Disruptive technology adoption, particularities of clustered firms
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ABSTRACT
This article explores to what extent the internal attributes of a clustered firm influence its capacity to adopt disruptive innovations. A multidimensional approach to the absorptive capacity (ACAP) model is used to distinguish between potential (acquisition and assimilation domains) and realized (transformation and exploitation domains) internal firm capabilities. Our evidence comes from an empirical analysis of the population of firms belonging to the Spanish ceramic tile cluster which have adopted a disruptive innovation – the so-called digital printing technology – on a massive scale. The econometric estimations suggest the relevance of the Exploitation dimension of ACAP for early adoption of a new technology. In contrast, the other dimensions do not seem to play a decisive role when it comes to adopting one novelty earlier than others. In conclusion, and contrary to what was expected for non-clustered firms, the results revealed an uneven effect of the potential and realized domains of ACAP of clustered firms regarding the rate of adoption of distant technologies.

KEYWORDS
Disruptive technological innovation; industrial clusters; technology adoption; absorptive capacity (ACAP); potential absorptive capacity; realized absorptive capacity

Introduction
In recent years, the territorial dimension of innovation has attracted the attention of scholars and practitioners (Moulaert and Sekia 2003; Doloreux and Parto 2005; Moulaert et al. 2005), particularly as a path in regional development. In many cases, authors have used the concept of district or cluster (Becattini 1979; Porter 1990) as their framework of analysis (Munari, Sobrero, and Malipiero 2012; Kesidou and Snijders 2012). Moreover, there are many contributions that attempt to describe how proximity facilitates frequency of contacts and closeness among actors in a cluster network (Piore 1990; Lorenz 1992; Inkpen and Tsang 2005). According to a part of the cluster literature, this characterization would generate tacit knowledge and high-quality information exchanges and, consequently, would promote innovation for firms (Molina-Morales 2002; Bathelt, Malmberg, and Maskell 2004).

Most authors, more or less explicitly, assume that the relational characterization of the cluster becomes far more appropriate for step-by-step or minor improvements and incremental innovations of products and technologies than for those considered as radical or disruptive changes (Maskell 2001; Bianchi and Giordani 1993; Hassink 2005).

The existing literature on innovation in clusters, while acknowledging the value of real disruptive changes for cluster renewal and sustainability, is often focused exclusively on what is behind the incapability of these agglomerations to carry them out (Østergaard and Park 2015; Peter Maskell and Malmberg 2007). Nevertheless, Saxenian (1991) found that in the rapidly changing environment of the computer industry, mostly in Silicon Valley, firms have moved away from arm-
length supplier relations in order to build close relationships with only a select number of them. More recently, some examples can be found describing how industrial clusters have renewed their possibilities of surviving through disruption (Hervás-Oliver et al. 2017; Molina-Morales, Martínez-Cháfer, and Valiente-Bordanova 2017).

Some authors, following the exploring and exploiting dimensions of organizational learning proposed by March (1991), but under a cluster perspective, have tried to identify activities related to these two categories of innovation and suggested that, in some cases, clustered firms may benefit from both exploiting and exploring advantages (Fontes 2005; Giuliani 2007; Rullani 2002).

Our work aims to address the above-mentioned discussion by analysing what attributes of cluster companies are related to the adoption of disruptive technologies. In fact, disruptive innovation processes have rarely been studied in the cluster context. Literature has focused more on describing cluster decline when facing disruption or inertia as a factor restricting disruptive novelty (Staber and Sautter 2011; Østergaard and Park 2013; Suire and Vicente 2009; Crespo et al., 2013; Isaksen 2014). These contributions are often focused on the cluster as a unit of analysis and stress the identification of key cluster elements supporting or inhibiting adaptation to disruption. They rarely address, from the firm perspective, the internal attributes of clustered firms as factors determining the adoption of disruptive innovations. In this vein, exceptionally, Hervás-Oliver et al. (2017) analysed how radical innovation occurs in Marshallian clusters and how they are able to overcome lock-in processes.

Exploratory in nature, our work uses the firm as a unit of analysis and captures their internal attributes using the absorptive capacity model (hereinafter ACAP), which was first defined by Cohen and Levinthal (1994, 1990). Contributions to previous industrial cluster literature have used this internal firm attribute to analyse how firms have different access to the knowledge provided by technological institutes (Hervas-Oliver et al. 2012) or how the heterogeneity of firms’ knowledge builds a cluster ACAP (Giuliani 2005). By distinguishing among the four dimensions of ACAP proposed by Zahra and George (2002), we aim to determine the firm-specific attributes that allow individual clustered firms to access and exploit a new disruptive technology more rapidly.

Literature has frequently analysed ACAP as a one-dimensional concept, measuring it through different indicators such as R&D activity (Cohen and Levinthal 1990), patents (Zhang et al. 2007) or number of employees with higher education qualifications (e.g. Caloghirou, Kastelli, and Tsakanikas 2004). These unidimensional indicators are receiving increasing criticism (Camisón and Forés 2010), and only a few papers have formulated a multidimensional operationalization of ACAP (e.g. Lane, Salk, and Lyles 2001; Jansen, Van Den Bosch, and Volberda 2005; Expósito-Langa, Molina-Morales, and Capo-Vicedo 2011).

A four-dimensional perspective becomes of interest, since each dimension requires distinct organizational processes and is developed in a different way in clusters. In short, this article aims to focus on a particular line of inquiry, namely, to determine which dimensions of ACAP have a more significant influence on the early adoption of a disruptive innovation when this innovation is introduced in the cluster.

The context of our research is the cluster and innovation literature. Furthermore, we aim to contribute to the debate about the possibilities of the future development of these territorial agglomerations, which is in fact closely related to the debate on the cluster policy for mature phases of the life cycle.

To develop these causal relations, the article is centred on the Spanish ceramic tile cluster, where digital printing technology has recently been introduced. In fact, the characteristics and effects of this innovation represented a major transformation of existing products and technologies, making most of them obsolete. This characterization fits well with refinements of the definition of the term ‘disruptive innovation’ proposed in the literature (Markides 2006) after a critical review of the original concept proposed by Christensen (1997).

The expected contribution is particularly relevant since the importance of disruptive innovations has increased in the current context (Christensen 1997; Markides 2006; Tellis 2006). In contrast to
incremental innovations, these represent major transformations of existing products or technologies and often result in the prevailing product designs and technologies becoming obsolete (Chandy and Tellis 2000).

In conclusion, we expect to contribute to the current debate about how industrial clusters are able to restart their life cycles and deal with important challenges with the aim of adapting their structures and strategies to the external global conditions. The paper also aims to contribute to a broader literature inspired by the controversy regarding the differential benefits of incremental and radical or disruptive innovations, as well as their specific differences according their specific contexts.

**Theoretical framework and hypotheses**

**Proximity and innovation**

Previous literature has suggested that firms find motivation in being located near others, as they may gain some benefit from common external resources (e.g. Folta, Cooper, and Baik 2006; McCann and Folta 2008). These arguments have traditionally been conceptualized as the industrial cluster or district (Becattini 1979; Porter 1990).

In general, research on clusters assumes that by being in the same place, organizations take advantage of external knowledge exchanges, since knowledge spillovers are geographically localized and locally bound (Krugman 1991; Alcacer and Chung 2007; Jaffe, Trajtenberg, and Henderson 1993). The stocks of knowledge created through these exchanges are concentrated and, in some way, exclusively available to located actors (Bell, Tracey, and Heide 2009). Innovation becomes, in consequence, a joint action among cluster members, where diverse relationships between firms and organizations foster not only trust and other shared norms and values but also the transmission of tacit knowledge (Bell, Tracey, and Heide 2009). In fact, many contributions have attempted to describe how spatially concentrated firms capture externalities deriving from access to information and reciprocal exchanges of tacit knowledge (Waxell and Malmberg 2007; Maskell 2001). To sum up, interactions among co-located actors probably have superior outcomes related to innovation compared to interactions among distant actors (Yli-Renko, Autio, and Sapienza 2001).

Since clustered firms operate within the boundaries of a close geographical scenario, they are idiosyncratic business networks (Sorenson 2003). Proximity fosters the frequency of personal contacts, the social relations between actors and reciprocity of benefits (Roxas and Chadee 2011). Interconnections and interactions among network members are a manifestation of their relational proximity. Close and mutual relationships (strong ties) are necessary to transfer and gain access to particular information and knowledge from other firms (Hansen 1999).

**Incremental and disruptive innovations. Technological change in industrial clusters**

The specificities in clusters, as an aforementioned idiosyncratic case of networks, have implications on the type of innovation that clustered firms develop. Clusters seem to be better adapted for incremental or contextual innovation. As is well known, incremental innovations involve minor changes and modifications which are introduced in order to refine or reinforce existing products and technologies. In contrast, radical or disruptive innovations consist in significant transformations that make current products and technologies obsolete (Chandy and Tellis 2000).

Previous research has extensively analysed the concept of disruptive innovation and other similar notions with the intention of capturing the radical and discontinuous nature of some new technologies (Adner 2002; Charitou and Markides; Christensen 1997; Christensen and Reynor 2003). We are aware that the emergence of several concepts capturing similar notions hampers their identification and clear delimitation (Gatignon et al. 2002). However, leaving aside the conceptual debate, we are interested in those technologies and innovations that go beyond incremental developments or small
changes. This implies the replacement of products and technologies by new ones that can be created or (in our case) adopted by companies. In this sense, disruptive changes can broaden and develop new markets but may also disrupt existing market linkages (Adner 2006; Danneels 2004; Gilbert 2003). Thus, we adopt the proposal suggested by Markides (2006), who, on the basis of Christensen’s work (1997), distinguished between radical innovation for products and disruptive innovation for technologies. In the same vein and for the purposes of this research, we refer to disruptive innovation as a technological change that incorporates new knowledge, resources or skills which make the value of incumbent systems and technologies in the cluster obsolete, following similar concepts suggested by different authors (Gilbert 2012; Danneels 2004; Markides 2006).

In clusters, the lack of exploring capabilities to scan and respond to external and radical changes was reported in seminal work by Harrison (1994) and, in similar terms, by Glasmeier (1991), who described how the Swiss watch firms presented a vulnerability in responding to disruptive external technological changes. Most of the later research has been focused on the weakness of the strong ties in clusters (Grabher 1993), the reduced capacity to create breakthrough innovations (Chiarvesio, Di Maria, and Micelli 2010) or how clusters are able to avoid decline through disruption (Østergaard and Park 2015). However, the above line of reasoning is somehow controversial, since at least some counterexamples refute these arguments by describing cases of industrial clusters accessing new opportunities (Molina-Morales, Martinez-Cháfer, and Valiente-Bordanova 2017; Reig-Otero et al. 2014; Corò, Gurisatti, and Rossi 1998).

How clusters can overcome the limitations for generating these radical or disruptive advances has become a central research question. Previous studies have nevertheless provided some suggestions. Sammarra (2005) and Biggiero (2006) proposed a selective relocation of activities outside the cluster. And others, like Giuliani (2011), have focused on the role played by technological gatekeepers to feed the cluster with new ideas, knowledge and technologies. Being aware of the aforementioned contributions, whose approach is focused on considering the cluster as a homogeneous entity, we suggest taking a different approach grounded on the individual company level and analysing what firm characteristics or attributes lead to the early adoption of a disruptive technology. The rate at which innovations are adopted by firms constitutes an important part of the process of technological change. In fact, research focused on how both firm- and market-specific characteristics influence the decisions to adopt innovations has long been recognized as an important area of study. The diffusion theory provides different tools to assess the likely rate of adoption and diffusion of a certain technology. Numerous factors have been identified as facilitators or hinderers of the adoption and implementation of a technology. These factors include not only the characteristics of the technology but also, and more relevant for us, the characteristics of the adopters and the means by which they learn and are persuaded to adopt the technology (Rogers 1983).

Clustered firm attributes through the absorptive capacity perspective. Effects on innovation

Extensive literature has already established a positive association between internal attributes (i.e. firm’s capabilities) and firm performance (including innovation results). In the same vein, Stock, Greis, and Fischer (2001) stressed the positive relationship between the capacity to assimilate and exploit knowledge and the company’s capacity to innovate. In a cluster context, it is particularly relevant for firms to absorb and to exploit external knowledge resources from other co-located actors (McCann and Folta 2011; Ahlin, Drnovšek, and Hisrich 2014). In clusters, individual firms benefit from accessing a series of capabilities which are not exclusive to an individual organization and belong to the community. Thus, the cluster creates its own mechanisms to identify changes in the external environment and to facilitate access to new ideas or new opportunities.

Previous studies have demonstrated the existence of a common agreement in favour of a positive association between internal capacities, innovation and competitive advantage (Cassiman and Veugelers 2006; Vega-Jurado et al. 2008; Barney 1991; Teece, Pisano, and Shuen
1997; Wernerfelt 1984). In this regard, some specific findings can be found, such as the argument defended by Belso-Martínez and Molina-Morales (2013), who suggested a curvilinear effect. They argued that, instead of investing continuously in internal resources, clustered firms should find an optimal balance since, at certain levels, costs would rise more than benefits. In the same vein, Molina-Morales and Expósito-Langa (2013) suggested that the connectivity among clustered firms amplifies the curvilinear effect of the R&D effort focused on innovation.

Among firm internal capabilities as determinants of innovation, ACAP has received greater attention from scholars since the seminal work carried out by Cohen and Levinthal (1990). According to these authors, firms possessing a high ACAP would develop higher organizational learning and a better ability to apply external information and knowledge. ACAP can be considered as a firm’s ability to identify valuable external knowledge, assimilate it and apply it for commercial purposes (Escribano, Fosfuri, and Tribó 2009). ACAP has been seen as a means of new knowledge creation through the development of problem-solving skills (Kim 1998) or even as the ability to recognize and understand a potential new technology for further internal implementation (Mowery and Oxley 1995). Moreover, the additive systemic ACAP generated in clusters interacts with individual organization capacities and amplifies the potential access to and exploitation of external resources (Giuliani and Bell 2005).

The notion of ACAP as an ability to anticipate future technological advances was introduced by Cohen and Levinthal (1994). These authors suggested that investments in ACAP were associated with the ability of firms to predict technological avenues and consequently to obtain time advantages with respect to their competitors (Lane and Lubatkin 1998; Van Den Bosch, Volberda, and de Boer 1999). Following this argument, our work raises questions about the possible causal relationship between the ACAP of a company and its innovative capacity through the rate of adoption of a new disruptive technology within the context of industrial clusters. In this sense, we follow other research (Isaksen and Trippi 2016, 2017) by considering novel technologies introduced on the market as the fundamental driving force behind new paths of development.

In our work, we follow Zahra and George (2002), who distinguished between the different dimensions of ACAP, and consequently we distinguish among a set of different routines and processes by which external knowledge is acquired, assimilated, transformed and exploited. More precisely, we refer to: (a) the acquisition dimension as the ability of the firm to identify and obtain knowledge from external sources; (b) the assimilation dimension as the ability to develop processes and useful routines by understanding, analysing and interpreting externally acquired knowledge (Szulanski 1996); (c) the transformation dimension as developing and refining those routines that facilitate the combination of the existing knowledge with that which has already been acquired and assimilated for future use (Zahra and George 2002) and (d) the exploitation dimension as the capacity of a firm to improve, expand and use its existing routines, competencies and technologies to create something new based on the transformed knowledge (Del Carmen Haro-Domínguez et al. 2007).

In our case, we consider it appropriate to disaggregate the ACAP notion into these different dimensions, following authors such as Zahra and George (2002), Jansen, Van Den Bosch, and Volberda (2005) and Escribano, Fosfuri, and Tribó (2009). We agree that each dimension requires different paths of development in the organizations and that they should determine the development of differential innovative outputs (Leal-Rodríguez et al. 2014). Moreover, in the context of the industrial cluster, specific conditions that clustered firms may present and strong interactions between firms make this differentiation particularly interesting (Expósito-Langa, Molina-Morales, and Capo-Vicedo 2011).

In addition, the existence of systemic effects can affect the different ACAP dimensions in several ways, as we will try to justify in the following sections. Indeed, specific cluster peculiarities such as proximity, interactions or cooperation, among others, condition the behaviour of these dimensions. Zahra and George (2002) defined and distinguished between two different dimensions of ACAP.
Under this perspective, knowledge acquisition and assimilation capacities are identified as potential ACAP, while knowledge transformation and exploitation are considered as realized ACAP. Potential ACAP has been defined as the ability to identify and evaluate new knowledge flows (Escribano, Fosfuri, and Tribó 2009). It leads the firm to renew its knowledge base and skills, consequently favouring its flexibility. This first dimension allows companies to reconfigure their bases of resources in order to adapt to new emerging opportunities (Zahra and George 2002).

Realized ACAP has been defined as the capability of firms to benefit from the external knowledge flows (Escribano, Fosfuri, and Tribó 2009). This second dimension comprises transformation capabilities (which enable firms to develop new processes or to add changes to existing ones) and exploitation capabilities (which enable firms to finally convert knowledge into new products and consequently enhance their performance and competitive advantage) (Zahra and George 2002).

**Hypotheses**

**Potential ACAP and technology adoption in clusters**

The acquisition of external knowledge refers to the ability of a company to locate and acquire knowledge that is critical for its activity from external sources. This first dimension of identification corresponds to the notion of competitive scanning (McEvily and Zaheer 1999), which has been associated in the literature with the innovative capacity of the company. The development of this capacity implies a continuous control and analysis of the environment to detect opportunities and threats. The capacity for acquisition is influenced by several factors such as the prior knowledge that the company has (Cohen and Levinthal 1990), recent scientific research and the effort devoted to generate routines for the acquisition of knowledge (Zahra and George 2002).

On the other hand, belonging to an industrial cluster conditions the way in which firms identify external knowledge. In many cases these companies do not access external sources directly, but do so through intermediaries. The existence of a series of local institutions, dedicated to supporting the cluster as a whole, and sometimes the leading companies themselves serve as links between internal-to-the-district companies and the external environment (Malipiero, Munari, and Sobrero 2005). In this way, internal companies can benefit from a low-level cost and high quality exploration activities, since they usually have systematic contacts with various external circles, other industries, other innovation systems, and so forth.

In short, the existence of intermediaries can affect both the quality and the focus of the searching activities of clustered firms. Undoubtedly, the ability to identify knowledge from external sources carried out by the district requires a complementary capacity of absorption by the individual company. The larger and better the firm’s sources of information are, the greater the firm’s possibilities for exchanging and combining useful knowledge will be, and therefore the greater the capacity to create and develop new products is.

The assimilation of knowledge involves coupling novelties with the company knowledge base. External knowledge is found in specific contexts, which mostly make it difficult to understand and replicate outside the scope in which this knowledge has been generated. Therefore, it is crucial for the company to be provided with internal processes that make all this knowledge useful and available to the organization (Teece 1981). For Nelson and Winter (1982) this process of assimilation is highly influenced by the tacit knowledge of the company, based on experience, know-how and other similar values, which distinguish it from explicit or codified knowledge. In the particular case of industrial clusters, the dimension of assimilation of knowledge benefits from the access to and exchanges of tacit knowledge within it.

The individual company has some instruments for these assimilation processes. For example, information technologies provide systematic processes of acquisition, storage and dissemination of organizational knowledge. Proximity, direct (formal and informal) relationships among people and organizations, and high mobility of technicians and employees within the district are elements that allow emulation and tacit knowledge acquisition that is difficult to acquire in other circumstances.
(Tallman et al. 2004). However, despite these externalities, the routines and processes manage knowledge and allow the generation of new products or adoption of new technologies occur, at the level of individual companies, by interacting with the aggregate level. We can, therefore, consider that the greater the firm’s capacity for assimilation of external knowledge is, the greater its capacity will be to develop new products and technologies. In short, the assimilation of external knowledge is a key element in the innovation processes, and more specifically in the innovation processes of industrial clusters. Considering the theoretical development outlined above, we can expect Potential ACAP to have a positive effect on clustered firms by enabling them to be early adopters of the new technology. In other words, it will allow them to adopt and introduce the technological change in a moment when it may provide them with a higher competitive advantage. A new technology could improve manufacturing processes and/or services offered by reducing cost or time, enhancing quality or flexibility, etc. Early adoption of the disruptive technology can be expected to enable new and important opportunities for clustered firms to improve their performance. This can be expressed more formally as the following hypotheses in relation to the two dimensions of Potential ACAP:

H1.1: Clustered firms having a high acquisition capacity increase their odds of being early adopters of disruptive technologies.

H1.2: Clustered firms having a high assimilation capacity increase their odds of being early adopters of disruptive technologies.

Realized ACAP and technology adoption in clusters

In their research, Cohen and Levinthal (1990) emphasized the importance of the application of assimilated knowledge. The exploitation dimensions refer to the routines that allow a company to perfect, expand and exploit existing skills, or create new ones, by incorporating the knowledge identified and analysed in their activity (Tiemessen et al. 1997). This involves internalizing the previously created knowledge to develop and obtain, as a result, new products, processes, knowledge or new organizational forms (Spender 1996). During this phase, high-quality information is required, and the ability of organizations and internal units to share and cooperate with other units and organizations acquires a prominent role.

In the context of industrial clusters, the literature has clearly proved how close contacts between organizations belonging to the same cluster generate a dense network of relationships. This density and recurrence in relationships provides organizations with a set of shared norms and values (for example, trust) that regulate exchanges of knowledge resources (Uzzi 1996, 1997). In contrast to other characterizations, dense networks are more efficient in the processes of continuous improvement which are linked to strategies for exploiting knowledge resources (Rowley, Behrens, and Krackhardt 2000). However, as the company networks of relationships are heterogeneous and distinctive, the companies in the district will present different capacities to exploit external sources of knowledge. Thus, the greater the capacity for exploitation generated by the network of relationships of the individual company is, the greater its innovative capacity will be.

In clusters, the exploitation capacity of the individual firm may positively affect its capacity to innovate. Clustered firms receive a large amount of knowledge and other resources from the other members of the cluster. In consequence, innovation performance primarily depends on the individual firm’s capacity to exploit these external knowledge resources. Therefore, we would expect a positive relationship between internal resources and capacities and innovation. More precisely, in line with what we stated in the previous hypotheses, we can expect Realized ACAP to have a positive effect on clustered firms in the sense of enabling them to be early adopters of the new technology. Accordingly, we can formulate the following hypotheses based on the different dimensions of Realized ACAP:
H2.1: Clustered firms having a high transformation capacity increase their odds of being early adopters of disruptive technologies.

H2.2: Clustered firms having a high exploitation capacity increase their odds of being early adopters of disruptive technologies.

All four hypotheses are summarized graphically in Figure 1, which illustrates our analytical framework.

**Empirical setting**

**Context of the research**

The empirical study is focused on the Spanish ceramic tile cluster. This cluster, which has previously been identified as a paradigm of a Marshallian-type industrial cluster (Boix 2009; Molina-Morales and Martínez-Fernández 2009; Reig-Otero et al. 2014), is located in the province of Castelló (Spain). Comprising an approximate area of 200 km$^2$, the cluster is defined by its main activity, which is the production of ceramic wall and floor tiles.

This territorial entity, which is mainly composed of small-sized firms, is considered as the Spanish locus of ceramic tile production. Around a hundred ceramic tile manufacturing companies are located in this area and they produce over 95% of the total Spanish production of ceramic tiles. In 2016 this represented a sales volume of 3,300 million euros, and provided 15,000 direct jobs according to ASCER.

The cluster comprises not only end-product firms, those which produce ceramic wall and floor tiles, but also other related firms devoted to other activities in the ceramics value chain. Integrated firms and also specialized firms are considered important active members of the cluster. In this group of firms, the glaze industries are considered the most important actors not only from a value creation point of view but also from the perspective of cluster knowledge supply. In this sense, the cluster has been identified by different authors as supplier-dominated, according to Pavitt’s (1984) classic taxonomy (Flor and Oltra 2004; Belso-Martinez, Molina-Morales, and Mas-Verdu 2011). In fact, according to ANFFECC$^2$ this sub-sector achieved a sales volume of 1,200 million euros in 2016 and provided 3,700 direct jobs. Finally, together with these different kinds of firms, the cluster is also made of a number of local, regional or even national institutions and organizations which support the development of the cluster, mainly in terms of technological and business knowledge. Table 1 provides detailed information about the different actors comprising the cluster.
The Spanish cluster experienced a disruptive innovative phenomenon based on a radical change in the way of printing ceramic tiles, namely, the digital printing technology. As widely described by Molina-Morales, Martínez-Cháfer, and Valiente-Bordanova (2017), this innovation, which was introduced into the cluster by a visionary agent, changed the value chain of the ceramic tile business, first in the Spanish ceramic tile cluster and later in the ceramic tile manufacturing industry worldwide.

**Data collection for the analysis**

This research is grounded on primary data collected at the firm level from the Spanish ceramic tile cluster. Due to the fact that this study is focused on the adoption of an innovation (the digital printing disruptive technological innovation), data come exclusively from the so-called end-product firms (those firms which perform the cluster’s defining activity and are able to introduce the new printing technology in their manufacturing processes). Other different cluster members such as specialized or integrated firms are, consequently, excluded from the present research.

| Cluster members               | Member description                                                                 | Specific cluster activity                                                                 |
|------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| End-product firms            | Firms carrying out the cluster’s defining activity                                | Ceramic wall and floor tile manufacturers                                               |
| Specialized firms (supporting firms) | Firms involved in supply activities for end-product firms                        | Glaze industries, chemical additives manufacturers, ceramic machinery and equipment suppliers, atomized clay producers, etc. |
| Integrated firms             | Firms performing activities belonging to other industries but integrated in the cluster | Industrial services, project services, shipping and road transport services, design and marketing services, packaging services, etc. |
| Institutions and organizations | Entities which support the cluster                                                 | Educational centres, research institutes, trade associations, etc.                      |
Data collection was carried out through a survey based on a structured questionnaire. The selection of the respondents’ profiles was, at this point, relevant, taking into account the information we intended to gather. The survey was aimed at members of the organization having appropriate knowledge regarding not only the specific peculiarities of the adoption process that had occurred in the company but also the general innovative profile and characteristic innovative dynamics of their respective companies. For this reason, the survey largely targeted CEOs or R&D managers. These respondents had first-hand information about how the innovation under study was detected (or not), as well as on how it was introduced into the organization, if this was the case (Figure 2). To a lesser extent, some questionnaires were answered by different profiles of respondents directly involved in the process of adopting the innovation and, consequently, in possession of the detailed information required (e.g. marketing managers or technical production managers).

The survey was conducted in two rounds between October 2016 and December 2017 and finally we were able to gather 75 completed questionnaires from a total population of the 118 end-product firms present in the Spanish ceramic cluster at that time. In order to extend the characterization of the cluster firms, business and performance information was also gathered from the SABI database (Iberian Balances Analysis System). In more detail, year of foundation as well as data regarding total assets, total revenues and number of employees were gathered for the companies from 2007 until 2013. This period of time was selected so as to cover a representative period around 2010 in accordance with our definition of the dependent variable. This information will allow us to build two of our control variables, as described in the following section.

**Methodology and variables**

To test our hypotheses, we computed a Binomial Logistic Regression (LOGIT) performed with the SPSS software package. This model enables us to explore the association of ACAP-related factors with the fact of being an early adopter firm. Hence, the model can be written as follows:

\[
\text{Early adopter} = \alpha + \beta_1 \text{ACAP}_{AC} + \beta_2 \text{ACAP}_{AS} + \beta_3 \text{ACAP}_{TR} + \beta_4 \text{ACAP}_{EX} + \beta_5 \text{TIO} + \beta_6 \text{OIO} + \beta_7 \text{SIZE} + \beta_8 \text{AGE} + \mu
\]

In Table 2, we describe all the main variables included in the LOGIT method that we used in this research. All the items used in the survey to build the variables are listed in Appendix A together with additional details and justification. The descriptive indicators for the dependent, control and independent variables are reported in Tables 3 and 4.

| Table 2. Variables. | Name of the variable | Type of variable | Description |
|---------------------|----------------------|-----------------|-------------|
| Early adoption      | Dependent            | This is a dichotomous variable. Its value is 1 when the company adopted the inkjet technology in 2010 or before and 0 otherwise. |
| Size of the company | Control              | Factor analysis of total assets, total revenues and number of employees (Cronbach’s alpha = 0.691; KMO = 0.864). |
| Age of the company  | Control              | Calculated by subtracting the year of the company’s foundation from 2017. |
| Orientation to technological innovation | Control | Factorial analysis concerning five items from our survey about product development and processes (Cronbach’s alpha = 0.860; KMO = 0.825). |
| Orientation to organizational innovation | Control | Factorial of eight items from our survey about organizational and marketing activities (Cronbach’s alpha = 0.929; KMO = 0.868). |
| Absorptive capacity – Acquisition (ACAP\_AC) | Independent | Factorial of three items concerning the previously described acquisition dimension of ACAP (Cronbach’s alpha = 0.819; KMO = 0.695). |
| Absorptive capacity – Assimilation (ACAP\_AS) | Independent | Factorial of four items regarding this particular dimension (Cronbach’s alpha = 0.925; KMO = 0.839). |
| Absorptive capacity – Transformation (ACAP\_TR) | Independent | Factorial analysis that comprises four items about transformation activities (Cronbach’s alpha = 0.957; KMO = 0.869). |
| Absorptive capacity – Exploitation (ACAP\_EX) | Independent | Three items about exploitation that are reduced to one dimension with a factorial analysis (Cronbach’s alpha = 0.817; KMO = 0.650). |
Results

The results show a general model that exhibits an 80% of correctness considering a cut-off value of 0.5. As we can see in Table 5, the model can correctly predict 60 cases out of a total of 75 that completed our data. Additionally, in this section we also report other significant indicators of the model that can be observed in Table 6.

Regarding the significance of the control variables (see Table 7), we observe how two control variables exert a positive and significant effect on the probability of being an early adopter of the technological innovation. On the one hand, the age of the company has an EXP (B) coefficient of 1.082, indicating that companies with more general experience in the market can multiply their probability of early adoption by this coefficient. On the other hand, companies with a high orientation on technological innovation can also multiply their probability of being early adopters.

| Table 3. Descriptive statistics of the dependent variable. |
|-----------------|-----------------|----------------|-----------------|
|                  | Code | Frequency | Percentage | Cumulative percentage |
| Adaptors after 2011/non-adopters | 0    | 24         | 32.0        | 32.0              |
| Adaptors before 2010 (included)   | 1    | 51         | 68.0        | 68.0              |
| Total                          |      | 75         | 100.0       |                   |

| Table 4. Descriptive statistics of the control and independent variables. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | N       | Mean   | Median | Mode    | S. Deviation | Variance | Range   | Minimum | Maximum |
| Size of the company | 75      | 0.00   | −0.28  | −0.49   | 1.00        | 1.00     | −0.48   | 7.14    | 7.48    |
| Age of the company  | 75      | 35.53  | 31.00  | 17.00   | 21.13       | 446.33   | 101.00  | 3.00    | 104.00  |
| Technological innovation orientation | 75      | 0.00   | 0.32   | 0.78    | 1.01        | 1.01     | 2.79    | −2.02   | 0.78    |
| Organizational innovation orientation | 75      | 0.00   | 0.58   | 0.83    | 1.01        | 1.01     | 2.59    | −1.76   | 0.83    |
| Acquisition         | 75      | 0.00   | 0.03   | 1.16    | 1.01        | 1.01     | 4.63    | −2.89   | 1.74    |
| Assimilation        | 75      | −0.01  | 0.14   | 0.14    | 1.00        | 1.00     | 4.96    | −3.33   | 1.63    |
| Transformation      | 75      | −0.01  | −0.05  | 0.11    | 1.00        | 1.01     | 6.09    | −3.83   | 2.26    |
| Exploitation        | 75      | −0.01  | 0.22   | 1.09    | 1.00        | 1.01     | 4.38    | −2.64   | 1.75    |

| Table 5. The observed and predicted frequencies for Early Adoption in the Logistic Regression. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | Observed | Predicted | Correct (%) |
|                  | NO   | YES | NO | YES | NO | YES | NO | YES | 70.8 | 84.3 | 80.0 |
| NO               | 17   | 7   | 70.8 |
| YES              | 8    | 43  | 84.3 |

| Table 6. General significance of the Binomial Logistic Regression (LOGIT). |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | Chi-squared     | df    | Sig.  | R² (Cox & Snell) | R² (Nagelkerke) |
| Model            | 30.173          | 8     | 0.000 | 0.331            | 0.464           |

| Table 7. Binomial Logistic Regression results (LOGIT). |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | B                | Std. Error      | Wald            | df              | Sig.            | Exp(B)          |
| Intercept        | −1.443           | 0.780           | 3.423           | 1               | 0.064           | 0.236           |
| Size of the company | −0.166          | 0.421           | 0.155           | 1               | 0.693           | 0.847           |
| Age of the company | 0.079           | 0.026           | 9.285           | 1               | 0.002           | 1.082           |
| Technological innovation orientation | 1.555          | 0.612           | 6.451           | 1               | 0.011           | 4.737           |
| Organizational innovation orientation | −0.421         | 0.664           | 0.402           | 1               | 0.526           | 0.656           |
| Acquisition      | −0.290           | 0.462           | 0.394           | 1               | 0.530           | 0.748           |
| Assimilation     | 0.129            | 0.412           | 0.099           | 1               | 0.754           | 1.138           |
| Transformation   | −0.278           | 0.400           | 0.480           | 1               | 0.488           | 0.758           |
| Exploitation     | 0.795            | 0.435           | 3.337           | 1               | 0.068           | 2.215           |
by 4.737. The rest of the control variables that we have considered (size of the company and orientation towards organizational innovation) both have negative, although not significant, coefficients on the regression.

In relation to the independent variables and regarding the different dimensions of ACAP, the results show how the exploitation dimension has a positive and significant effect on the dependent variable. Companies that perform exploitation-related activities have more than twice as much chance of being early adopters, as suggested by the EXP (B) coefficient. However, this is the only dimension of ACAP that affects the dependent variable in such a positive manner. Acquisition, assimilation and transformation activities do not seem to be relevant for our sample of tile producer companies when it comes to adopting the technology earlier. This distribution of significances among the different dimensions also has some implications if we consider the separation between potential and realized ACAP. In fact, our results indicate that tile manufacturers benefit from doing internal activities that aim to enhance their realized rather than their potential ACAP. Hence, our results do not confirm H1, concerning the positive effects of the potential ACAP, and partially support H2, which refers to the realized ACAP.

**Discussion of results and conclusions**

This article has attempted to determine the effect of ACAP on innovation through the adoption of a disruptive technological innovation in the context of an industrial cluster. By doing so, we aimed to provide a better understanding of the factors determining the earlier adoption of a disruptive technology by firms in an industrial cluster. The ACAP model has been studied through the potential (exploring) and realized (exploiting) domains, consequently distinguishing among the four dimensions proposed by Zahra and George (2002), namely acquisition, assimilation, transformation and exploitation.

Undoubtedly, the analysis of the association between individual attributes and exploration/exploitation activities concerning new technologies was not at all novel (McDermott and O’Connor 2002). However, adapting the ACAP perspective to clustered firms is, as far as we know, a relatively undeveloped avenue of research. Moreover, in our opinion, the study of the different factors comprising ACAP may contribute to clarify the innovative dynamics in clusters.

It must be mentioned that, whereas Hypotheses 1.1, 1.2 and 2.1 were not confirmed, Hypothesis 2.2 was statistically supported. This result suggests that the early adoption of a disruptive technology is not fostered by the acquisition and assimilation capacities of firms when they belong to a cluster. In other words, potential ACAP does not seem to have a clear effect on the early adoption of a technological novelty for clustered firms. Furthermore, the fact that the variable indicating the transformation capacity is not significant stresses its irrelevance for a clustered firm in the early adoption of a distant technological innovation. Conversely, the analysis shows how exploitation capabilities have a significant influence on this adoption.

What our study reveals and, in our opinion, what constitutes its main contribution is the uneven effect of the potential (exploring) and realized (exploiting) domains of the ACAP model on the early adoption of disruptive technologies for clustered firms. Network peculiarities and proximity in these kinds of territorial organizations may be underlying this result.

Our results confirm that it makes sense to draw a distinction between the two dimensions of ACAP. This means that potential absorptive capacity does not seem to have a clear effect on the early adoption of a technological novelty for clustered firms. Firms belonging to a cluster have access to a number of systemic capacities that can cover their need for acquisition and assimilation capacities.

This research is relevant for many reasons, some of which may be the importance of industrial clusters as a regional development phenomenon, the predominant focus of previous research (mainly based on the dynamics of adopting incremental innovations) and the current challenges facing territorial agglomerations (aiming to adapt their structures and strategies to the external global conditions (Cooke, Parrilli, and Curbelo 2012)). Disruptive technologies and innovation can be
understood as possible alternatives for survival and for the further development of clusters (Østergaard and Park 2015). Moreover, the factors that once explained clusters’ success can today become their main threat and restraint. Indeed, clusters’ relational structure – which is far more appropriate for incremental technological improvements than radical or disruptive ones (Maskell 2001) – or other related factors such as a leadership vacuum for the change or the resistance coming from core members of the cluster (Pinkse, Vernay, and D’Ippolito 2018) may prevent the introduction and development of breakthrough novelties into clusters, consequently thwarting to some extent their potential renewal.

As we understand things, and in contrast to what might happen in other contexts, proximity between firms in clusters may affect the mechanisms for introducing (and afterwards exploiting) new technologies or external knowledge. Dense and recurrent relational structures in clusters lead individual organizations to share norms and values that regulate exchanges of knowledge resources (Uzzi 1996, 1997). This peculiarity transforms clusters into efficient contexts for continuous improvement processes, linked to the exploitation strategies of knowledge resources (Rowley, Behrens, and Krackhardt 2000). In addition, individual companies are heterogeneous and distinctive, so they will vary their capacity to exploit external sources of knowledge coming from the other members of the cluster. The interactions between cluster and individual firm levels can be relevant in a close relational context. The finding that the dimensions of ACAP differentially influence innovation in a clustered firm contrasts with the way they have traditionally been regarded as a full benefit to organizations (Veugelers 1997; Stock, Greis, and Fischer 2001). An established stream of research contains a number of examples which are worth mentioning (Belso-Martinez, Molina-Morales, and Mas-Verdu 2013; Expósito-Langa, Molina-Morales, and Capo-Vicedo 2011). In both these studies, ACAP was analysed as a factor to create innovative capacity in firms. Even though several researchers have suggested that some dimensions of ACAP could have a downside, our findings are particularly important to extend the existing literature. In fact, the different contributions of the dimensions of ACAP in a cluster context are, in our opinion, understudied and open a new line of research to better understand the internal efforts performed by firms. Clustered firms may benefit from those cluster externalities which are focused on exploring new technologies, consequently focusing their efforts on carrying out exploitation of the innovations.

The practical implication of our findings is for both the cluster and the individual firm levels. In order to foster adaptation and renewal, clusters should establish systematic mechanisms to detect and introduce new and exclusive ideas through cluster networks. On the other hand, first, clustered firms should develop their own portfolio of abilities to enhance their interaction with the actors in clusters and take advantage of the exchanged knowledge that naturally flows throughout the agglomeration. As a matter for further discussion, we suggest that, in order to access external sources of new and exclusive knowledge, firms in districts can use indirect ties by means of intermediary agents (Molina-Morales and Martínez-Fernández 2004). In particular, local institutions and supporting organizations are relevant actors in territorial networks that provide external scanning abilities for the cluster (Molina-Morales, Martínez-Cháfer, and Valiente-Bordanova 2017).

Second, they should concentrate especially on developing exploiting capabilities since, as our results suggest, they will play an important role in being able to benefit from a novelty and this is not easily obtained from the cluster. Commercial exploitation of new knowledge (through, for instance, the development of prototypes, the fast adaptation of existing technologies to upcoming knowledge or efficient work when adopting new technologies) would provide companies with a differential ability to obtain early advantage from it.

In short, our results highlight the importance of identifying the relevant dimensions of the ACAP in a certain cluster as not all of them have the same impact on the firm’s development of competitive advantage. Consequently, developing the management areas in relation with those
dimensions of ACAP that have a major influence on innovative performance can be crucial for the competitiveness of clustered firms.

We are aware that our research has some limitations. They are related with the specific conditions that are developed in the cluster, which were probably acting as a moderator of these causal relationships. On the other hand, only one industry has been analysed and, more precisely, just one type of cluster configuration has been studied. The Spanish ceramic tile cluster can be considered as supplier dominated, according to the taxonomy proposed by Pavitt (1984). In this sense, clustered firms are so particular and specific conditions are so difficult to replicate that general conclusions can be biased. We acknowledge the need to apply this approach to other contexts not only belonging to the same part of the taxonomy but also to different ones (production-intensive or science-based clusters (Pavitt 1984)). Comparison of similarities and dissimilarities among them would strengthen the results of the research and conclusions would gain broader validation. In this way, we would be able to observe whether or not the important ACAP dimensions correspond to the intrinsic cluster dynamics or typology.

The following points can also be viewed as possible future avenues of research for the development of this study. The fine-grained process through which network structure is created or modified is an interesting and important area for future research. It is critical to know to what extent firms are externally conditioned or, on the contrary, they have a degree of freedom to decide the pattern of internal interactions within the cluster. Another fruitful area of inquiry is the dynamics of how firms’ networks evolve and change in response to external challenges and new opportunities, such as a disruptive technological innovation.

Notes

1. Spanish Association of Wall and Floor tiles manufacturers. Data in this section come from ASCER website http://www.ascer.es checked on April, 2018.
2. Spanish Association of frit, glaze and ceramic colour manufacturers. Data in this section come from ANFFECC website http://www.anffecc.com/es/ checked on April, 2018.

Acknowledgments

This work was supported by the Spanish Ministry of Economy and Competitiveness under Grant [ECO2015-67122-R].

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Spanish Ministry of Economy and Competitiveness under Grant [ECO2015-67122-R].

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Appendix A

Additional details and the list of items used in the survey for building the variables are:

**Early Adoption**

This is a dichotomous variable. Its value is 1 when the company adopted the inkjet technology in 2010 or before and 0 otherwise. We established 2010 as the cut-off year because different technical and business events (produced mainly between 2008 and 2010) led to a general feeling at that time that the disruptive innovation had been successfully introduced, developed and adapted in the cluster. There was no doubt from that point on that technological change would be a matter of time and diffusion of the new printing technique would be quite fast. In consequence, we consider early adopters as those firms which decided to adopt the novelty before all uncertainties and resistances were removed.

**Absorptive Capacity**

For the purposes of the present research, a multidimensional measure of ACAP was chosen. In more detail, we adopt the scale proposed by Flatten et al. (2011). 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 pre-tests 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 (Flatten et al. 2011). The four-factor ACAP measure is made up of 14 items, each of them based on an 11-point Likert scale (0: strongly disagree to 10: totally agree) grouped as follows: (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. Each dimension is measured as follows:

**Absorptive capacity – Acquisition**

Use of external resources to obtain information (e.g. personal networks, consultants, seminars, internet, database, professional journals, academic publications, market research, regulations, and laws concerning environment/technical aspects/health/security):

- Acquire 1. The search for relevant information concerning our industry is every-day business in our company.
- Acquire 2. Our management motivates employees to use information sources within our industry.
- Acquire 3. Our management expects employees to deal with information beyond our industry.

**Absorptive capacity – Assimilation**

Communication structure in your company:

- Assimilate 1. In our company ideas and concepts are communicated cross-departmentally.
- Assimilate 2. Our management emphasizes cross-departmental support to solve problems.
- Assimilate 3. In our company there is a quick information flow, e.g. if a business unit obtains important information, it communicates this information promptly to all other business units or departments.
• Assimilate 4. Our management demands periodical cross-departmental meetings to interchange new developments, problems and achievements.

**Absorptive capacity – Transformation**

Knowledge processing in your company:

• Transform 1. Our employees have the ability to structure and to use collected knowledge.
• Transform 2. Our employees are used to absorbing new knowledge as well as preparing it for further purposes and making it available.
• Transform 3. Our employees successfully link existing knowledge with new insights.
• Transform 4. Our employees are able to apply new knowledge in their practical work.

**Absorptive capacity – Exploitation**

Commercial exploitation of new knowledge in your company (NB: Please think about all company divisions such as R&D, production, marketing and accounting):

• Exploit 1. Our management supports the development of prototypes.
• Exploit 2. Our company regularly reconsiders technologies and adapts them according to new knowledge.
• Exploit 3. Our company has the ability to work more effectively by adopting new technologies.

**Orientation towards technological innovations**

In accordance with the product and process innovation questions of the Community Innovation Survey on Spanish manufacturing firms (PITEC), we asked respondents to specify whether their company is 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.

**Orientation towards organizational innovations**

In accordance with the product and process innovation questions of the Community Innovation Survey on Spanish manufacturing firms (PITEC), we asked respondents to specify whether their company is aligned with the following statements:

• During the last three years, the company has introduced new practices to improve work organization in the company.
• During the last three years, the company has introduced new methods to improve the attribution of responsibilities and decision-making.
• During the last three years, the company has introduced new practices to improve the external relationships with other companies and institutions.
• During the last three years, the company has introduced new practices to improve knowledge management (internal or external knowledge).
• During the last three years, the company has introduced significant changes into the design or packaging of products.
• During the last three years, the company has introduced new channels or techniques for product promotion.
• During the last three years, the company has introduced new practices to improve the positioning of products in the market or in the sales channels.
• During the last three years, the company has introduced new practices for pricing products.