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# Are technology gatekeepers constraining my cluster? Unfolding radical changes in clusters

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Abstract

Which type of firms do create knowledge in clusters through the different stages of the cluster life cycle? Industrial district literature assumes that large leading firms with high absorptive capacity and high-intensity R&D expenditures, i.e. technology gatekeepers, do shape the district learning process. This paper challenges this assumption introducing in the conversation two important moderators. First, the type of knowledge created (continuous vs radical) by technology gatekeepers and, second, the stage of the cluster life cycle (CLC) at which that knowledge is created. This work tackles the technological gatekeepers and the cluster life cycle in conjunction, trying to push the knowledge about firms, the learning process and the knowledge creation in industrial districts, in order to understand better how clusters evolve and get renewed. Results show that there are temporary technological gatekeepers taking the role of leaders and bringing disruptive knowledge sourced from other clusters and distant non-related industries. The study presents implications for scholars and policymakers

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**Are technological gatekeepers constraining my cluster? Unfolding radical changes in clusters**

**New version!**

**Abstract: the e**conomic geography literature assumes that large leading firms (technology gatekeepers ) (TGs) with high absorptive capacity and high-intensity R&D expenditures, shape the district learning process. However, there is an absence in the literature of a dynamic analysis of the role of the TG. Instead, most of the evidence provided is set at a single point in time and considers only one stage of the cluster life cycle (CLC). This paper challenges the aforementioned assumption, and introduces into the discussion two important influences on outcomes: the type of knowledge created (whether it be continuous or radical) in the cluster by technology gatekeepers, and the stage of the cluster life cycle (CLC) at which that knowledge is created. This work addresses the roles of the TG and the CLC together, responding to the gap that not much is known about the role and the persistence of the TG dynamically across different stages of the cluster life cycle. Using qualitative longitudinal case-study research, a world-class cluster is analyzed over its last twenty years. The results show that there are temporary technological gatekeepers across the cluster life cycles which take the (temporary) role of leaders when it is a question of bringing in disruptive knowledge. The study's findings have important implications for scholars and policymakers.

**Key words**: technological gatekeepers, cluster life cycle, clusters, radical knowledge, spin-offs.

## 1. Introduction

This paper tells a story about a technology disruption which challenges assumptions in the industrial district[1] (ID, hereinafter) literature. The paper attempts to answer the question of how clusters evolve, change and reinvent themselves, focusing especially on the role of technology gatekeepers (TGs, hereafter). Most works on TGs have been set at a single point in time (e.g. Morrison, 2008), and little research has been undertaken on gatekeepers over an extended period, with two exceptions (Giuliani, 2011 and Graf and Krüger, 2011). This is the case despite the existence of a rich stream of research analyzing the cluster life cycle (CLC hereafter) (e.g., Menzel and Fornahl, 2010). In fact, the majority of studies about technology gatekeepers are contextualized at central stages of a cluster's life cycle (e.g., Giuliani, 2011; Morrison, 2008), and there is little in the literature that analyses their roles across a life cycle, helping "push" a cluster froma mature stage to a renewal stage. This study aims to fill this gap.

[1] This paper recognizes "social" differences between industrial districts and clusters, although we refer to both terms throughout the text indistinctively.

The study aims first and foremost to answer the following question: which types of firms create knowledge at the different stages of a cluster's life cycle? Most of the literature on IDs assumes that the main providers of knowledge are TGs, i.e. focal firms which orchestrate networks and access external flows of knowledge (Allen, 1977). TGs carry out two key functions for a cluster's innovation system: sourcing knowledge from outside the cluster and then diffusing that knowledge within the local system (Allen, 1977; Giuliani, 2005). Therefore, most of the research conducted on TGs assume that large leading firms, with high absorptive capacities and high R&D expenditures, shape a district's learning process (e.g. Lorenzoni and Lipparini, 1999; Morrison, 2008) by making significant investments in searching, learning and diffusing knowledge within their own networks for the purpose of maximizing profits. However, this argument does not hold up when the linearity of such a TG-led learning process is challenged by considering the effects of two important influences, namely: first, the influence of type of knowledge that TGs create, and, second, the influence of the particular stage of the cluster*'s* life cycle at which the aforementioned knowledge creation and diffusion process occurs.

The aforementioned literature implicitly assumes circumstances of continuous (i.e. non-radical) innovation generation in a context where TGs seek to maintain a central position in inter-firm networks. Radical or breakthrough innovations can be based on novel technologies (new to the firm) or emergent technologies (new to the entire industry)[2]. Bower and Christensen (1995) defined disruptive technologies as those which "bring to a market new value propositions. While TGs are supposed to maintain stable and high-quality linkages (Lorenzoni and Lipparini 1999; Giuliani, 2011:1339-40) a potential technological disruption in the cluster could alter the status quo. When a TG is dominant in a cluster it focuses research and knowledge creation to its own benefit (Agrawal and Cockbrun, 2003), and whole networks could be locked-in to a particular knowledge paradigm. Consequently, as Gargiulo and Benassi (2000) point out, cluster firms embedded in stable local networks can be trapped in their own net due to the fact that technological breakthroughs or radical changes could threaten the existing power of TGs (Allarakhia and Walsh, 2010). This argument is confirmed in the entrepreneurship and strategic management literature, contradicting the economic

[2] See Ahuja and Lampert (2001) for a discussion, extension and deep analysis of the terms.

geography assumption that has characterised TGs as firms which lead and shape learning in IDs (e.g., Lazerson and Lorenzoni, 1999, Lissoni, 2001). TGs as incumbent firms are more engaged in providing incremental improvements to existing products while small new entrepreneurial firms are the ones which create radical innovations (Baumol, 2004), which incumbents are unable to challenge (Christensen 1997).

The literature about the different stages of the CLC (e.g. Menzel and Fornahl, 2010), however, has established that knowledge is more heterogeneous in the early stages and, then, after a shake-up process has quietened down, cluster maturity occurs, leading firms become dominant, the knowledge heterogeneity is reduced, and the leading firms head the cluster knowledge and learning process. Most of the works on TGs (e.g., Morrison, 2008; Albino et al., 1998) are focused on clusters that are at a central stage of their life cycle when there are few new entrants and when knowledge is more homogenous, and the context is one where continuous (rather than radical) innovation is the norm. Other studies on TGs focus on single points in time (e.g. Morrison, 2008) and no analysis of the CLC is carried out. This produces the problem that consequently little is known about whether existing TGs will continue as TGs in the following stages of a CLC: whether they will be bearers of renewal or decline. In fact, there are few articles addressing these later stages of the CLC (e.g. Grabher, 1993). Indeed, to the best of our knowledge, there are neither articles discussing the role of the TG at the renewal stage of a CLC, nor are there ones that address explicitly the theoretical cross-fertilization between TGs and the CLC. Put differently, when it comes to the issue of renewing a cluster, not much is known about which TGs are involved, how active they are, and what their roles are. Indeed, are the TGs the same firms at different CLC stages?

Thus, this paper addresses an important paradox. While TGs play an important role as knowledge leaders , they have no incentive to alter the status quo by promoting new technologies which threaten their own roles in clusters. In fact, the literature says that new knowledge is created by new entrepreneurial firms. Without new knowledge the cluster cannot be renewed, and eventually it may face lock-in and decline. Consequently, the question is who can act as technology gatekeepers that contribute to renewing clusters before they decline? By drawing on a range of literatures, including that focussed on economic geography, as well as others concerned with entrepreneurship, management and technology strategies, this article develops an integrated perspective.Through such a perspective we look at the roles of technological gatekeepers in cluster life cycles, in order to better understand the mechanisms which dynamically shape the learning process and how clusters evolve. In addition, we specifically focus on the renewal stage in the CLC extending knowledge about the learning process at that point. We also provide novel insights about different type of TGs and the new technological trajectories which open up a cluster's knowledge architecture.

This paper considers the interplay between technological discontinuities, cluster dynamics and external (to the cluster) sources of new knowledge. The study supports the findings of previous research that incumbent firms are often unable to adapt to the impact of new knowledge and that small entrepreneurial firms are the major sources of radical innovations. The major contribution lies in the finding that the renewal stage of the CLC fosters the establishment of new and complementary TGs, challenging the established assumptions about the role of TGs in clusters. In addition, the paper extends the concept of external linkages by providing a different approach, one in which the actors which exchange knowledge and information are from non-related industries. By accessing radical knowledge a cluster avoids potential knowledge lock-in and opens itself up to new paradigms which could potentially serve to promote a general rejuvenation and reinvention.

This paper is based on a qualitative longitudinal case-study of how the Castellon ceramics cluster in Spain has evolved over the last twenty years. The objective has been to first describe the cluster's initial stages, and then the subsequent consolidation of a technological discontinuity together with the evolution of the TGs. After this introduction, section 2 addresses the theoretical treatment of technology gatekeepers and spin-off processes. Then, in a third section, the paper considers the issue of different cluster life cycles. In a fourth section, the qualitative case study is presented. Finally, the last two sections discuss and conclude, pointing out the implications of the paper for theory, scholars and policy makers.

## 2 Technology gatekeepers and spin-offs.

TGs are said to be essential to cluster learning processes by accessing external (to the cluster) knowledge, and conducting a conversion process which deciphers external knowledge and turns it into something locally understandable and useful (Becattini and Rullani, 1996). Technological gatekeepers (Allen, 1977; Morrison, 2008) or anchor tenants (Agrawal and Cockburn, 2003; Baglieri et al., 2011) are focal companies or agents which mobilize knowledge, orchestrate the cluster by attracting investments, provide a vision for nurturing innovation, and supply technological knowledge to local start-ups (Baglieri et al., 2011). Anchor tenants are said to generate new knowledge by combining specific local knowledge with external knowledge components (Agrawal and Cockburn, 2003). This is facilitated by having abundant external (to the cluster) ties that enable the exploration of new forms of knowledge (Baglieri et al., 2011; Giuliani, 2007), through both formal and informal channels (e.g. Gittelman and Kogut, 2003). In particular, most of the research conducted on TGs assumes that large leading firms with high absorptive capacity and high-intensity R&D activities shape the district learning process (Morrison, 2008; Lazerson and Lorenzoni, 1999; Albino et al., 1998; Lorenzoni and Lipparini, 1999; Lissoni, 2001; Munari et al., 2011; Baglieri et al., 2011; Giuliani, 2007) by engaging in major investments to search for, acquire and diffuse knowledge within their own company networks in order to maximize profits.

Nevertheless, the literature about technological gatekeepers and their effects on clusters presents a diverse set of paradoxes. First, the technology strategies literature highlights the notion of competence destroying technological discontinuities (or radical innovations) (Tushman and Anderson, 1986), with the suggestion that such discontinuities can trigger changes in the competitive landscape in ways that frequently disadvantage incumbent firms. Such new technological changes allow new entrants to establish innovative and dominant designs (Abernathy and Utterback, 1978) and incumbents often prove unable to respond (Bower and Christensen, 1995; Christensen 1997). In addition, the literature on entrepreneurship has pointed out that new small entrepreneurial firms are the ones responsible for major revolutionary breakthroughs (Baumol, 2004; Zucker et al., 1998; Jorgenson, 2001), while the incumbents are more engaged in providing incremental improvements to existing products (Baumol, 2004). Therefore, the assumption that the technological gatekeepers are the incumbents which orchestrate a cluster, and provide its dynamism, and are the firms which provide the cluster with knowledge, is only valid as long as there are no radical changes. When radical knowledge appears the TG incumbents oppose it in order to maintain the status quo and their central positions in the cluster's networks (e.g., Allarakhia and Walsh, 2010).

According to Tushman and Anderson (1986), technology evolves through periods of incremental change, punctuated by technological breakthroughs that either destroy or enhance a firm's competences in an industry and especially in IDs. In general, competence destroying discontinuities are initiated by new firms while actions to enhance competence are initiated by existing firms. Leading companies stay closely tuned to their customers' needs and new technologies may either be perceived as (a) presenting different performance attributes, not valued or known, by existing customers or (b), as creating value attributes which may improve at such a rapid rate that the new technologies can threaten established markets (Bower and Christensen, 1995). Incumbent firms tend to stay close to their customers, and the processes of identifying customer needs, and forecasting technology trends, as well as the allocating of resources, are centred on current customers and markets, and therefore such firms may not be attracted by new technologies and will probably avoid disruptive technologies (Bower and Christensen, 1995). In addition, Tellis (2006) highlights an incumbent's lack of vision of its market and a a desire not to destroy existing assets when serving the market. He points out that not only do small new entrants introduce disruptive technologies, but also large and incumbent firms can be later developers of such new technologies. For Tellis (2006), incumbents do not consider investments in disruptive technologies a rational financial decision.

According to our theory, and as has been pointed out by other authors (Baumol, 2004), incumbent TG firms will be reluctant to destroy the status quo, and will be less effective than new entrants in introducing radical or disruptive innovations that threaten their own product portfolio. But what are the characteristics that new entrepreneurial firms need to possess? These firms have been termed as visionary leaders (Tellis, 2006) and according to Assink (2006) they should have disruptive innovation capabilites[3] defined

[3] We prefer the concept of Disruptive Technology [3] which is more precise and is more useful for explaining industry change, the processes involved and the implications. Bower and

as the *"internal driving energy to generate and explore radical new ideas and concepts,* to experiment with solutions for *potential opportunity patterns detected in the market's* white space and to develop them into marketable and effective innovations, leveraging internal and external resources and competencies.

Therefore, taking into account that new small entrepreneurial firms are disruptive agents, the next question is: are those small entrepreneurial firms new start-ups or spin-offs? Put differently, are the new entrants, as opposed to incumbents, from inside or outside the cluster? The literature on clusters, mainly from the strategic management perspective, is clear about the answer: knowledge spillovers are related to heredity, that is, knowledge flows from successful incumbents to those organizations with previous experience in the industry. This means that organizations (incumbents in our reasoning) spawn new enterprises through spin-off processes (Klepper and Sleeper, 2005; Klepper, 2007). According to Klepper's and Thompson's (2006ab) framework, spin-offs follow from disagreements which arise because incumbent management has a limited ability to recognize superior ideas from employees. In addition, as Klepper (2007) suggests, spin-offs are the key reasons to explain agglomeration economies.

**3 Cluster life cycle, lock-in and renewal**

The burgeoning cluster life cycle literature emphasises the problem of knowledge lock-in, (Menzel and Fornahl, 2010; Giuliani, 2011; Bergman, 2008). The characterisation of different stages of the cluster life cycle vary depending on the author (Lorenzen, 2005; Van Klink and De Langen, 2001; Menzel and Fornahl, 2010), but all of them agree that there are distinct "emergence", "growth", "maturity" and "decline" phases. In the first stages of a CLC, knowledge has a more heterogeneous character (Menzel and Fornahl, 2010) and clustered firms have higher growth rates than in later stages, and there is a pervasive spin-off process (Klepper 2007) which drives cluster growth. In the growth stage, self-reinforcing processes based on trust and reciprocal interactions are crucial. Audretsch and Feldman (1996) found that clustered firms have a high innovation rate during the growth phase. By the time of the maturity phase, the competitive shake-up period is largely over, and the cluster has been shaped with

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Christensen (1995) defined disruptive technologies as those which "bring to a market new value propositions".

leading firms playing a dominant role as TGs. Knowledge has become more stable and homogenous. . Finally, in the latter stages there is a decrease in innovation (Pouder and St. John, 1996) which potentially leads to knowledge lock-in.

There is a diversity of explanations for the emergence of clusters and the development of the decline stage (e.g. Shin and Hassink, 2011). However, what is missing is analtsis of a CLC's renewal stage.How a cluster moves through its life cycle depends on whether there is an increase or decrease of heterogeneity amongst the cluster's organizations (Menzel and Fornahl, 2010) and whether there is a renewal of its technology life cycle (Anderson and Tushman, 1990). The question is how can heterogeneity be increased in order to renew a cluster and initiate a new growth stage? Most cluster studies focus on successful cases at a time when they are in their central life stages. Some studies analyse emergence (Bresnahan et al., 2001), and a few cluster decline (Grabher, 1993), but literature on cluster renewal is scarce. Klepper (2007) showed how radio producers in the USA shifted to making televisions, and Tappi (2005) documented the shift from mechanical manufacturing methods to the use of electronics in the accordion cluster in Marche, Italy. But neither of them analysed the role of TGs, nor the processes by which new knowledge is created. The reason to expect that incumbents cannot cope with technological disruption is related to the phenomenon of the learning trap (Levinthal and March, 1993) whereby leading organizations foster specialization and inhibit experimentation, and find it difficult to adapt and diversify (March, 1991). Ahuja and Lampert (2001:527) summarized why it can be so difficult to increase knowledge heterogeneity:

> Mature technologies are likely to have highly developed value networks and organizational and extra-organizational assets that are co-specialized with these technologies (Christensen and Rosenbloom, 1995). These co-specialized assets and networks make subsequent innovations on these existing technologies easier, but may impede experimentation with nascent technologies that require different sets of assets, inputs, and complements.

Our argument can be summarized as follows. First, the TG orchestrates the networks that control and shape most of the learning process in a cluster, focussing mainly on the creation of non-radical incremental knowledge. In this process, a TG's superior resources provide it with centrality and control over the networks. Second, while the

TG is able to dominate during the mature or central stages of a CLC when knowledge is more homogenous and stable, there is no evidence suggesting the TGs will then lead the creation of radical knowledge which can move the cluster on a renewal trajectory and thereby avoide decline. On the contrary, it is new entrepreneurial local spin-offs that may threaten the existing technological status quo and thus rejuvenate the cluster. See table 1 which explicitly addresss the proposed framework.

Insert table 1 here

Our argument does not imply that TGs cannot maintain and provide some form of renewal to the cluster by continuous non-radical innovation.

**4 Case study.**

The study utilizes secondary data analysis alongside in-depth interviews aimed at understanding the evolution of the Castellon ceramic cluster over the last 20 years. Interviewed respondents included: the inventors of a new technology; the lead users of, and improvers of, the technology; the managers of leading firms; officials of public research laboratories; academics; consultants; and policy officials. Iinterviews were conducted informally from 2000 to 2011 by one author of this paper, who was aconsultant tothe inventors of the technology and was commissioned to find government funding for the intensive R&D process which led to the new breakthrough. Formal semi-structured interviews with the inventors and other complementary firms have also been carried out, especially during 2011. In total, 12 key informants were formally interviewed over periods of 2-3 hours per person. In rerspect of the inventors of the technology, the formal and informal interviews carried out amounted to around 200 hours. In addition, we achieved triangulation of data through specific questions with interviewees, discussion with experts in the industry and policymakers and also by comparing results with secondary data (e.g. Baxter and Eyles, 1997). Consistent with Yin (2008), we document how the cluster, its anchor firms and the new entrants have evolved over time by analyzing archival data, internal documents and reports, academic publications, together with the aforementioned interviews.

**4.1 The Castellon cluster in Spain** The Castellon ceramics cluster is a meta-cluster (Hervas-Oliver and Albors-Garrigos (2007) that includes all the activities of the ceramics value chain, as well as various public R&D organisations such as the Institute of Ceramic Technology (ITC-ALICER, hereafter), educational centres such as the Jaume I Universitat and private institutions such as trade associations (including Ascer, Anffecc, Asebec). The cluster organises international congresses on frits and glaze (Qualicer), andr private international fairs (Cevisama). The cluster provides 20,000 direct jobs (in 2010) and there are 300 firms in related industries (Ascer 2010)

Within the cluster, glazing is the most important of the auxiliary industries (Meyer-Stamer et al., 2004; Hervas-Oliver and Albors-Garrigos, 2008). The Castellon glazing industry is the world leader with 26 firms exporting around 66% of total production valued at 900 million euros; and employing around 3,200 workers in 2010 (Anffecc, 2010). It has extensive operations in other clusters including in Italy and Brazil. The strength of the concentration of companies from different, but interrelated, industries in the Italian and Brazilian ceramics clusters is reflected in high location quotients for these districts. For example, in the Italian (Sassuolo) ceramics cluster the quotients range from from 3.5 to 5.70, which means that the the level of concentration for the industry ranges from about 350% to 570% higher than the national mean (depending on the specific municipalities within the cluster) (Boix 2009). As in Castellon, the ceramics industry in Italy has a location coefficient of about 4.5 in the cluster, which means that the concentration of the industry in the cluster is 450% above the national average (ISTAT 2006).

Institutional support in the Castellon cluster is strong. For example, the local university in Castellon (Universitat Jaume I, UJI) offers a chemical ceramic engineering degree, as well as a masters and a PhD - which are unique in the world. These academic qualification are offered by UJI jointly with the ITC-Alicer R&D centre. The R&D centre (ITC-Alicer) is the body responsible for transferring knowledge to the cluster through conducting research projects with local firms. It has around 120 researchers. Collaboration between ITC-Alicer and UJI constitutes an excellent example of university-industry knowledge exchange.Lecture in the UJI are provided by ITC-Alicer researchers who have daily contact with the industry.

According to Meyer-Stamer et al. (2004) and Hervas et al. (2008) the cluster has sufficient public R&D centres, and educational institutions, and private organisations such as fairs and trade associations, to provide proper support to the value chain. However, it is inter-organisational interaction interaction exemplified by that of the ITC with the Jaume I Universitat that is a crucial part of the cluster's "innovation engine" (Meyer-Stamer et al. 2004; Hervas, 2004), and the true strength of the Castellon cluster lies in its systemic behaviour. The mechanism of innovation diffusion is very difficult to replicate elsewhere – as confirmed in interviews carried out while preparing this paper. Ceramic tile company technicians are in continuous contact with technicians from glazing companies. At the same time, ceramic tile companies hire chemical engineers specialized in ceramic tiles and trained at the ITC and the Jaume I Universitat. Accordingly, there is a dynamic information and knowledge flow within the cluster network system. This is why the glazing industry is the main signatory of contracts with the ITC and is the cluster sector with the most developed R+D. Knowledge is transferred through its interrelations and links with tile companies. At the same time, these links are strengthened by the ITC's support for the tile companies and the hiring of technicians experienced in the various industries. This creates a fluid circulation of tacit and explicit knowledge. This process is aided by the use of a common language, culture, understanding, and personal relationships between local workers – who are implicitly motivated by the same objectives (Meyer-Stamer et al., 2004). Similarly, the ceramic machinery equipment industry from the Emilia-Romagna area is also the world leader, with a total turnover of 1,393 million euros in 2010 and exporting around of 76% of the total production (Acimac, 2010). Summarizing, the Castellon cluster is embedded on the frits-glazing decoration application because its local innovation system is rooted in the chemistry applied to ceramics.

### 4.2 Technology Disruption from Rotocolor to INKJET technology

#### 4.2..1. The technology status quo

Until 1994, the decorating process in the tile ceramics sector was mainly based on screen printing technology utilising flat or cylinder screens, an inefficient process which required large batch series. In 1994, the Italian company System, produced the Rotocolor machine. This important innovation replaced the screens with laser engraved polyethylene rollers which transferred the design colour patterns to the tiles. Although this technique was a significant improvement, it did not solve all the design reproduction problems and implied the need for specialized technicians that would manage the production process. Furthermore, it still required electronic engraving of the rollers and needed large production batches. Furthermore, the design transfer process was arduous, lengthy and costly. As a proof of Rotocolor becoming a dominant technology, a number of competitors copied this design which opened a number of legal litigations (Russo, 2004). By the end of the 1990s this technology had been adopted in 20-25% of ceramic tile producing plants.

### 4.2.2. Developing a disruption

In 1998, a local Spanish computer entrepreneur engineer with extensive experience in the tile ceramic industry, along with a chemist working in a leading glaze and pigment multinational firm, began exploring new possibilities for decorating tile ceramics based on digital technologies, and in 1999 they developed a first prototype based on inkjet printing. The initial prototype proved its feasibility and led to the founding of a spinoff entrepreneurial firm, Kerajet, spawned by a leading frits and glazing incumbent MNE firm, Ferro. Based on a design consisting of multiple inkjet head systems, control hardware, software design transmission, and inkjet handling subsystems, Kerajet presented their first industrial prototype in the CEVISAMA exhibition in 2000 and also acquired two PCT patent applications.

At this early stage the financial support from the glazing firm Ferro was crucial. It was agreed that Kerajet would develop electronics and software applications and the decorating machine, while the glazing MNE would focus on the development of inks for the new technology. The new technology consisted of four basic subsystems: inkjet print heads; inks or colours to decorate the tile; mechanical parts; and software that ensured the transfer of the design artwork to the printing system and controlled the process. The third and fourth subsystems continually evolved while the first and second ones had more punctuated evolutions. Inkjet technology constituted a complete breakthrough in the decoration process.A cooking craft process (Russo, 2004) was replaced by a digitized process.

### 4.2.3. The adoption of the technology.

Tile ceramic producers were confronted with the innovator's dilemma (Christensen, 1997). The decision to make was whether to adopt a new technology that would mean a change from an existing craft production culture to a digital computing one, while realising that the advantages were not clear. Moreover, for Italian producers there was the added factor that the new technology had been invented by a Spanish firm. In Italy, the design leaders and leaders in mechanical equipment manufacture were Italian, and for non-Italians trying to break into the market there was a significant "non invented here" barrier.

Although the new technology promised users the possibility for cutting edge designs and applications, during the early years of development (2000-2004) only four tile producers with capacities in advanced production technologies really understood the innovatory implications, and so committed themselves to inkjet technology. Their profile was varied. A medium sized firm (300 employees) that exported to Germany and England, and specialized in cutting edge designs, acquired four inkjet printers. The firm also contributed suggestions to Kerajet for printer improvements.. This firm was the first in the Spanish cluster to envision the capabilities of the new technology and so was the first to incorporate digital control of the decoration process. In a personal interview their plant engineer showed us reports demonstrating the enormous savings made by using the inkjet technology.

The other early inkjet adopters were remarkably small companies (only employing around 60 to 70 employees each). In an interview, one plant foreman explained to us how the new technology increased his firm@s ability to cope with short batch runs, to cut down inventory and to satisfy niche customers. However, a problem associated was that these lead users believed they were developing competences that differentiated them from competitors and so avoided disseminating their new knowledge throughout the cluster. At the same time, there were lead producers who tried the technology but who rejected it because it did not meet the needs of their mainstream customers and this time their knowledge about the rejection was disseminated[4]. The lead-users which

[4] One of the largest tile ceramic producers pointed out "when our Italian competitors buy it we'll buy it as well"

contributed to refining the Kerajet prototypes were neither TGs nor leading firms and were not embedded in large networks orchestrated by leading TG incumbent firms.

The development of the digital inkjet technology was accompanied by its slow adoption by ceramic tile producers.. Communication between, and mutual influence of, the Italian and Spanish ceramic tile clusters was central to the initial difficulties, but also to the eventual success, of the new technology.

**4.2.4 Technology development and success.**

The kerajet team needed to solve two particular technical problems, both of which required sourcing knowledge from outside the cluster. First, there was the problem of developing a print head adapted to tile ceramic decorations. The necessary knowledge for this was available in neither the Castellon nor Sassuolo clusters.. In fact, this knowledge was new to the entire industry. The entrepreneurs decided to search for appropriate printing technology competences within the high tech Cambridge cluster, UK.. After various trials and mishaps, the Cambridge firms SEIKO and XAAR were selected, and finally an agreement was reached with with SEIKO to develop print heads specifically designed for tile ceramic applications. Cooperation between Kerajet and SEIKO lasted from 2002 to 2009. Additionally, Kerajet also made agreements to develop software with research lab oratories external to the Castellonn cluster. These are two interesting examples the creation of knowledge linkages that were not only external to the cluster but also to the industry.

In respect of the inks required for the application, it soon became clear to the entrepreneurial team that the existing state of the art pigment technology (based on inorganic soluble salts) was not compatible with the print heads required by the new inkjet technology. There were two problems. First, Ferro, the sponser of Kerajet, was reluctant to invest heavily in the new technology. Second, there were technologicl barriers to producing the new organic pigments that were needed because the pigment size required could not be met by existing ceramic tile milling technology. Consequently, Kerajet built on their premises a small laboratory to develop the new inks. They utilized nano-technology micro mills and tested new organic solvents for the required inks. By 2004, significant advances had been made with the new print head and inks technologies and the most acute problems associated with inkjet ceramic tile decoration had been solved. Micro milling technology capable of ensuring that the new ink powder for the inkjet technology would be fine-frained was ssourced in Germany, in the heart of where equipment suppliers for the chemical industry were located.

It must be emphasized that incumbent TG firms in the Italian mechanical equipment industry, which had traditionally dominated the sector, were reluctant at that time to follow the new developments. These firms were slow to react.. It was not until 2007 that System, the industry's leading firm, located in Emilia Romagna, signed an agreement with Kerajet. System's expectation was to adapt its own Rotocolor technology[5]. Sacmi, another TG equipment manufacturer based in Italy, registered its own patent with powder injection in 2008.

It can be concluded that by 2005 Kerajet was the leader and the pioneer in inkjet technology. Indeed, its printers were recognized internationally in the Technargilla Fair of September 2004 in Rimini Italy. It has also since developed and commercialized not only conveyor inkjet printers but also a large flat bed printer with moving print heads.

### 4.2.5 The new technology becomes a dominant design

The mid 2000s marked the development of inkjet technology as a dominant design. The glaze and pigments leaders followed the path of Kerajet and started to develop and market new inks for the inkjet technology after realising that they had much higher added value.

Kerajet was challenged by new entrants, basically from within the pigment and glaze industrty. The first follower was a pigment producer, Torrecid, which partnered with Durst to offer on the market in 2005 the second inkjet printer using organic pigments. It was followed later by Cretaprint, a small rotocolor manufacturer in Spain.

Print head producers, pioneered by XAAR, began to develop inkjet print-heads adapted for tile decoration. After five years, ceramic tile inkjet print heads became a standardised product, with four international firms accounting for 99% of the market.

[5] Kerajet had a temporary agreement with System, the inventor of Rotocolor, to integrate its technology into their system,.

Organic pigmented inks (necessary for the new technology) also became a standard, and today 10 Spanish glaze and pigment Spanish producers have them in their catalogues while 4 of them cope 85% of the international market. Three inkjet printer manufacturers (also based in the Spanish cluster) dominate the market, with a combined 75-80 % share[6]. The rest is accounted for by three or four manufacturers, including two Italian equipment producers. Durst has a plant in Spain.[7] The Spanish cluster dominatyes the technology.

It must be pointed out that the initial lack of infrastructures inhibiting the development and dissemination of inkjet innovation, such as a lack of software competencies, a lack of microelectronic suppliers in the cluster, a lack of print head technology suitable for the ceramic tile application, and a lack of computer trained operators, have been surmounted by the visionary efforts of the entrepreneurs who initiated change and established external linkages for sourcing knowledge from distant clusters - different to those in the industry.

The new technology offers extraordinarily sharp image resolutions, fast line speeds and heightened productivity, as well as the potential for producing cutting edge designs unthought of a few years ago. It has been recognized as a leading competitive technology and the major inkjet equipment manufacturers are inundated with orders. New printer models have been developed with an increased number of attributes and improved specifications. It is estimated that there are currently more than 500 ceramic tile manufacturing lines equipped with inkjet machines.

During the early years (2000-06) the pioneer firm (Kerajet) dominated completely the market with printer sales going to leading customers. Even now, according to interviews with the leader firms, Kerajet still has a strong penetration, accounting for an estimated 50-60% of the purchases of the technology.. The evolution of printer sales has followed an exponential curve, and the technology still seems to be in a growth phase. According

[6] Técnica Cerámica, 349, pp. 1307-1322.

[7] Técnica Cerámica, 394, pp. 497-498

to the estimates of experts (Ceramic World Review, 2011)[8], in 2011, 18-20 % of total worldwide ceramic tile producing lines were digital while the projection is that by 2013 the percentage will reach 63-65%. In 2011, the leading countries in inkjet adoption were Spain, with a 30% share of the use of the technology, and Italy with 23 %. As was mentioned earlier, Italy's low adoption figure may be interpreted as being a consequence of barriers associated with the non invented here syndrome[9]. In emerging countries, the penetration of inkjet technology is lower. China only accounts for 1.0, % of global technology takeup, while Brazil and India account for 10 % each. The "disruptive innovation" theory can explain the slower takeup since in these countries the technology still does not meet the needs of mainstream markets. However, expert projections for 2013 for these countries is that by then China, Brazil and India will account for 10%, 55% and 56%, respectively of global takeup, implying that the value proposition changes – as predicted by the disruptive innovation theory (Ceramic World Review, 2011[10], Tecnica Ceramica, 2010[4]).

## 5. Discussion of results

According to our study, a number of elements were determinant in the final success of the inkjet expansion, most of which were crucial for neutralizing the inhibitors of disruptive innovation capabilities in the cluster, as pointed out by Assink (2006).

The main actors responsible for the project's success were the initial entrepreneurs, the enterprise of whom had been spun-off from a leading TG. Their knowledge of the various actors in the Spanish cluster (such as equipment suppliers, tile producers, customers, and pigment and glaze producers), along with their skills (in the fields of information and communication technologies, mechanical engineering, electronics and chemistry), and also their vision for the industry, were the main drivers of the new project. Their vision was a necessary requirement for overcoming a conservatism in

[8] Ceramic World Review (2011), Ceramic Inkjet Printing, making sense of the technology, 92, pp. 165-159.

[9] This is the reason why in 2007 kerajet opened an office in the centre of the Italian Sssuolo ceramics cluster.

[10] Ceramic World Review (2011), Ceramic Inkjet Printing, making sense of the technology, 92, pp. 165-159.

respect of innovation and the appliance of new technologies to tile decoration processes, an area where craft was the dominant paradigm[11]. Incumbent TGs were reluctant to embrace the new technological trajectory, and in fact saw the new technology as threatening their main business areas (Tellis, 2006; Danneels, 2004).

A fundamental role was played by lead users in the tile producer sector. Four producers in Spain made a commitment to the new technology, and demonstrated this, not only by the early acquisition of machines but also by offering numerous suggestions for the development of new models (von Hippel, 1986; Urban and von Hippel, 1998). In some instances, 80% of the changes in a new model came out of lead users' comments. Early in the development of the technology the 4 Spanish producers were aware of the cost advantages offered by the inkjet technology and they profited from improvements to its design. When inkjet technology started to be popular some lead users substituted almost all their screen printing lines with digitized equipment[12]. They were firms not strongly embedded in the established networks orchestrated by the incumbent leading frits and glazing firms. They carried out a bridging role between research and development and market adoption (Adner, 2002).

Our results confirm various parts of the literature. First, the technology gatekeepers cannot be the ones which introduce radical technologies. That role belongs to new entrepreneurial firms (Audretsch and Feldman, 1996) which have spun offs from incumbents (Klepper, 2007). Through them the cluster can be renewed and re-set on a new growth trajectory. In fact, the spin-offs which introduce radical knowledge into the cluster act as temporary technology gatekeepers.

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[11] For a view on the production technology approach of ceramic tile producers see Albors et al (2006)

[12] One of the main marketing errors made by Kerajet was to go for global marketing rather than concentrate on selling to innovative lead user producers. The standard ceramic tile producer required a standard technology suited to their mainstream customers' markets, and was not prepared to endure the learning curves that the new technology required. A reliance on word of mouth worked against the spread of the new technology since it was for lead users a source of technical advantage which they did not want to pass on to others.

Second, the networks controlled by the TG follow the rules and constraints imposed by the TG, because the latter has incentives to orchestrate the network in its own favour. This implies that an incumbent TG tends to deter the adoption of any new technology which might threaten the status quo (e.g. Allarakhia, M., Walsh, 2010). Thus, the lead users which are early adopters of the radical knowledge cannot belong to the TG's stable networks. Nevertheless, once the new technology has become more established the traditional or incumbent TGs also become adopters in order to keep pace with the new technological trajectory,

and thus maintain their previous role of TG.

Pigment and glaze producers facilitated the growth of the technology either by being early followers and competitors , or simply through being late adopters and facilitating the standardisation of pigments for the new application. Despite initial reluctance from incumbent pigment and glazing producers to accept a new technology that challenged the status quo, a multinational firm, Ferro, contributed equity and capital to the enormous investment required initially by the project. Later, cooperation between pigment producers and equipment suppliers to the pigment industry was fundamental to the development of process innovation for the new pigment production.

Though Italian equipment manufacturers viewed the new technology as a threat to their main business areas (Tellis, 2006; Danneels, 2004), System, the Italian inventor of Rotocolor, was a temporary partner in the project and contributed indirectly to technology dissemination in the latter phases of the consolidation of the new technology paradigm. System's collaboration with the new temporary TG Kerajet confirms Giuliani's (2011) observation that TGs mainly exchange knowledge with other TGs (Kerajet with Ferro, Torrecid and System). Similarly, this knowledge exchange also permitted new spin-off TGs to enter the established networks.. In fact, nowadays the incumbent TGs previous to the disruption still retain their roles, sharing the role with the new inkjet leaders.

Strikingly, Kerajet acted as a focal firm and a temporary gatekeeper by overcoming the district's lack of critical competences by making a bridge to knowledge external to the cluster and the industry when required, thereby confirming the view of the role of a TG to be an accessor to global pipelines. Specifically, research cooperation was carried out with two inkjet print-head manufacturers from the Cambridge cluster (XAAR and Seiko). This led to the development of customized print-heads for use in the ceramic tile field, and eventually to standardisation of the application. The development of electronics and software for control and management of the equipment was carried out in cooperation with various external research centres and firms. Artwork software selection and training was essential for the transference of designs to the production line. A pigment micro-milling application (Netzsch) solved the initial phases of organic pigment development, and was brought in from other external industries such as pharmacy and electronics. These facts support the view of the importance of the external linkages (e.g. Bathelt et al., 2004) in improving the resources available to clusters and avoiding myopia (Maskell and Malmberg, 2006). Nevertheless, in our argument the novel result obtained in this study is the fact that the new knowledge was sourced from different industries and knowledge domains, specifically from the printing industry (from within the Cambridge cluster) and from the micro- milling industry (from within the pharmaceutical industry). This confirms Jeppesen's and Lakhani's (2010) assertion that the provision of winning solutions to problems is positively related to increasing distance between the solver's field of technical expertise (in this case printing, and micro-milling) and the focal field of the problem (in this case ceramics). The importance of "marginality" or technical and social distance from the focal problem field (Jeppesen and Lakhani, 2010) is supported by studies in the sociology of science which stress that:

*"inventions are usually made by outsiders, that is, by men who are not engaged in the occupation which is affected by them and are, therefore, not bound by professional customs and traditions"* (Ben-David, 1960:557).

Thus, the marginality effect is explained by individuals from outside bringing knowledge perspectives different to those held by the focal companies in the problem field (e.g. Gieryn and Hirsh, 1983). The cluster literature has also pointed out this fact, although with some reservations, that is not specifically referring to new-to-the-industry knowledge. As such, Menzel and Fornahl (2010:231) stated that:

*"Clusters can increase heteroge*neity and renew themselves by enlarging their boundaries, either by integrating firms in the same industry, but in other places, or by integrating organisations in spatial *proximity, but outside the thematic focus of the cluster"*

The clusters' main institutions contributed to the dissemination of the new technology. International industry exhibitions and fairs, such as CERSAI in Italy and CEVISAMA in Spain, witnessed a progression of the technology from the 2000s onwards. New equipment was exhibited and ceramic tile producers presented cutting edge designs that imitated marble, natural stones, and photographs, as well as showing off old classic decorations applied with the new technology. Nevertheless, the transition of the disruptive technology to high market use was slow, and took almost six years. The comments published in professional magazines after each exhibition show how the inkjet moved from a disruptive technology to an accepted standard.

The other actors in both the Castellon and the Sassuolo clusters played important roles as well. Lead users played critical parts as early adopters, and as reviewers of successive developments. ITC contributed to disseminating the technology, training operators and technicians. Industry associations (i.e., ASEBEC, ACIMAC, ASCER, Assiopiastrelle) and technical-professional magazines (i.e., Técnica Cerámica, Ceramic World Review, Tile & Stone Journal) sponsored many workshops in Italy and Spain where the inkjet applications were discussed and thus helped to disseminate the new technology worldwide. Incumbent firms in the equipment sector also played active roles. For example, System was a distribution-partner, Cretaprint was a follower, and Ferro was an equity-partner). Once the technology was clearly defined, these firms resumed the TG role, sharing it with the newcomers (Cretaprint, Kerajet, and Durst). Pigment and glaze producers facilitated the progression of the technology, either by being early followers and competitors (such as Torrecid), or simply by being late adopters (as was all the Castellon glazing industry), and by helping to ensure the standardisation of pigments for the new application.

Insert table 2

Figure 1 illustrates the critical internal and external networking and partnering connections in the innovation process that led to the development and dissemination of the new inkjet technology.

Insert figure 1 here

As shown in table 3, the dynamics of the TGs across the differing stages of the CLC are really interesting. Overall, the previously existing TGs have prevailed (except one Italian company: Tecnoitalia) but now there are also other technology gatekeepers. The most important new TGs are Kerajet, the focal spinoff, and Cretaprint which successfully completed a transition to the new technology and has been bought by EFII a printing company in Silicon Valley[13]. The incumbents also made the transition and now are key actors developing the special inks for the new technology. In addition, and confirming CLC theory, new entrants arrived in the cluster (that is to say, Durst and Jettable) during the early stages of the new technology. Overall, the incumbent TGs did not renew the cluster. Rather, it was but the spin-off companies which temporarily adopted the main roles, developing external ties and engaging technology creation and diffusion – which are traditionally supposed to be performed by the TG. This is the most interesting part of the success story

Insert table 3 here

Thus, this research differs from others which implicitly focus on non-radical knowledge changes. For instance, Klepper and Sleeper (2005) analyzed spin-offs from incumbent laser firms which then produced similar lasers to their parents' products. Similarly, in the spin-off process in the US automobile industry, documented by Klepper (2007), the new firms did not face, or provoke, a disruption: the new entrepreneurial firms exploited the available technical knowledge in the field, i.e. that existed in the car industry. In contrast, in our study the spin-off focal firm is spawned

[13] A world leader in customer-focused digital printing innovation in Silicon Valley in the USA, EFI (Nasdaq: EFII), announced it has acquiredthe privately-held Cretaprint [a small Spanish ceramic equipment firm] based in the ceramic tile cluster of Castellon, Spain, a leading developer of inkjet printers for ceramic tile printing. Retrieved in January, 2012. http://www.bookbusinessmag.com/article/efi-acquires-cretaprint-expands-inkjet-focus-ceramic-tile-printing/1

from a frits (chemical) and glazing tile firm and, despite inheriting knowledge, it started to produce equipment (based on IT and electronics) to decorate or rather “print” tiles through new to the ceramics industry disruptive inkjet technology. Put differently, the technical change triggered from the spin-off process ion Castellon was a radical one, and thus the CLC moved to a new stage: renewal from a discontinuous innovation.

**6 Conclusions**

The paper attempts to answer the question of how clusters evolve, change and reinvent themselves in order to prevail. Specifically, the objective has been to dissect the dynamics of technology gatekeepers across different stages of the cluster life cycle. In order to fulfil this goal, the paper used a qualitative longitudinal case-study research methodology, covering the last twenty years of the cluster. For this, analysis of archival data and interviews with key informants was carried out. The paper has challenged the assumption that technology gatekeepers are large leading firms with high absorptive capacity and high-intensive R&D expenditures which shape the district learning process.

The paper looked at two key aspects : the type of knowledge created by technology gatekeepers and the stage of the cluster life cycle at which knowledge is created. Using a perspective derived from both the economic geography and entrepreneurship, management and technology strategy fields of literature, this work has used provides a fertile cross-field framework to study the themes of technological gatekeepers and cluster life cycles in conjunction. The aim has been to increase our knowledge about firms, the learning process and knowledge creation in clusters through a dynamic Perspective.

A main finding in the study is that TGs are resilient, confirming Giuliani (2011), but they do not create knowledge in all stages of the cluster life cycle. This contradicts assumptions in the mainstream TG literature (e.g., Morrison, 2008; Lazerson and Lorenzoni, 1999; Albino et al., 1998; Lorenzoni and Lipparini, 1999). Instead, we see the appearance at the point of transition from one CLC stage to another of temporary technological gatekeepers which take the role of leaders and introduce disruptive knowledge into the cluster. Further, these "temporary" TGs then become permanent when through alliances they are able to enter into the incumbents' networks, a development which also helps incumbents to maintain their centrality. Consequently, disruption can be expected to be led by new entrepreneurial firms and not from incumbent TGs, confirming previous research in entrepreneurship (e.g., Audretsch and Feldman, 1996) and technology strategy (Baumol, 2004; Zucker et al., 1998; Jorgenson, 2001). Similarly, the economic geography view is also confirmed by the incumbent TGs' rejection of the disruptive technology in order to maintain the status quo and their centrality in their networks (e.g., Allarakhia and Walsh, 2010). Therefore, it is new spin-offs from incumbent TGs, and not the TGs themselves, which create knowledge for renewing clusters, confirming the management literature perspective which asserts that knowledge is inherited and that the main engine of the cluster (re-)formation is the spinoff process (Klepper, 2007). Once the new technology has become established the incumbent TGs still retain control of their networks by accessing the new technology and sharing centrality with the new TGs that created the new technology.

Temporary TGs established global pipelines to access external knowledge, corroborating what is being said in the external linkages debate (e.g. Bathelt et al., 2004). Nevertheless, our findings have gone one step further: the type of knowledge necessary to challenge incumbent TGs must be new to the industry and to the cluster, that is to say disruptive ideas must come from other industries. If this was not so, the incumbent TGs would have an advantage and a new entrepreneurial firm can be blocked.

This study contributes to the open innovation literature (Chesbrough, 2002) but also highlights the multiplier effect (Becattini, 1990) that the cluster atmosphere exerts on the knowledge creation and diffusion process. The paper has important implications for policymakers and scholars. First, policymakers should understand the positive and contributory role of TGs, but also their limited role in amplifying technological trajectories in clusters. Therefore, new spin-offs should be promoted, or supported, and assistance given to the development of channels to new technologies and knowledge from outside the cluster, while encouraging also the exploration of new-to-the-industry knowledge. Second, scholars should also research the potential role of temporary technology gatekeepers and how it relates ro cluster life cycles. These insights open up new research avenues, including the need for more empirical evidence to support theory building regarding technology gatekeepers and how they relate to cluster life cycles.

The paper's findings are limited in the first place by an analytical focus on a single industry (glazing for ceramics) during a certain period of time. Secondly, account has to be taken of the fact that the type of TG addressed is one which channels technical knowledge, and not one which conveys knowledge concerning new markets and fashion trends.

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## Tables

Table 1 Framework obtained from integrating different strands of the literature

| | **Continuous knowledge innovation** | **Radical knowledge appearance** |
|---|---|---|
| Cluster life cycle | Central stages | Renewal or growth stages |
| Knowledge heterogeneity | Moderate and a low technology paradigm has been established and is mature | High uncertainty, with different technological trajectories, |
| Technology gatekeepers | Leading firms which control networks and the learning process; established incumbents after the shake-up stage and the consolidation of the technology | Incumbent TGs are limited<br>Expectation of new entrepreneurial firms from within the cluster, i.e. spin-offs |
| Networks | TG are central to existing networks | Stable but changing, subject to a new configuration brought about by TG changes |
| New entrants | Not expected, unless multinationals from other related clusters. | Expected, mainly from the cluster, new spin-offs and even start ups. |

Source: own

Table 2 Summary of the case study for discussion.

| | Results |
|---|---|
| Cluster life cycle and Knowledge heterogeneity | Mature, dominant design established in Castellon and Sassuolo up to the 2000s. In particular, in Castellon big leading glazing firms acting as TGs. High knowledge heterogeneity after 2000, when inkjet concept arises and technological trajectories differ. At that time, Rotocolor and traditional (rollers) technology were more productive but limited in design application. Innovator's dilemma was observed in the first stages of the inkjet application, the performance of which was poor but promising. Testing with isolated firms (those not belonging to established TG networks): lead users. In the Italian cluster inkjet technology enters significantly later on, around 2005. |
| Technology gatekeepers | Small entrepreneurial spinoff (Kerajet) acting as a temporary gatekeeper. Incumbent TGs reluctant to accept the new technology. Only some TGs contribute to the development of the new technology  Preliminary ideas rejected by incumbent TGs. Once the dominant design is more accepted the traditional TGs establish alliances with inkjet firms and resume their roles as TGs together with the new leading inkjet firms (Kerajet, Cretarpint, Durst, etc.) |
| Networks | Becoming more stable after the disruption shock when incumbent TGs resume the role of centrality in the decorating process by establishing alliances with the new leading inkjet firms. The latter are also new TGs in most networks. |
| Lead users | Were central at the renewal stage. Were non-leading firms not constrained by stable networks led by TGs. Later on, the new lead users are the incumbent TGs which incorporate the new technology in their capability portfolios. |
| External knowledge | Crucial, from different non-related clusters and industries:<br>-High-tech Cambridge cluster, (Xaar, Seiko)<br>-Germany (micro milling technologists, Nezstch)<br>-Silicon Valley (EFI) since 2011 (acquisition of Cretaprint).<br><br>In addition, key external knowledge from the Italian cluster. |
| New entrants | -Kerajet (disrupter): spinoff from an incumbent TG (Ferro, established in the Castellon cluster)<br>-Cretaprint (follower, former equipment ceramic producer in the Castellon cluster)<br>-Durst (follower, from another industry, new entrant)<br>-New start ups |

Source: own

Figure 1. Facilitating elements in technology development and diffusion.

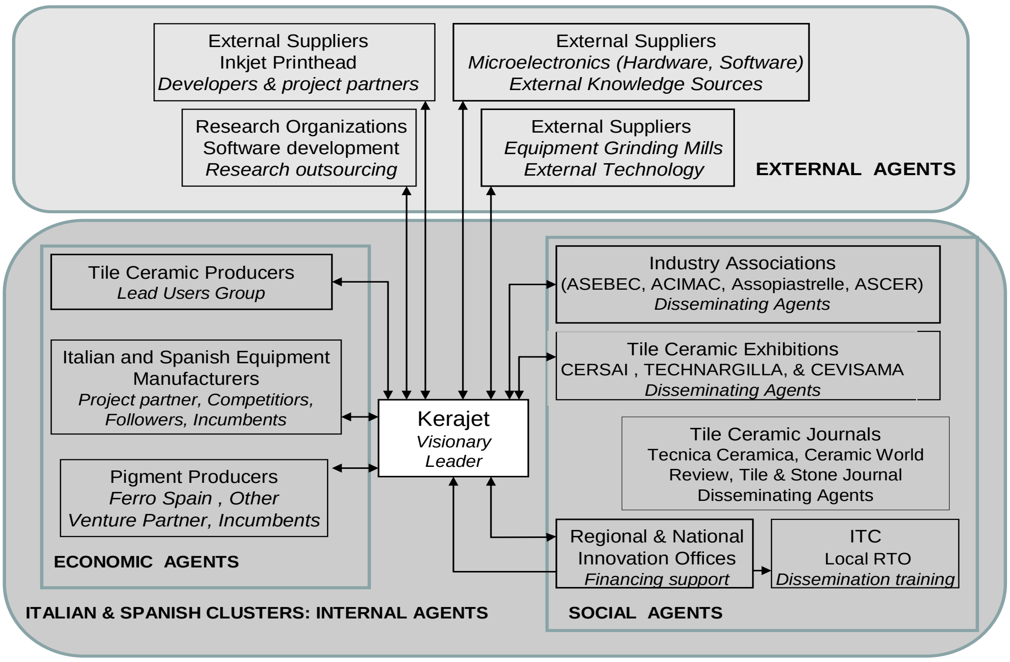

Table 3. Evolution of Main Technological Gatekeepers in Ceramic Tile Decoration technology.

<table>
<tr><th colspan="2">CLC: central stages</th><th colspan="2">Emergent renewal stage</th><th colspan="2">Growing stage</th></tr>
<tr><td colspan="2">Rotocolor technology dominant paradigm;<br><br>Knowledge heterogeneity reduced and focus around Rotocolor<br><br>Established TGs</td><td colspan="2">Knowledge heterogeneity increase in the transition from Rotocolor towards Inkjet<br><br>Spinoff process leading disruption<br><br>Temporary technology gatekeepers<br><br>Main existing TGs reluctant to new tech adoption<br><br>Knowledge uncertainty<br><br>Resistance to change to the new technology.</td><td colspan="2">Acceptance of the inkjet technology and paradigm changing from Rotocolor towards Inkjet<br><br>New entrants expected<br><br>Sassuolo and Castellon leading clusters adopting new technology.<br><br>New TGs in the cluster, plus the previous incumbents</td></tr>
<tr><td colspan="2">Gatekeepers in Cluster (1990-1999)</td><td colspan="2">Breakthrough Gatekeepers (2000-2006)</td><td colspan="2">Current Gatekeepers (2006- 2011)</td></tr>
<tr><td>Mechanical Equipment</td><td>Pigment Producers</td><td>Mechanical Equipment</td><td>Pigment Producers</td><td>Mechanical Equipment</td><td>Pigment Producers</td></tr>
<tr><td>2 Italian companies co-located in Castellon with headquarters in Sassuolo (System, Tecnoitalia) Technology: Rotocolor</td><td>1 Italian producer in Castellon, headquarters in Sassuolo (Coloribbia) Technology: Frits and glazes for Rotocolor</td><td>0 Sassuolo</td><td>0 Sassuolo</td><td>2 from Sassuolo cluster (System-Tarozzi)</td><td>1 Italian producer in Castellon, headquarters in Sassuolo (Colorobbia)</td></tr>
<tr><td>1 Firm in Castellon (Cretaprint) Technology: Rotocolor</td><td>4 Firms world-class frits-glazing firms with headquarters in Castellon (Torrecid, Esmalglass, Ferro and Endeka)* Technology: Frits and glazes for Rotocolor</td><td>1 Castellon (Spin-off firm: Kerajet)</td><td>1 Castellon (FerroSpain, the firm which spawned Kerajet)</td><td>2 Castellon (Kerajet, Cretaprint)<br>2 Firms from outside the Sassuolo and Castellon cluster (Durst, Jettable): new entrants from printing technology field, no spin-offs</td><td>4 Castellon firms; Leaders (Ferro Spain, Endeka, Torrecid, Esmalglass)</td></tr>
</table>

Source: Own, based on Serri, A., Ceramic decoration paradigms, Cuaderni di cer 2008, 5-1-2008
Dossier Inkjet, Tecnica Ceramica, 369, pp. 1308-1315.2010

*Ferro has US equity and is listd in the NY Stock Exchange and Endeka has part of UK equity