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Different Paths to Achieve High Technological Innovation in Clustered Firms: An Analysis of the Spanish Ceramic Tile Industry [†]

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Abstract: This paper uncovers the different factors behind the high technological innovation performance of clustered firms. Moreover, we aim to investigate the necessary and sufficient conditions of factors to achieve innovative outcomes of clustered firms. This is done by analyzing the Spanish ceramic tile cluster and using a configurational comparative method, namely, fuzzy set qualitative comparative analysis (fsQCA). The results reveal the presence of equifinality, as there are diverse paths or combinations of factors that lead clustered firms to higher technological innovation performance. Additionally, early adoption of new technologies and a high absorptive capacity are included in most of the successful combinations of factors.

Keywords: innovative performance; disruptive technological innovation; industrial clusters; technology adoption; absorptive capacity; fsQCA analysis

1. Introduction

In recent decades, a growing amount of research has focused on innovation in territorial contexts like clusters and regions [1–3]. The intensive relationships in the local context, and the existence of different levels of resources at both systemic and individual firm levels [4], provide clustered firms with opportunities for innovation that may be difficult to benefit from in other different contexts. In short, cluster peculiarities lead to a specific context for firms' innovation. In this paper we aim at finding out the diverse combinations of factors that are present in the clustered firms that exhibit a remarkable innovation performance. Consequently, the context of the research is the cluster, while the object of study is the individual firms belonging to it.

More in detail, we develop an approach that is focused on two main potential determinants for clustered firm innovation. First, we address firm positioning in relation to the adoption of new technologies, particularly disruptive technologies [5], and, second, we highlight the importance of individual firm's attributes (i.e., absorptive capacity), which are supposed to be critical in this highly connected context [6]. Following Markides [7], disruptive technologies are those that incorporate a pool of knowledge, resources, and skills with a degree of novelty that threatens to make incumbent technologies obsolete. However, in clusters, simply having easy access to disruptive technologies does not guarantee success, in terms of innovative performance, if firms are not able to exploit them by using their internal capabilities or absorptive capacity [8–10]. In fact, absorptive capacity can be seen as a reflection of firms' abilities regarding the identification of external knowledge that is valuable, along with its assimilation and commercial implementation [11]. Furthermore, the absorptive capacity has been previously related to several internal skills and practices related with problem solving or the recognition of new technological opportunities and potentialities [4,6,12,13].

Previous studies explained the success or failure of firms regarding the quick adoption of a new technology associated to factors such as the investment in developing the new technology, in-house technical capabilities, or specialized complementary assets [14]. Firm leaders, which normally control the well-established technology, are likely to show less adaptability to disruptive changes. Consequently, they present more difficulties in retaining their dominant position when a new technology becomes the new standard. Their rigid and established organizational routines [15], and their major focus on the benefits offered by existing products [16–19], are some of the reasons behind this situation.

Firms' positioning in relation to the adoption of new technologies for clustered firms has a strategic value in this specific context. In fact, to adopt a technology at an early stage, before the technology can be considered the "new state-of-the-art" on the cluster, provides early adopters with a distinctive advantage in terms of technological innovation outcomes. Earlier adoption of the new technology in this context is more valuable due to some inherent cluster factors, such as intense exchange, easy flow of knowledge and ideas, emulation mechanisms, and others, among companies [20].

On the other hand, and also in the previous literature, another traditional explanatory line of how companies differ in reacting to changes comes from their absorptive capacity level [9]. In fact, this firm's internal attribute has been found to be determinant of its innovation performance by an important avenue of research [21–23].

Although these explanatory factors have been already used in previous studies, even in the cluster context, additional efforts can be made in order to disentangle the diverse configurations of factors, or paths, leading cluster firms to strong innovative performances. Differences among cluster companies are rarely addressed in the literature. Consequently, considering internal heterogeneity in clusters in terms of firms' typologies, we suggest that there are diverse paths to reach innovation outcomes, and we aim to gauge whether disruptive technology adoption and absorptive capacity are necessary and/or sufficient conditions to lead to innovation performance. Addressing this gap, we aim to offer a more complete and real picture of the innovation determinants in clusters.

To reach the above purpose, this paper relies on a complex causality [24] methodology, the Qualitative Comparative Analysis (QCA) technique [25–27]. Empirically, we focused our analysis on the Spanish ceramic tile cluster. This territorial agglomeration is situated in the Eastern region of Spain and it consists of a small area containing 118 ceramic tile producers along with an ecosystem populated with specialized firms, institutions, and supporting organizations. In this context, in the last decade, a disruptive technology was introduced that has significantly affected not only the cluster structure as a whole, but also the individual companies' strategies and performances.

Relying on this comparative analysis of innovation determinants in firms, our research has a two-fold contribution. First, we provide empirical evidence of the mechanisms that companies use to achieve technological innovation in clusters, and, second, we contribute to the existing literature on cluster innovation by widening the understanding of the effects of interactions between firms' internal attributes and technology adoption.

The paper is structured as follows. First, we describe the theoretical framework; then we justify and formulate our propositions. After that, we introduce the empirical section, and, finally, we address the discussion of results and further conclusions.

2. Theoretical Framework and Propositions: New Technology Adoption and Absorptive Capacity in Clusters

The literature has widely demonstrated how clustered firms are able to benefit from a series of resources and capacities that, flowing at cluster level, are not considered to be exclusive of a specific company. Authors have named this type of "common" resource as "higher-order resources and capabilities" [4]. Acknowledging the importance and influence of this systemic level [28] on firm behavior, from an individual firm perspective internal attributes influence on its individual outcomes. This internal firm perspective is the focus of this paper.

On the other hand, another avenue of research has focused on disruptive innovations, intending to capture the radicalness and breakthrough of some new technologies and innovations [29–35]. In this research, we stress the importance of those technologies and innovations beyond incremental or minor changes. These distant technologies, which may be created or adopted by companies, frequently lead to the replacement of previous products and technologies by new ones that provide the market with higher value. In this sense, scholars highlight the importance of disruptive changes as promoters of new markets that may break existing market linkages [16,32,36,37]. We adopted the suggestion made by Markides [7] about the work by Christensen [34] of distinguishing between “radical innovations” (for product innovations) and “disruptive innovations” (for technological/process innovations). In short, for the purpose of this paper, and with a focus on the cluster context, we consider a disruptive innovation as a technological change that incorporates new knowledge, resources, or skills that make obsolete the value of incumbent systems and technologies in the cluster.

Previous literature has described how local cluster characteristics, such as intense relationships, or trust among others make these contexts receptive to improvements thanks to the sharing and modification of existing flowing knowledge and technologies [38] rather than the generation of new and disruptive one. Literature has widely argued how clusters barely alter the stock of knowledge in more than an incremental way [39]. In fact, previous literature has critically analyzed the role of those internal mechanisms which are developed into the boundaries of the cluster [40]. This is the case in Glasmeier’s seminal work [41], who highlighted the challenge for Swiss watchmaking companies facing an external radical technological change regarding the introduction of digital technologies. Similar conclusions come from other Italian failure cases that have been reported by the authors of [42]. Despite this major dominant trend, previous research offers some cases that may be considered as counterexamples as they show how disruptive technologies have been successfully introduced in clusters thanks to disruptive exploration and exploitation activities (i.e., the work by the authors of [43]). Besides, the ability of clusters to generate or adapt disruptive innovations has been recently addressed by different authors even though in a marginal way [5,44–46].

In a complementary perspective, different responses may be observed in the way that clustered companies face the introduction of disruptive technologies. Some firms succeed (improving their competitive position and opening new development opportunities), while others, probably due to their better adaptation to the previous technological regime, fail [31,47].

Current venues of research have analyzed the patterns of technological innovation [48–51]. Nevertheless, determinants of success or failure of radical or incremental innovation in markets are far from being completely understood by scholars [52]. To sum up, despite the short body of work developed, we highlight the possibility of generation and development of disruptive innovations in the cluster contexts. Therefore, we embrace the significant influence on firm innovation outcomes, on the one hand, of the adoption of these new technologies, and, on the other hand, of its internal attributes related to the exploration and exploitation of external knowledge. In this sense, we adopt the perspective of the ambidexterity in firms to study how firms achieve and sustain innovation. Exploratory and exploitative activities have been highlighted as supporters of innovation (radical and incremental) by literature [53,54].

In particular, the internal attributes of firms promoting absorptive capacity [9] are suggested to be directly related to organizational learning, which, in turn, is critical in the assimilation of external information [9]. The literature on innovation has analyzed the role of organizational learning, particularly learning from external sources, on the innovation performance of firms as stressed by [55]. Similarly, since innovation can be identified as a knowledge-intensive process, Stock et al. [56] explain how higher levels of absorptive capacity are associated to more effective innovation outcomes. In fact, another avenue for fruitful research has shown a strong correlation between absorptive capacity indicators and the innovation output of the firms (i.e., the work by the authors of [57]).

In conclusion, we emphasize that the internal attributes of the firms are determinants of firms’ innovation performance, as a growing body of work has also highlighted [21,23,58].

2.1. Equifinality of the Combinations of Conditions Leading to Technological Innovation

In the context of our research, equifinality means that there are several paths or combinations of conditions that may lead to the same outcome; in our case, the innovation performance of the clustered firms and, more precisely, the technological innovation outcome, as we are focusing on adoption of technologies.

Far to consider a cluster as a homogenous group of companies, it is normally composed of a wide variety of firms in terms of competitive positioning, knowledge bases or innovation strategies. Some contributions attempted to analyze, under a core–periphery network perspective, how larger and peripheral companies (having high amount of internal resources devoted to internal research) share the location with smaller companies, which, having a limited amount of R&D resources, are highly interconnected with other similar companies in the core of the cluster [59,60]. Cluster categorization, following Morrison and Rabellotti's analysis [53], divides cluster networks into two different areas. On the one hand, the network core, where the companies benefit from the intensive exchange of knowledge and information, and, on the other hand, the network periphery, where relationships are more distant and the flow of knowledge among companies is less intensive.

Previous studies have demonstrated how these two different network levels use different paths to explore and exploit the stocks of knowledge and technologies [61]. Consequently, we conclude that there is not a unique path for firms in a cluster to improve their innovative performance, but these paths are created according to the predominant ways they are using to explore and exploit new sources of innovation. More precisely, to the purpose of the present research, we focus attention on the way the internal cluster diversity prevents a unique path for reaching the major firms' technological innovation outcomes; companies can alternatively develop internal or external factors to obtain a higher level of technological innovation. Therefore, we highlight that diverse combinations of factors, including high values of internal attributes related to absorptive capacity, are likely to lead to a higher level of technological innovation. Thus, we state the following proposition.

Proposition 1. *There are different configurations of attributes (paths) leading to strong technological innovation in clustered firms.*

2.2. Role of Early Adoption of Disruptive Technologies in Clustered Firms

Early adoption of new technologies has been studied in previous research. According to Tripsas [14], several factors are behind the success of firms in adopting new technologies. Among others, factors, such as the investment in developing new technologies, the permanent improvement of the technical capabilities, as well as the development of appropriability mechanisms of the technological innovations, can be highlighted. In the same vein, recently, Gutierrez et al. [62] identified, for instance, the key factors behind the adoption of new computing technologies: competitive pressure, complexity, technology readiness and trading partner pressure.

In an opposite sense, previous studies demonstrated that incumbent leaders may have difficulties preserving their dominant technological position when a novel technology bursts into the market. Relatedly, authors such as Leonard-Barton [15], Adner & Zemsky [16], Burgelman [17], or Christensen & Bower [32] illustrated how, among other reasons, established organizational routines, the fact of being focused on the current demand or the benefits offered by existing products may be considered inhibiting factors to the adaptation of new and disruptive technologies by incumbent firms.

In a territorial context, such as an industrial cluster, disruptive innovations have been studied and revised by authors like Molina-Morales et al. [45], Hervás-Oliver et al. [63], or Reig-Otero et al. [46], who stressed the implications from a cluster perspective of the new technology adoption.

Different contributions attempted to describe how disruptive technologies produce changes in the technological trajectories of clusters and open new opportunities in different types of clustered companies, as previous technological advantages disappear during the technological shift [64,65].

Accepting this point, we argue that this set of opportunities is likely to be related to the improvement of the firm's innovation performance. Consequently, disruptive technologies are called to enhance the product performance as well as to create new product categories. Similarly, a new technology could improve firms' processes and services offered through different elements, such as cost reduction, decrease of processing time, or increase of flexibility, among others.

In conclusion, we embrace a perspective grounded in the adoption of disruptive technologies as enablers of significant opportunities for clustered firms to improve their technological innovation performance. And more precisely, we emphasize not only adoption, but early adoption, as an important driver for clustered firms to achieve a distinctive advantage in terms of technological innovation outcomes. We underline that, especially in the cluster context, it is particularly important for firms to be early adopters due to the existence of important emulation mechanisms caused by specific cluster dynamics, such as the ease of knowledge flow and ideas, intense exchange, and others [66].

Considering the aforementioned arguments, we emphasize that those clustered companies who firstly adopt a disruptive technology will achieve a higher innovation performance from a technological perspective. In the context of the fuzzy set QCA methodology (fsQCA), which we are using in this research, we can suggest that being an early adopter will be present in the paths (or combinations of conditions) leading to higher technological innovation for the clustered firms. Indeed, all given paths towards our outcome usually consist of a combination of conditions that is sufficient to produce that outcome. In addition, it is possible to find a necessary path to reach the outcome, which means that this combination of conditions must be present if the outcome is present. However, despite this possibility, normally paths are not necessary combinations, as often some other alternative paths (with different combinations, at least partially) can produce the same outcome. Hence, we propose the following proposition.

Proposition 2. *Different combination of factors including the condition of being an early adopter of the disruptive technology are paths to strong technological innovation in clustered firms.*

2.3. Role of Different Internal Attributes Related to Absorptive Capacity on Innovation Performance of the Clustered Firms

A wide body of theoretical and empirical work has highlighted the importance of absorptive capacity [9], exerting a positive effect on innovation performance of the firms [21,23]. In the context of clusters, firms can amplify their opportunities of innovation through new and valuable resources, since the knowledge base of the individual firms has an additive effect to the systemic absorptive capacity characteristic of these territorial contexts [67]. Similarly, Belso-Martínez and Molina-Morales [68] describe how R&D results are related to the knowledge base of the firm, and consequently to its absorptive capacity. Thus, it is expected a positive relationship between internal attributes related to absorptive capacity and innovation performance of clustered firms. However, the literature offers different explanations, even divergent ones, in the way that this link is carried out. A curvilinear effect, for example, has been found in the literature [68]. This result advocates the need of reaching an optimal balance, since costs arising from internal R&D resources development would arise, beyond a certain level, more than benefits. Similarly, authors demonstrated how clustered firms receive a large stock of knowledge and other technological-related assets from the co-located firms within the boundaries of the cluster. Hence, connectivity among firms is established, which amplifies the curvilinear effect of the R&D effort [69]. In this sense, technological innovation performance in clustered firms depends, to a certain extent, on their ability for capturing and exploiting this external stock of knowledge.

Consequently, we expect that clustered firms developing high levels of internal attributes that can enhance their absorptive capacity are likely to experience improved technological innovation performance. In other words, the absorptive capacity may be an important factor leading to higher technological innovation outcomes for clustered firms. Thus, we state the following proposition.

Proposition 3. *Having a different combination of factors, including the condition of having internal attributes that favor the development of absorptive capacity, is a path to strong technological innovation in clustered firms.*

3. Empirical Setting: Context of the Research and Methods

3.1. Context of the Research: The Spanish Ceramic Tile Cluster and the Digital Printing Technology Innovation

The research work done in this scientific article focuses on the ceramic cluster of Castellón, Spain. This agglomeration of companies is highly representative of this type of industrial context and has been systematically studied in the literature [69–72]. Technological knowledge, a highly qualified workforce, a feeling of identity, roots in the industry, having an institutional ecosystem, the activities of knowledge transmission, and the importance of business and technological knowledge networks are some of the characteristics that support their relevance at the international level.

Moreover, this cluster is thought to be supplier-dominated, according to the taxonomy proposed by Pavitt [73]. This is, in our opinion, a significant reason to be selected as the object of the study. In this context, large companies have a prevalent position in capturing knowledge and expertise through technological leaders as those leaders (who provide the companies with different ceramic raw materials and machinery) are in turn their main providers. Therefore, we point up the fact that large firms are in a favorable position for increasing their innovation performance through a close relationship with their own providers. Consequently, the existence of different strategies of innovation among the different company profiles is present in the cluster.

The main industrial disciplines involved in the production process of ceramic tiles are represented in the ceramic cluster of Castellón. Among these activities we find the production of frits and enamels, ceramic machinery, additives, atomized clay, digital design, decorative pieces, and, of course, ceramic tiles. This conglomerate of activities is responsible for the production of ceramic tiles in the cluster, amounting to 94% of the total Spanish cluster. Another outstanding characteristic of the ceramic cluster of Castellón is its institutional ecosystem, which is focused on innovation. This ecosystem provides support to ceramic companies relating to technological development and business [71]. Figure 1 shows the ecosystem of innovation of the ceramic tile cluster in Castellón as it was described by Gabaldón et al. [74].

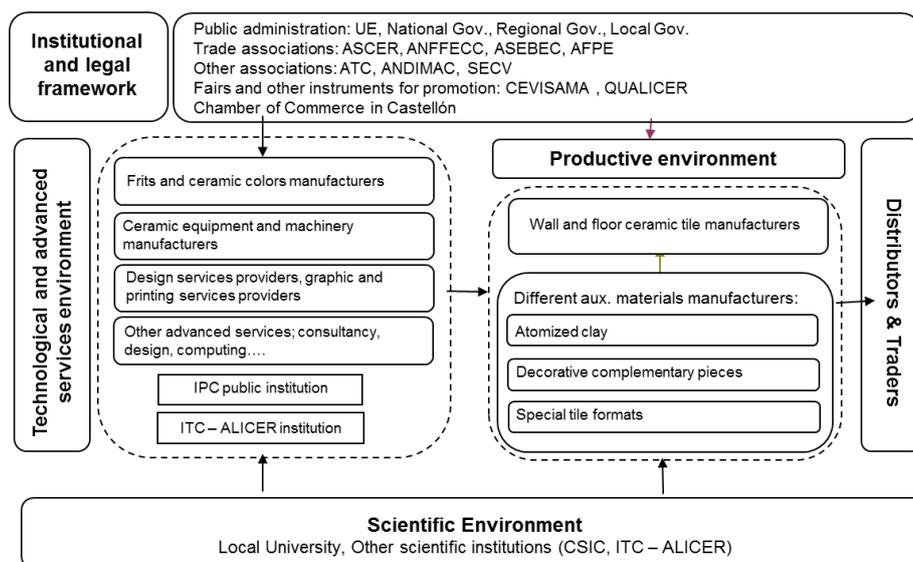


Figure 1. Ecosystem of innovation of the ceramic tile cluster in Castellón. Source: own elaboration based on [74].

The institutions that provide the most support in the ceramic cluster of Castellón are The Ceramic Technological Institute of Castellón (ITC), the local university (Universitat Jaume I), important trade associations (ASCER (Spanish Association of Tile Manufacturers), ASEBEC (Spanish Association of Machinery Manufacturers), and ANFFECC (Spanish Association of Frit, Glaze and Ceramic Color Manufacturers), chambers of commerce, and others.

The Spanish ceramic sector, represented largely by the Castellón cluster, directly employs 15,000 people, according to the main business association (ASCER). The volume of sales registered in 2017 by the companies of the cluster was 5225 million euros. This figure can be broken down into the 3510 million euros invoiced by the manufacturers of ceramic tiles (ASCER (According to ASCER website <http://www.ascer.es> consulted on September 2018)), the 1322 million euros reported by the manufacturers of frits and glazes (ANFFECC (According to ANFFECC website <http://https://www.anffecc.com/es/> consulted on September 2018)), and the 423 million euros that correspond to the manufacturers of machinery (ASEBEC (According to ASEBEC website <http://www.asebec.org> consulted on September 2018)).

One of the most relevant events in the cluster, in relation to its technological development, is the introduction of digital inkjet printing at the beginning of the 21st century. This fact supposes a radical change in the process of decoration of the ceramic pieces and has been the object of study for several authors, such as Albors-Garrigos and Hervás-Oliver [70], Molina-Morales et al. [45], and Reig-Otero et al. [46]. One of the most important effects of the introduction of this new technology, thanks to the contribution of a visionary agent, is the alteration of the value chain of the ceramic tile business both locally and globally.

Indeed, the introduction of the inkjet technology in the production of ceramic tiles has had a major impact on the manufacture of the product and the structure of the ceramic industry. In terms of manufacture, the inkjet technology mainly affects the decoration process of tiles, allowing companies to dramatically reduce the batch size of every model. This feature is very important, as it has direct impact on reducing manufacturing costs as well as the possibility to increase the scope of products portfolio. After implementing the inkjet technology, companies need to consider several strategic moves towards both cost leadership and differentiation. Furthermore, the Spanish machinery manufacturers that developed this disruptive technology have become leaders in this particular subsector of the ceramic industry. After years of Italian leadership in ceramic machinery production, the development of the inkjet technology has produced a major shift in the competitive dominance in this important subsector. The aforementioned reasons make this radical change very important in comparison to previous innovations applied in the sector like the tunnel kiln, the single-fired porous ceramic, guided tile transport, or the glazed porcelain tile, among others [75].

3.2. Sample and Data

The data used in this research are drawn from a survey that was carried out among firms belonging to the Spanish ceramic tile cluster. Based on a structured questionnaire, the survey aimed to gather detailed information on how ceramic tile firms faced the adoption process of digital printing technology, a technological disruptive innovation. This innovation stirred up the decoration tile stage of the manufacturing process, as explained by Molina-Morales et al. [45]. Consequently, interviews were addressed to the wall and floor ceramic tile manufacturing firm category among the different categories of firms which are part of the cluster (such as equipment manufacturers, raw material providers or auxiliary services suppliers). Indeed, only the wall and floor ceramic tile manufacturers were those members of the cluster who were able to adopt the disruptive technology under study. Specialized or integrated firms are, consequently, out of the scope of the research.

Two polling rounds were conducted from October 2016 to February 2018. As a result, a total of 88 completed questionnaires were obtained. At that time, the universe of firms in the cluster (total amount of independent tile manufacturers) totaled 118 independent manufacturers.

The targeted group of respondents is mainly comprised of CEOs or R&D managers. These respondents were considered by the researchers as the most suitable profiles because they are expected to have first-hand information about the impact of the new technology as well as the innovative patterns in their own companies. Nevertheless, to a lesser extent, some questionnaires were answered by different profiles of respondents such as marketing managers or technical production managers. They are similarly involved in the innovation processes of their corresponding companies.

Moreover, secondary information was gathered from the SABI database (Iberian Balances Analysis System) in order to obtain other relevant features of the companies as well as their business and performance information. Besides, data regarding total assets, total revenues, and the number of employees were gathered for the respondent companies from 2007 to 2013. This period of time was selected so as to cover a representative period around 2010 due to the fact that this year has been chosen as the threshold for a clustered company to be contemplated as an early adopter of the disruptive technology as described in the previous section.

3.3. Methodology: Qualitative Comparative Analysis

Qualitative comparative analysis (QCA) is a methodology that, although initially developed for the field of sociology and political sciences [76–78], is also used in other areas such as marketing, innovation, and business strategy [76,79–83]. The main characteristic of this analysis methodology (QCA) lies in the search for causal recipes that lead to an output (Ragin, 2008). A simplification of the main mechanism involves locating alternative combinations (recipes) of antecedent conditions (ingredients) that produce a certain outcome or its negation. Therefore, it allows unraveling the causal complexity of the conditions instead of analyzing their net contributions [84]. As a result, the methodology (QCA) is characterized by the presence of equifinality. That is, the same result can be obtained by combining different causal combinations [25,84].

In order to achieve our main objectives, we used the fuzzy set QCA (fsQCA). This is the last version of this methodology [25,80,85,86] that allows analysis of the relationships among variables based on membership to certain sets. On the basis of Boolean algebra, QCA reveals configurations and combinations of variables (and associated conditions) that result in necessary and/or sufficient conditions to obtain a certain outcome.

In short, on the one hand, we are dealing with an outcome (the feature we are aiming to explain), and, on the other hand, with different conditions (or attributes). In the present research, the outcome is related to the technological innovativeness of the companies, as previously stated in the theoretical propositions. The conditions have been defined from a set of variables (or internal features of the companies) that may be related with the outcome. Among them, early adoption and absorptive capacity are suggested to play an important role as previously justified. We selected these specific factors to focus on related characteristics belonging to the same domain of the company, and to describe how these similar factors behave, even interact, in the proposed model.

Indeed, we acknowledge the existence of potential interactions among different innovation factors. In this particular research, we suggest that those interactions can be captured through the fsQCA methodology. Rather than to establish simple and direct causal associations between variables, this methodology allows us to uncover combinations of variables (interactions) to obtain a certain outcome, in our case the innovation performance of clustered companies.

In Table 1, we can find the outcome scope, the variables, and the conditions. All items used in the survey to build the outcome as well as the variables, which, in turn, will lead to the conditions, are listed in Appendix A with additional details and justifications.

Finally, Table 2 identifies the property space in our analysis in terms of outcome and sets (condition) definition. We would like to underline that in order to measure the technological innovation, we use a validated scale from the Community Innovation Survey questionnaire (PITEC). The items used (listed in the appendix) have a technological component including the ones regarding logistics and auxiliary processes.

Table 1. Outcome scope, variables, and associated conditions.

| Outcome Scope | Variables for Explaining the Outcome | Associated Condition to the Variables |
|------------------------------|---|---|
| Technological Innovativeness | Early adoption | Early adopter |
| | Absorptive capacity | Strong absorptive capacity |
| | Experience in research and development activities | Experienced company in research and development |
| | Size | Large company |
| | Intensity in R&D activities | High intensity in R&D activities |

Table 2. Outcome and conditions: description and codifications.

| Type | Name and Code | Description |
|-----------|--|---|
| Outcome | Strong Technological Innovator (INN_TEC) | Being a strong technological innovator means to introduce, intensely, product, and process innovations into the company. |
| Condition | Early adopter (EARLY) | Being an early adopter means adopting the technology before its massive adoption in the cluster. |
| | Strong absorptive capacity (ACAP) | To have a strong absorptive capacity means to have a high capacity of acquiring, assimilating, transforming and exploiting new knowledge coming from outside. |
| | Experienced R&D Firm (ARD) | Being an experienced R&D firm means to have an experienced R&D department in terms of years of activity. |
| | Big firm (SIZE) | Being a big firm means to have a big size in terms of employees, assets y revenues (average values from 2007 to 2013.). |
| | High intensity in R&D activities (PID) | High intensity in R&D activities is defined by having a high number of employees in R&D departments (% over total employees of the company). |

After defining the different sets, we assigned a value to determine membership. In the field of QCA analysis, this process is known as calibration. The calibration can be done directly or indirectly [25]. Regarding this research work, we opted for direct calibration, as recommended by Ragin [25], when the samples are small or medium size. Direct calibration involves determining when a certain condition is fully in or fully out of a specific set at the point of maximum ambiguity. To carry out this process [87], we used the fsQCA package in R. The results obtained for the calibration can be found in Table 3. This table shows the membership cut-off points used in each of the conditions defined above.

Table 3. Main calibration points and summary of the descriptive statistics.

| | Descriptive Statistics | | | Calibration Anchors | | |
|---------|------------------------|-------|---------------|---------------------|-----------|-----------|
| | Max | Min | Mean (S.D) | Fully-In | Crossover | Fully-Out |
| INN_TEC | 5 | 0 | 3.52 (1.76) | 5 | 4 | 1 |
| EARLY | 17 | 0 | 8.05 (3.88) | 9 | 6 | 4 |
| ACAP | 2.0 | -3.4 | 0.00 (0.99) | 1.3 | -0.6 | -1.5 |
| ARD | 100 | 0 | 11.97 (12.34) | 20 | 13 | 5 |
| SIZE | 7.7 | -0.50 | 0.00 (0.99) | 0.3 | 0 | -0.4 |
| PID | 40 | 0 | 6.23 (7.88) | 10 | 5 | 0 |

Once the variables have been calibrated, we constructed the truth table, which, as the analysis methodology dictates, serves to organize all possible configurations of conditions and their correspondence with the presence of the outcome. The truth table was made with software package fsQCA 3.0 [25]. This computer program provides the relevant solutions through logical

reduction. The analysis process concludes with the obtainment of the necessary and sufficient conditions. In this way, we can identify whether the presence of a specific condition, or a combination of them, produces the outcome or is/are always present in the diverse combinations that yield it. In parallel, the importance of each of the solutions obtained is also evaluated. For this purpose, we use the characteristic measures of the QCA methodology, namely consistency and coverage, provided by the software package.

4. Results

4.1. Analysis of Necessary Conditions

The first analysis aims to find any necessary conditions for the achievement of the outcome, which in this case is to be a strong technological innovator. As proposed by the authors Schneider and Wagemann [79] and Rihoux and Ragin [80], the corresponding test to determine the presence or absence (~) of these necessary conditions provides the results that can be seen in Table 4. A condition, or combination of conditions, is considered as necessary if the value of the consistency exceeds 0.90 and the coverage is greater than 0.50 [88].

Table 4. Results of the necessity analysis.

| Outcome: Strong Technological Innovator | | |
|--|--------------------|-----------------|
| Conditions | Consistency | Coverage |
| Early adopter (EARLY) | 0.762 | 0.635 |
| ~ Early adopter (EARLY) | 0.331 | 0.597 |
| High intensity in R&D activities (PID) | 0.581 | 0.729 |
| ~ High intensity in R&D activities (PID) | 0.580 | 0.606 |
| Experienced R&D Firm (ARD) | 0.512 | 0.750 |
| ~ Experienced R&D Firm (ARD) | 0.623 | 0.580 |
| Strong absorptive capacity (ACAP) | 0.814 | 0.698 |
| ~ Strong absorptive capacity (ACAP) | 0.335 | 0.569 |
| Big firm (SIZE) | 0.442 | 0.826 |
| ~ Big firm (SIZE) | 0.684 | 0.560 |
| EARLY and ACAP | 0.663 | 0.727 |
| EARLY or ACAP | 0.913 | 0.627 |
| Outcome: ~ Strong Technological Innovator | | |
| Conditions | Consistency | Coverage |
| Early adopter (EARLY) | 0.704 | 0.443 |
| ~ Early adopter (EARLY) | 0.419 | 0.571 |
| High intensity in R&D activities (PID) | 0.500 | 0.474 |
| ~ High intensity in R&D activities (PID) | 0.714 | 0.563 |
| Experienced R&D Firm (ARD) | 0.403 | 0.447 |
| ~ Experienced R&D Firm (ARD) | 0.775 | 0.545 |
| Strong absorptive capacity (ACAP) | 0.664 | 0.430 |
| ~ Strong absorptive capacity (ACAP) | 0.534 | 0.685 |
| Big firm (SIZE) | 0.291 | 0.410 |
| ~ Big firm (SIZE) | 0.877 | 0.543 |
| EARLY and ACAP | 0.516 | 0.428 |
| EARLY or ACAP | 0.851 | 0.442 |

As can be seen from Table 4, the combination “early adopter” or “strong absorptive capacity” exceeds 0.9 for consistency. However, we cannot consider this combination of conditions as necessary since the Relevance of Necessity (RoN) is less than 0.6 [25,88]. Consequently, we can suggest that there is not a specific feature that necessarily leads the tile manufacturers to be strong technological innovators in activities related to process and/or product development.

4.2. Sufficiency Analysis

After verifying that there are no necessary conditions in our case study, we proceed to the analysis of sufficiency conditions. In order to perform this analysis, the truth table must be calculated [25,89]. This table contains all possible logical combinations, which in our configuration of variables totals 32. This figure is obtained through the mathematical operation 2^5 , where the superscript 5 corresponds to the number of conditions considered in our analysis. After identifying all combinations, a process of categorization is performed [90].

FsQCA offers three types of solutions depending on the type of approach used in the simplification of the assumptions. These solutions are, namely, complex, intermediate, and parsimonious [25]. Under the premise that these three solutions will never contain contradictory information, the causal recipes derived from each of them may present some differences [91]. The intermediate solution is one of the most used in the literature to analyze the causal complexity of the QCA analysis. This option is optimal mainly because it represents a good compromise between the other two [85,86,89,90,92–94]. The main assumptions made in our analysis, considering the dynamics of the innovative processes in the ceramic sector, were the presence of the conditions early adoption and strong absorptive capacity.

Table 5 presents the main results in terms of the analysis of sufficiency under the intermediate solution, whose results are validated according to the insights from the authors of [24,77,89,90]. The table uses the notation proposed by Ragin [80] and Fiss [77]. That is, black circles correspond to the presence of a certain condition, while white indicates the absence of a condition. On the other hand, the blank spaces represent that the condition “does not matter”. Finally, the larger size of the circles represents that a condition is core, while the small circles indicate peripheral conditions. The author defines core elements as, “those causal conditions for which the evidence indicates a strong causal relationship with the outcome of interest and peripheral elements as those for which the evidence for a causal relationship with the outcome is weaker” [86] (p. 394). In our case, all recipes shown in the table contain a combination of core and peripheral conditions.

Table 5. Results of the intermediate solution.

| Outcome: Strong Technological Innovator ¹ | | | | | | | | |
|--|---------------|-------------|----------------------------------|----------------------|----------|--------------|-----------------|-------------|
| Consistency cut-Off: 0.82 | | | | | | | | |
| Frequency Threshold = 1 | | | | | | | | |
| Antecedent Conditions | | | | | | | | |
| Path Number | Early Adopter | Strong ACAP | High Intensity in R&D Activities | Experienced R&D Firm | Big Firm | Coverage Raw | Coverage Unique | Consistency |
| 1 | ● | ● | ● | ● | | 0.356 | 0.157 | 0.845 |
| 2 | ● | ● | | | ● | 0.347 | 0.042 | 0.867 |
| 3 | | ● | | ○ | ● | 0.241 | 0.013 | 0.893 |
| 4 | ● | | | ○ | ● | 0.237 | 0.009 | 0.870 |
| 5 | | | ● | ○ | ● | 0.157 | 0.011 | 0.887 |
| Solution coverage: 0.56 | | | | | | | | |
| Solution consistency: 0.84 | | | | | | | | |
| Overlapping coverage score: 0.33 | | | | | | | | |

¹ black circles “●” indicate the presence of antecedent conditions. White circles “○” indicate the absence or negation of antecedent conditions. The blank cells represent ambiguous conditions. Furthermore, large circles, either black or white, indicate core conditions, and small circles refer to peripheral conditions.

Each of these paths are characterized by three different scores: raw and unique coverages and consistency. The raw coverage score reflects the extent to which this recipe can explain the outcome. The lower a coverage score, the less empirically relevant a causal recipe; it is able to explain fewer cases in which the outcome occurred [91]. On the other hand, the unique coverage score shows the proportion of cases that can be explained exclusively by that recipe. It is meaningful because it indicates how many cases a given recipe can explain without any other recipe offering explanation. Often there is considerable overlap between recipes, so it is not unusual for the unique coverage scores to be rather low (<0.15) [91]. Thus, recipes with higher unique coverage gain relevance, because without them more cases would be beyond the explanatory reach of the model. Finally, the recipe's consistency score reflects the amount of cases that do not fit with this specific path. The lower the consistency score of a path, the more cases do not fit the patterns identified by it, or, in other words, the more substantial are the contradictions that certain cases pose to this recipe. Ragin [95] recommends a consistency threshold of 0.80; in our case, all recipe scores comply with this threshold.

Moreover, Table 5 shows the overall coverage and consistency for the solution which indicates the robustness of our solution. The solution coverage score reflects the empirical importance of a given solution. It should be as high as possible, usually above a score of 0.25. The solution consistency score confirms that the specific configuration of antecedents is sufficient for explaining the outcome condition [25]. Different authors consider robust solutions as those whose consistency thresholds are at least 0.75, but preferably 0.85 or higher [84,95,96]. Regarding the overall consistency and coverage values obtained from the intermediate solution of our research, we stress that they surpass the minimum value considered suitable; the consistency score is 0.84 (indicating that the combined recipes account for about 84% of the membership to the outcome), while the coverage score is 0.56.

Finally, Table 5 shows the overlapping coverage score. The extent of overlap indicates two things. At dataset-level, cases gather along certain dimensions on the causal conditions. At single case-level, many cases with the occurrence of the outcome can be explained in more than one way [91]. In our case, the overlapping coverage score is 0.33.

Our sufficiency analysis shows five different paths to the outcome in line with our proposition 1. Actually, as stated before, all of them comply with the threshold of 0.8 recommended by Ragin [25].

The analysis suggests two differentiated tendencies for achieving the outcome (to be a highly technological innovator). Configurations 1, 2, 3, and 4 refer to companies that either are early adopters of the disruptive technology (as stated in proposition 2), or have a strong absorptive capacity (as stated in proposition 3), or both together (they are early adopters and furthermore they have a strong absorptive capacity). This group of configurations, in which the condition of size of the company is not present, reaches a higher raw coverage scores and consequently represents a higher amount of cases. This means, regardless of the size, a firm can reach high levels of technological innovation through different paths. On the other hand, configuration 5 refers to those companies that, not being early adopters or not having a high absorptive capacity, are large and experienced in R&D tasks as well as they invest important amount of resources in R&D activities.

In short, in four out of the five paths proposed by the fsQCA analysis, early adoption, strong absorptive capacity, or both are present as antecedent conditions to be a strong technological innovator in terms of product or process developments. These findings show that early adoption and high absorptive capacity may be important conditions, which matches our theoretical expectations and is in line with the innovation and knowledge management literature. Hence, our results are aligned with the propositions that we outlined in the theoretical framework, as the presence of equifinality, the inclusion of early adoption, and factors associated with absorptive capacity are present in most paths. Nevertheless, we should note that their contribution is considered by the fsQCA analysis as peripheral in comparison with other elements. Despite this fact, we consider that the repeated presence of both factors in paths obtained (four out five paths contains the early adoption or the high absorptive capacity or both) highlight their important influence as determinants of innovation.

Path 1 is especially interesting because its raw coverage is 0.356. This means that around 36% of the cases can be explained through this configuration of antecedent conditions. On the other hand, this configuration also has a unique coverage value of 0.157, which means that it is able to exclusively explain almost 16% of all cases. Moreover, this path shows two core conditions, high amount of R&D resources and to be an experienced R&D firm. This configuration leads to the conjecture that companies may be highly technological innovators (regardless of their size) if they adopt early a new technology and they combine a strong absorptive capacity, a high amount of R&D resources and an extensive experience in R&D tasks. Concurrently, path 2 (having a similar raw coverage score but a lower unique coverage) substitutes, in comparison with path 1, the big size of the firm for a high amount of R&D resources and an extensive experience in R&D tasks. This result points out that companies may be strong technological innovators (regardless of their budget for R&D activities and the experience of their R&D department) if they adopt early a new technology and are big enough. This path presents only a core condition, the large size of the firm.

On the other side, path 5 corresponds to highly innovative companies that are characterized by big size, high investment in R&D (both conditions are core) even with the absence of an experienced R&D department. This path is the less representative as the raw coverage score is 0.157 meaning that just the 16% of the cases can be explained through it. This finding is in line with the researchers' expectations as, not only in the Spanish ceramic tile cluster but also generally in the ceramic tile industry, big tile companies have easy access to knowledge and innovation capabilities through the specialized companies. In this sense, the Spanish ceramic tile cluster is considered as a supplier dominated cluster [73] where technological innovation is developed and provided by the specialized suppliers (mainly the frits, glazes and digital inks suppliers) to their customers, the final tile manufacturing companies.

5. Discussion of Results and Conclusions

Based on the configurational comparative analysis, namely, fsQCA analysis, it is possible to uncover the different combinations of factors causing clustered firms to develop a strong technological innovation performance through the adoption of disruptive technologies. From a general perspective, we were interested in knowing why some companies in clusters adopt a disruptive technology earlier than others, and, more precisely, what the consequences of early adoption for those companies are, once this technology is fully available in the cluster. In sum, we focus on a disruptive innovation and its process of introduction into a cluster in order to broaden our knowledge of this unusual innovation development on this specific context. We agree that disruptive innovation can deliver other incremental innovations in a cluster, and consequently, this can open a new venue of research. Nevertheless, the fact that, generally, clusters are much more associated to incremental rather than to disruptive or radical innovations [97] is the main reason which motivates our research.

First, as a preliminary conclusion, related with proposition 1, the results stress the existence of an equifinality, represented by a number of combinations of firm's assets to achieve the outcome, that is being a strong technological innovator. In other words, clustered firms can reach a high innovative performance combining different features (more precisely the presence and/or the absence of them).

Second, and related with propositions 2 and 3, empirical evidence has been obtained regarding how early adoption of a new and disruptive technology combined with high absorptive capacity is a trigger for firms to reach high results of technological innovation. Our empirical analysis has shown that these two factors are present in most of the paths traversed by clustered firms who perform a high technological innovation. In short, the analysis shows how the early adoption of disruptive technologies, in combination with the absorptive capacity, is a strong determinant of innovation.

In our perspective, this knowledge can be profitable firstly for firm's managers, who look to increase the innovative performance of their companies as they recognize innovation as an important drive of competitive advantage and, in short, as a paramount source of value creation. In this sense

our results, enabling different possibilities in terms of internal and external capabilities combinations, open a handful of possibilities for them.

For instance, it is worth noting that our analysis suggests that size is not a limitation to firms achieving high innovation performance. In fact, small clustered companies may obtain similar performance (in terms of innovation results) to larger ones by different combination of factors including the early adoption of a disruptive technology, the ACAP and R&D expertise, for example. On the one hand, our results show how large clustered companies can benefit from new technology and the ability to detect and assimilate external knowledge to become strong technological innovators, even those without strong R&D capabilities.

We highlight, as well, that our results may guide policy-makers who are looking to enhance the performance of their territories. In the literature, there is an emerging consensus drawing special attention to the importance of innovation and networks of innovative companies as determinants of resilience of territories and clusters [98–101]. In this sense, we explore research acknowledging the influence of innovation in the development of “the adaptive capability that allows a cluster to make changes to overcome internal and external disturbance and still function with its identity as a cluster” [99] (p. 4). In doing so, we suggest the important role that early adoption of a new technology by clustered firms may play in the development of resilience at a cluster level and beyond the individual innovation performance achieved by individual firms through this adoption. Policy-makers, in short, have in new technologies, and their adoption, a significant option to boost new trajectories of development in cluster (mainly if they are facing a maturity stage). This is, in our opinion, a key point as nowadays clusters are facing important challenges mainly caused by globalization. This global phenomenon is forcing them to design new strategies in order to be able to face new and changing global conditions.

Furthermore, we consider that our research work also contributes to the cluster literature reinforcing the argument that companies belonging to these agglomerations benefit from externalities whose impact may be amplified by its combination with internal capabilities. In this line, our results are complementary to other studies that show how the relationship between internal capabilities and innovation is often diverse or contingent to the firm’s access to external resources [68,69]. Furthermore, the proposed methodological framework based on the introduction of QCA analysis has direct implications as it complements the insights obtained through widely used correlational statistics. Indeed, the use of complex causality enables to open an interesting avenue for future research on cluster literature. This empirical approach would offer different necessary or sufficient configurations of factors (or paths) leading to important outcomes acknowledged in cluster literature such as innovation, business performance or resilience, among others. In this sense, in sum, this study opens new opportunities to new approaches using the QCA methodology to reinforce argumentations and insights about cluster firms’ dynamics.

Finally, we are aware that our research has some limitations. First, we acknowledge the limited room for generalization of the results, the implications and the conclusions obtained as just a concrete cluster reality has been analyzed. Indeed, the innovation dynamics of the cluster under analysis may be conditioned by the peculiarity of being a supplier dominated cluster [73]. Further research should be carried out in order to strengthen the results of the research and to gain broader validation. For instance, a comparative analysis of this case with other cases of clusters not only belonging to the same part of the Pavitt’s taxonomy [73] but also to different ones (i.e., production-intensive or science-based clusters) should be carried out. Additionally, our study is a cross-sectional approach that has the opportunity of extending, with a longitudinal perspective, as a future line of research. Regarding the technology adoption, we acknowledge that there are additional possibilities that can be considered for future research endeavors; this is the case in the diffusion theories by Rogers [102]. The use of this interesting approach will enable future research to disentangle the effects of different phases of technology adoption on the innovative performance. Hence, this could be a potential extension

of the dichotomic approach used in this paper as an interesting path to follow up in the upcoming research efforts.

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Appendix A

The additional details used in the survey for building the variables, and therefore defining the conditions, are as follows.

Appendix A.1 Technological Innovativeness

Companies are classified according their capability to develop technological innovations, meaning their intensity in terms of product development and process innovations. For the purposes of the present research, a measure of technological innovativeness of the companies was built from questions belonging to the Community Innovation Survey on Spanish Manufacturing Firms (PITEC). Consequently, we asked respondents to specify whether their company was aligned with the following statements.

- During the last three years the company has introduced or improved new products/services based on those previously introduced by competitors.
- During the last three years the company has introduced or improved new products/services before competitors.
- During the last three years the company has introduced or improved new manufacturing methods.
- During the last three years the company has introduced or improved new delivery or logistical methods.
- During the last three years the company has introduced or improved new auxiliary processes.

Appendix A.2 Early Adoption

Companies are classified in two groups (early adopters or non-early adopters) according when they adopted the digital printing technology as printing method for their manufacturing lines. We established 2010 as the cut-off year because different technical and business events (produced mainly between 2008 and 2010) led to the general feeling in the cluster that, finally, this disruptive innovation had been successfully introduced and adapted for the ceramic industry. In conclusion, we consider early adopters those companies who adopted from 2000 (when the first digital printer prototype was presented) until 2010 (included). There was no doubt after this cut-off year that the technological change would take place massively. That is the reason why we considered early adopters as those firms which decided to adopt the novelty before all uncertainties and resistances were removed.

Appendix A.3 Absorptive Capacity

For the purposes of the present research, a multidimensional indicator was chosen to measure the ACAP of the companies. In more detail, we adopted the scale proposed by Flatten et al. [103]. These authors carried out the development and validation of a four-factor ACAP measure based on a relevant prior literature review, followed by a series of pretests and two large survey-based studies which validated it. This measure assesses the degree to which a company engages in knowledge acquisition activities, assimilates acquired information into existing knowledge, transforms the newly adapted knowledge, and commercially exploits the transformed knowledge to its competitive advantage [103]. The four-factor ACAP measure is made up of 14 items; each item is based on an

11-point Likert scale (0: strongly disagree to 10: totally agree): (a) acquisition: 3 items; (b) assimilation: 4 items; (c) transformation: 4 items; and (d) exploitation: 3 items. We asked respondents to use this scale to specify to what extent their company is aligned with the following statements regarding the four dimensions of ACAP proposed.

Appendix A.4 Experience in R&D Activities

Firm experience in developing R&D activities was measured through the age of the R&D department.

Appendix A.5 Size

Size of the company is measured through a factor built from the average values of the number of employees, the total assets and total revenues of the companies. The average values for the respondent companies were calculated from data gathered from 2007 until 2013. This period was selected to cover a representative period around 2010 in accordance with the consideration of this year as the threshold for a company to be considered as early adopter of the disruptive technology as previously described.

Appendix A.6 Intensity in R&D Activities

The level of R&D activity carried out by the companies was measured through the percentage of employees belonging to the R&D department over the total amount of employees.

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