicate the presence of antecedent conditions. White circles "◯" indicate the absence or negation of antecedent conditions. Big circles indicate core conditions and small circles indicate peripheral conditions. The blank cells represent ambiguous conditions. Frequency threshold = 1; consistency threshold =. 806. Direct Expectations (0;1;1;0;1;1;1;1).

Table 5. Path analysis for end-product focused firms

Path	Presence of conditions	Absence of Conditions	Analysis	Representing companies	References
1	**SUPPLIERS**	*competitors*	The combination of these two factors leads to technological innovation and has the largest coverage among the solutions obtained. It represents one of the most popular mechanisms among end-product firms to innovate in the ceramic sector regardless the size. A great portion of the tile producers do not invest in R&D and rely on providers to implement the technological developments that these third parties develop.	Strong cases that represent this path are: Company A, a clear leader of the sector with a renowned brand and top five in operating income, but also Company B a small company of just 24 employees at the bottom end of the operation income ranking.	(Gabaldón, Molina-Morales, and Fernández de Lúcio, 2010; Hervas-Oliver and Albors-Garrigos, 2014; Tortajada Esparza et al., 2008)
2	**R&D** **size**	*competitors* *buyers*	In the ceramic sector, there are a number of end-product firms that make their own efforts in R&D. This is a path where the firms do not rely on external sources. Normally this is the case of big companies that possess enough resources to do so. This is corroborated with the presence of size as a peripheral condition in the solution.	A representative example of this case is Company C, a known large company in the ceramic sector that has R&D activity both in process and product development and more than 400 employees.	(Bilbao-Osorio and Rodríguez-Pose, 2004; Cerulli and Potì, 2012; Expósito-Langa et al., 2011)
3	**SUPPLIERS** **R&D** **size**	*buyers*	This case represents an option where the companies combine their internal strengths with the external resources of knowledge coming from suppliers. Again, it is representative of the typical ceramic cluster dynamics, highlighting the importance of the externalities together with the necessary internal efforts in order to take real advantage of them.	Company D, an international subsidiary of a world leader in the ceramic industry with great tradition on R&D development and supplier partnerships with more than 1000 employees.	(Fernandez de Lucio, Gabaldón, and Gómez, 2005; Hansen, 1992; Tortajada Esparza et al., 2008)
4	**TEC. CENTRES** **universities** **age** **size**	*competitors*	This path is also representative of the conjoint effect of internal and external sources of knowledge in order to develop technological innovations. In this particular case, size and age complement the knowledge coming from supporting institutions with technological centres as the prominent source among them.	Sector leaders like company F with around 500 employees and a clear tradition of collaboration with institutions along with company D which also is strong in developing bonds with institutions to carry out important innovation projects. Both firms have a history of technological innovation awards in the annual fair Cevisama.	(Bessant and Rush, 1995; Molina-Morales and Martínez-Cháfer, 2016)

Table 5 (Continuation). Path analysis for end-product focused firms

Path	Presence of conditions	Absence of Conditions	Analysis	Representing companies	References
5	**TEC. CENTRES** **age** **size**	*competitors* *buyers*	Path 5 is another example where the combination of internal and external factors matters. In this case the institutional framework is the protagonist and it obtains the complement of some internal features in this particular path.	A good sample of historical companies in the sector like company E with more than 700 employees and a clear tradition of collaboration with institutions along with company D which also is strong in developing bonds with institutions to carry out important innovation projects. Both firms have more than 50 years of age.	(Bessant and Rush, 1995; Molina-Morales and Martínez-Cháfer, 2016)
6	**UNIVERSITIES**	*AGE* *competitors* *buyers*	It represents an alternative to path 1 in the sense that end-product firms without internal resources can rely on external sources to enhance their innovation performance. In this particular solution the institutional framework is the element chosen by end-product firms. The absent factors also confirm the lack of relevance of the relationships with buyers for end-product firms as set out in the methods section.	Firms that belong to this option are characterized to be a rather younger group of medium sized end-product firms in terms of income and / or employees. Examples of these are Company G with around 100 employees and total dependence on external resources for innovation or Company H with around 30 employees and the same lack of own R&D resources.	(Capó-Vicedo, Molina-Morales, and Capó, 2013; Capó i Vicedo and Capó-Vicedo, 2011; Molina-Morales and Martínez-Cháfer, 2016; Ortega-Colomer, 2013)
7	**TEC. CENTRES** **R&D** **universities** **size**	*competitors*	Another version of the conjoint effect of internal and external factors where both supporting organizations are involved. As happens in every case where the R&D factor is present, the size of the firm is a peripheral condition. In this particular solution, the firms also combine these internal characteristics with external institutional knowledge.	Representative examples of these path are again big companies such as Companies F, A, D or E where the size allows them to implement own R&D efforts and combine them with external collaborations.	(Bessant and Rush, 1995; Bilbao-Osorio and Rodríguez-Pose, 2004; Molina-Morales and Martínez-Cháfer, 2016)

Note: Letters A to H are pseudonyms used to describe the representative companies in the configurational paths.

Table 6. Sufficiency analysis. Specialized firms.

	Solution				
	1	2	3	4	5
Competitors	◦	◦	◦	◦	◦
Rel. Universities		○		•	•
Tec. Centres		○	○	●	
Rel. Buyers			•		
Rel. Suppliers	○				
R&D Investment	●	●	●		●
Age		•	○	○	●
Size				●	•
Consistency	0.80	0.87	0.90	0.87	0.85
Raw Coverage	0.58	0.35	0.20	0.15	0.13
Unique Coverage	0.18	0.00	0.02	0.04	0.00
Overall Solution Consistency		**0.81**			
Overall Solution Coverage		**0.65**			

Note: As per Fiss (2011) black circles "●" indicate the presence of antecedent conditions. White circles "○" indicate the absence or negation of antecedent conditions. Big circles indicate core conditions and small circles indicate peripheral conditions. The blank cells represent ambiguous conditions. Frequency threshold = 1; consistency threshold = .823. Direct Expectations (0;1;1;1;0;1;1;1).

Table 7. Path analysis for specialized firms

Path	Present conditions	Absent Conditions	Analysis	Representing companies	References
1	**R&D**	*SUPPLIERS* *competitors*	It is the path with the greatest coverage. Indeed, this solution represents the intrinsic dynamics of the ceramic sector very well. Specialized firms are highly reliant on internal R&D efforts as they have been recognized as carrying the weight of the sector's innovation.	A representative example of this path is company I which is a leader in the frits and glazes sector. Born local with an international expansion. More than 600 employees and a great tradition on R&D efforts that have received a considerable number of awards and patents.	(Gabaldón et al., 2010; Hervas-Oliver and Albors-Garrigos, 2014; Tortajada Esparza et al., 2008)
2	**R&D** **age**	*UNIVERSITIES* *TEC. CENTRES* *competitors*	In line with path 1 this is another representation of the internal focus of specialized firms. In this particular case, the solution emphasizes the combinations of those factors with the absence of external collaborations with supporting organizations. This is also quite representative of this particular cluster dynamics. In fact, an opportunistic behavior by researchers of a technological centre that occurred in the late 1990s did a lot of damage to the trust that specialized firms had in these entities. This solution is a representation of that latent conflict.	Specialized historical firms dedicated to the frits and enamel subsector. Here we have cases like company I commented above along with smaller frit and glazes producers like company L with just 50 employees approx. but decades of experience and internal strong R&D efforts.	(Gabaldón et al., 2010; Hansen, 1992; Hervas-Oliver and Albors-Garrigos, 2014; Tortajada Esparza et al., 2008)
3	**R&D** **buyers**	*TEC. CENTRES* *AGE* *competitors*	This solution shows the combination intensive R&D efforts together with the complement of feedback coming from buyers. These buyers are mainly end-product firms, a result that also represents a real cluster dynamic for some of its companies. Here we also observe how the absence of experience and relationships with technological centres are also core conditions. This indicates that younger specialized companies rely on buyers more than on institutional entities to develop technological innovations.	Representatives of this path are Company J founded in the early nineties with a relatively low number of employees (around 30) dedicated to machinery manufacturing and Company K which doubles the number of employees but as young as the previous one and also dedicated to machinery development.	(Bidault et al., 1998; Gabaldón et al., 2010; Hervas-Oliver and Albors-Garrigos, 2014; Tortajada Esparza et al., 2008)

Table 7 (continuation). Path analysis for specialized firms

Path	Present conditions	Absent Conditions	Analysis	Representing companies	References
4	**TEC. CENTRES** **SIZE** **universities**	*AGE* *competitors*	This solution shows how younger companies are less affected by historical conflicts and are more likely to rely on external sources coming from supporting institutions. However, the presence of internal factors such as size is still in the combination of elements as a core condition.	Big specialized firms dedicated to the atomization of clays and other activities not related with machinery or frits and glazes. Examples of these are company M, dedicated to clay atomization an activity that does not perform internal R&D operations with around 100 employees and young in age, and company N with the same characteristics as the previous one but with slightly higher operating income and ten years less of age.	(Bessant and Rush, 1995; Molina-Morales and Martínez-Cháfer, 2016)
5	**R&D** **AGE** **size** **universities**	*competitors*	This last path shows a great deal of significance coming from internal features such as the R&D Investment and experience, both complemented by the firm's size. However, this solution still shows some hints of external collaboration in the mix of factors given the fact that universities have a peripheral presence.	Small group of specialized historical firms dedicated to the frits and enamel subsector. This group of firms represents the companies that still trust in the collaboration with institutions and where not been negatively affected by past conflicts and opportunistic behaviours. This is the case of company O, a leader of the corresponding subsector with more than 500 employees and several patents and awards related to R&D ceramic developments	(Gabaldón et al., 2010; Hansen, 1992; Hervas-Oliver and Albors-Garrigos, 2014; Tortajada Esparza et al., 2008)

Note: Letters I to O are pseudonyms used to describe the representative companies in the configurational paths.

APPENDIX

to

EXPLAINING TECHNOLOGICAL INNOVATION OF THE CLUSTERED FIRMS: INTERNAL AND RELATIONAL FACTORS

In the following section of the appendix we establish how the outcome and casual conditions were done and calibrated.

OPERATIONALIZATION AND CALIBRATION of the OUTCOME

The outcome, *Technological Innovation*, was measured using a question with 5 dichotomous items based on the Spanish Community Innovation Survey (PITEC).

During the past three years, has your company introduced any of these innovations? (YES / NO)

1. *New or improved goods and services, already available in the competitors*
2. *New or improved goods and services, before the competitors*
3. *New or significantly improved methods of manufacturing for producing goods or services*
4. *New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services*
5. *New or significantly improved activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing.*

We used an addition method to perform the construct (*Technological Innovation)*. So, the maximum value is 5 (if the firm answers "yes" to the five items) and the minimum is 0 (if the firm answers "no" to the five items)

The method used to calibrate the raw data into set data was the direct method proposed by Ragin (2008). As Ragin (2000, p.7) indicated, the calibration must be a "fine-grained transformation based on the previous theoretical-knowledge". However, as per Greckhamer et al. (2018) postulated, if there is no previous theoretical-knowledge, a way to establish the thresholds to calibrate could be to use directly the properties of the study's sample.

In this study, we follow Schneider et al. (2010), the authors use the 2 extreme values as fully in and fully out and the average value between them as cross over point.

In our study, the selected values were Fully In (5), Cross over point (2.5) and Fully Out (1).

OPERATIONALIZATION AND CALIBRATION of the CASUAL CONDITIONS

The casual conditions related with the ***relation between the Innovation agent*** were done in the equal way (*relation with competitors, universities, technological centres, clients and suppliers*).

Based again on the PITEC survey, the following binary questions were done:

Has your company established any type of relationship with any of the following agents during the last three years?

The options proposed were the following: cooperation in R&D or contract R&D services.

So, the theoretical value was 2 (if the firm answers "yes" to both questions) or 0 (if the firm answers "yes" to both questions).

After that, another question related to the frequency of the collaboration was used.

Frequency level of the relationship (1 = Low; 2 = Medium; 3 = High)

Finally, the construct relationship was perform multiplying the value of collaboration and the frequency of the collaboration.

For example, if a firm cooperates in R&D activities with a University (1), have some R&D contract (1) and the degree of the relation is medium (2) the value of the construct is 4.

*Relation with Universities = (1+1) * 2 = 4*

Considering the maximum and the minimum theoretical values 6 and 0 respectively and there is no previous theoretical-knowledge (the same reasoning provided with the outcome) the thresholds are as follows: Fully In (6), Cross over point (2) and Fully Out (0). So, the calibration is: value 6 means highly intensive relation, value 2 means relation and 0 means no relation.

Finally, casual condition ***R&D investment***, representing the effort (and the capacity) of the firms regarding innovation. The condition was measured using the following scale based on the PITEC Survey:

Percentage that represents the total expenses of innovation activities carried out during the last year on the turnover of your company

Where:

1 = 0%;

2 = 0-0.5%;

3 = 0.5-1%;

4 = 1-3%;

5 = 3-10%

and 6 > = 10%

This condition was calibrated using the following anchors: fully in = 5; cross over point = 3 and fully out = 1. The meaning of the calibration is that 5 means highly investment in R&D activities, 3 means investment in R&D activities, and 1 no effort in R&D activities.

The condition "***age***" reflects the number of the years that the firm is operating. In other words, the experience of the company. The direct method of calibration was used in order to transform the raw data into a set.

The threshold for fully in was 50 years, the cross over point was 25 and the fully out was 10 years. These three threshold values are based on the historical development of the ceramic cluster (Nadal J., 2003; Budí-Orduña, 2008)

The condition "***size***" is calculated using the number of the employees. In this case, the direct method of calibration was also used in order to transform the raw data into a set.

The threshold for fully in was 250 employees, the cross over point was 50 and the fully out was 10 employees. These three anchors are based in the general classification of European Commission (2015) (medium-sized, small and micro).

ABSENCE OF THE TEC. INNOVATION

Analysis of Necessary Conditions

	~ TEC (Final)		~TEC (Specialized)	
	Consistency	Coverage	Consistency	Coverage
Competitors	0.139824	0.609500	0.127747	0.909416
~ Competitors	0.988979	0.436488	0.976938	0.471382
Rel. Universities	0.314539	0.479535	0.367840	0.617661
~ Rel. Universities	0.895883	0.487092	0.793100	0.490346
Tec. Centres	0.268486	0.490631	0.263264	0.612237
~ Tec. Centres	0.919772	0.472175	0.865432	0.485389
Rel. Clients	0.253051	0.503281	0.262363	0.537598
~ Rel. Clients	0.902453	0.452954	0.895587	0.519199
Rel. Suppliers	0.396200	0.407653	0.268459	0.555407
~ Rel. Suppliers	0.841536	0.552454	0.906129	0.523891
R&D Investment	0.355639	0.427109	0.366490	0.379650
~ R&D Investment	0.843928	0.507623	0.807355	0.647110
Age	0.620254	0.452840	0.515297	0.606615
~Age	0.593385	0.527231	0.712770	0.522749
Size	0.663134	0.410272	0.420637	0.497308
~Size	0.621768	0.707483	0.761111	0.556718

NOTE: (~) means absence of the condition.

ABSENCE OF THE TEC. INNOVATION IN FINAL FIRMS

	Solution							
	1	2	3	4	5	6	7	8
Competitors	◦	◦	◦	◦	◦	◦	◦	◦
Rel. Universities	●				○		●	◦
Tec. Centres	◦			●		●	○	
Rel. Clients	◦	●	●	◦	●	•	●	◦
Rel. Suppliers	◦	○	○	•				•
R&D Investment	◦	◦			○	◦		◦
Age			◦	○	●	○	◦	
Size	○	•	•	•	•	•	•	◦
Consistency	0,86	0,76	0,71	0,78	0,77	0,82	0,83	0,81
Raw Coverage	0,20	0,20	0,18	0,17	0,17	0,16	0,15	0,14
Unique Coverage	0,06	0,01	0,00	0,01	0,01	0,01	0,00	0,00
Overall Solution Consistency	**0,63**							
Overall Solution Coverage	**0,31**							

Note: As per Fiss (2011) black circles "●" indicate the presence of antecedent conditions. White circles "○" indicate the absence or negation of antecedent conditions. Big circles indicate core conditions and small circles indicate peripheral conditions. The blank cells represent ambiguous conditions. Frequency threshold = 1; consistency threshold =. 820. Direct Expectations (-; 0; 0; -; -; 0; -; -)

ABSENCE OF THE TEC. INNOVATION IN SPECIALIZED FIRMS

	Solution											
	1	2	3	4	5	6	7	8	9	10	11	12
Competitors	○	○	○	○	○	○	○	○	○	○	○	○
Rel. Universities	⬤	●	⬤		⬤	⬤	⬤	⬤	⬤		○	
Tec. Centres		⬤			○	○	○		○	⬤	⬤	⬤
Rel. Clients	○	●	⬤	●	⬤	⬤	⬤			●	●	○
Rel. Suppliers	○		●	⬤	●			⬤	⬤	●		○
R&D Investment	◯	⬤	○	◯		○		○		⬤	⬤	⬤
Age	○	○		⬤		○	○	○	●		○	○
Size	◯	○					○	●	●	●	○	●
Consistency	0,81	0,82	0,78	0,82	0,76	0,80	0,73	0,76	0,84	0,81	0,80	0,75
Raw Coverage	0,26	0,22	0,20	0,19	0,18	0,17	0,17	0,15	0,14	0,13	0,13	0,13
Unique Coverage	0,00	0,01	0,00	0,02	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Overall Solution Consistency	**0,64**											
Overall Solution Coverage	**0,34**											

Note: As per Fiss (2011) black circles "●" indicate the presence of antecedent conditions. White circles "○" indicate the absence or negation of antecedent conditions. Big circles indicate core conditions and small circles indicate peripheral conditions. The blank cells represent ambiguous conditions. Frequency threshold = 1; consistency threshold =. 820. Direct Expectations (-; 0; 0; -; -; 0; -; -)

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