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Are Technological Gatekeepers Constraining my Cluster?

Unfolding the paradox of gatekeepers resilience

across cluster life cycle stages

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Abstract:
The economic 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 disruptive or not) 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 analysed over the last eighteen years. The results show that there are temporary technological gatekeepers across cluster life cycles which assume 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.

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1. Introduction

This paper tells a story about a technology disruption which challenges assumptions in the industrial district[1] (ID, hereafter) 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

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

literature that analyses their roles across a cluster life cycle, helping "push" a cluster from a mature stage to a renewal stage. This study aims to fill this gap.

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 assumes 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 argument is as follows.

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, disruptive or breakthrough innovations can be based on *novel* technologies (new to the firm), or on *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 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 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) 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,

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

2008; Albino et al., 1998) are focused on clusters that are at a central stage of their life cycle when there are few or none new entrants and when knowledge is more homogeneous, 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 our knowledge of the learning process at that point. We also provide novel insights about different types 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 in line with the literature on cluster evolution and its dynamics over time (Audrestsch and Feldman, 1996; Ter Wal and Boschma, 2011; Boschma and Fornahl, 2011). This paper advances to key contributions to the evolutionary economic geography (e.g., Boschma and Frenken, 2006; Martin and Sunley, 2011). First, drawing on the seminal contribution of Menzel and Fornahl (2010) about the cluster life cycle, which clarify cluster firm heterogeneity and the inter-organizational linkages, our paper has gone an step further by responding the following unanswered question: Which type of firms (cluster, non-cluster, technological gatekeepers, spinoffs, start-ups, etc.) re-shape and drive the cluster evolution at its different stages? The answer to the former question is done by borrowing concepts and ideas from the strategic management and the entrepreneurship literature, conducting a cross-field integration which enrich and reinforce the evolutionary economic geography. Second, this paper challenges and discuss previous findings which suggested the key role of technological gatekeepers in the early stages of clusters (Giuliani, 2011) or in the central phases (e.g., Morrison, 2008), incorporating into the conversation a dynamic analysis of the technological gatekeepers through all the different stages of a cluster and thus providing empirical evidence about the resilience of some of them and the appearance of temporary and new technological gatekeepers mainly responsible for the cluster evolution through technological disruptions. Put differently, going beyond the incremental innovation assumption at which the economic geography is mainly based, this paper utilizes the radical innovation in clusters to explain the emergence of new technology and the subsequent pass to a renewal stage.

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). The 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 certain paradoxes. 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 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? Such firms have been termed as visionary leaders (Tellis, 2006) and according to Assink (2006) they should have disruptive innovation capabilites[3] defined 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] 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 Christensen (1995)

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 leading firms playing a dominant role as TGs. Knowledge has become more stable and homogeneous. 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 analysis 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

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defined disruptive technologies as those which "*bring to a market new value propositions*".

(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 homogeneous 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 avoid decline. On the contrary, it is new entrepreneurial local spin-offs that may threaten the existing technological status quo and thus rejuvenate the cluster[4].

4. The case study: the Castellon cluster and its emergent technology.

The case study utilizes secondary data analysis alongside in-depth interviews aimed at understanding the evolution of the Castellon (Spain) ceramic cluster over the last 20 years. Interviewed respondents (twenty nine) 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. Interviews were conducted informally from 2000 to 2011 by one author of this paper, who was a consultant to the inventors of the technology and was commissioned to find government funding for the intensive R&D process which led to the new

[4] It should be pointed out that our argument does not imply that TGs cannot maintain and provide some form of renewal to the cluster by continuous non-radical innovation.

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 respect 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). As well as carrying out the aforementioned interviews, we have also analysed archival data, internal documents and reports, and academic publications to document how the cluster, its anchor firms and the new entrants have evolved over time. This approach is consistent with Yin (2008).

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, and Asebec). 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)[5]. 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 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 qualifications 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

[5] 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 76% of its total

university-industry knowledge exchange. Lectures in the UJI are provided by ITC-Alicer researchers who have daily contact with the industry. Indeed, inter-organisational interaction is 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.

4.2 Technology Disruption from Rotocolor to INKJET technology

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.

production (Acimac, 2010).

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 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. In effect, a *cooking* craft process (Russo, 2004) was replaced by a digitized process.

A problem for the issue of knowledge dissemination was that the early lead users believed they were developing competences that differentiated them from competitors and so this perceived competitive advantage persuaded them to avoid disseminating their new knowledge throughout the cluster. At the same time, there were other 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[6]. The lead-users which 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 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 ceramic tile 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 Japanese (SEIKO) and the Cambridge XAAR were selected, and finally an agreement was reached with SEIKO to develop print heads specifically designed for ceramic tile applications. Cooperation between Kerajet and SEIKO lasted from 2002 to 2009. Micro milling technology capable of ensuring the new ink powder for the inkjet technology was sourced from Germany. Additionally, Kerajet

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

also made agreements to develop software with research laboratories external to the Castellon cluster.

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 for the inkjet technology new inks, after realising that they provided much higher added value. The new technology offers extraordinarily sharp image resolutions, fast line speeds and heightened productivity.

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

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

Italian equipment producers – of which, one, Durst has a plant in Spain.[8] The Spanish Castellon cluster dominates the technology and concentrate 80% of the world production of inkjet technology (accounting for the machinery, 99% of the world especial inks) and one third of the world inkjet ceramics production.

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 leading firms, Kerajet still has a strong penetration, accounting for an estimated 50-60% of global 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 to the estimates of experts (Ceramic World Review, 2011)[9], in 2011, 18-20 % of total worldwide ceramic tile producing lines were digital while the projection is that by 2013 the percentage will double.

5. Discussion of results

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 off 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.

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

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, those lead users which are early adopters of 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 TG role.

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 an 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

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

technology dissemination in the latter phases of the consolidation of the new technological 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). This knowledge exchange also permitted new spin-off TGs to enter the incumbents' established networks.. In fact, nowadays the incumbent TGs previous to the disruption still retain their roles, but now sharing 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 access agent 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 (company Netzsch) solved the initial phases of organic pigment development, and was brought in from other external industries such as chemicals and electronics. These facts support the view of the importance of external linkages (e.g. Bathelt et al., 2004) in improving the availability of resources 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 chemical 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 into play 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 the reservation of not specifically referring to new-to-the-industry knowledge. Thus Menzel and Fornahl (2010:231) stated:

"Clusters can increase heterogeneity 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 transition of the disruptive technology to significant market use was slow, and took almost six years. As shown in table 1, the dynamics of TG development across the differing stages of the CLC are particularly 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, Cretaprint which successfully completed a transition to the new technology and has been bought by EFI a printing company in Silicon Valley[10] and *Durst*. All these three companies retain more than 75% of the market share. 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, Jettable, Intesa, Projecta, Tecnoferrari*, among others) during the growth stages (2007 to 2012), not when the technology was experimental and emergent (2000-2006). Overall, the incumbent TGs did not renew the cluster. Rather, it was a spin-off company which temporarily adopted the main roles, developing external ties and engaging in technology creation and diffusion – which are traditionally supposed to be performed by the TG. Nevertheless, incumbent TGs established strategic alliances with the new entrants to ensure access to the latter's products (new inkjet equipment producers are the distribution channel for the new inks developed by traditional frits-glazing firms, i.e., the

[10] AFI is a world leader in customer-focused digital printing innovation *in* Silicon Valley in the USA. In 2012 it was announced it had acquired Cretaprint,, a leading developer of inkjet printers for ceramic tile printing, based in Castellon. Retrieved in January, 2012. http://www.bookbusinessmag.com/article/efi-acquires-cretaprint-expands-inkjet-focus-ceramic-tile-printing/1

existent incumbents), and the new entrants also took advantage of the alliances to enter to the incumbent TGs networks.

Insert table 1 here

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. Framework in the aforementioned objectives, the main questions answered are: (1) Are small new entrepreneurial firms or incumbent TGs the ones which create knowledge to reinvent clusters? (2) Are TGs resilient at different CLC stages?

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 based at the economic geography, the entrepreneurship and the management and technology strategy literature, this work has constructed a fertile cross-field framework to study the themes of technological gatekeepers and cluster life cycles in conjunction.

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. Our results are in line with those of Brenner and Schlump (2011) which suggest that most of the policy making in clusters is designed irrespective of the different stages of the cluster life cycle. As showed, the emergence phase in which the technology is in its infancy and the cluster heterogeneity increases requires specific policies which are different from those tailored for a growth phase in which new (start-ups and alliances) entrants appear and the technology is disseminated reducing thus the cluster heterogeneity and the technological trajectories again. Second, scholars should also research the potential role of temporary technology gatekeepers and how it relates to the dynamics of 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 their relation 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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Table

Table 1. Evolution of Main Technological Gatekeepers in Ceramic Tile Decoration Technology.

CLC: central stages	**CLC: Emergent renewal stage**	**CLC: Growing stage**
Rotocolor technology dominant paradigm; Knowledge heterogeneity reduced and focused around Rotocolor and traditional screen tech. Established TGs (big frits and glazing firms: Esmalglass, Ferro, Torrecid, Endeka, Colorobbia	Knowledge heterogeneity increases in the transition from Rotocolor towards Inkjet Spinoff process leading disruption Temporary technology gatekeepers Main existing TGs reluctant to adopt new technology Knowledge uncertainty Resistance to change to the new technology.	Acceptance of the inkjet technology and a process of paradigm change from Rotocolor towards Inkjet New entrants expected Sassuolo and Castellon leading clusters adopting new technology. New TGs in the cluster, plus the previous incumbents Inkjet market leaders (around 75% of the inkjet market) allied with incumbent TGs producers of inks for inkjet (80% of the new inks market share): exchange of networks and collaboration to establish standards -Torrecid with Durst -Ferro with Kerajet -Esmalglass with Cretaprint Big Sassuolo TGs from the equipment Industry also spinoff laggards in the inkjet technology (less than 15% of the market share for inkjet): Intesa, Project, Espectra, Tecnoferrari, etc.

Table 1 continued

Gatekeepers in Cluster (1990-1999)			Breakthrough and temporary Gatekeepers in Inkjet technology (2000-2006)			Current Gatekeepers in all technologies (2007- 2012)		
Mechanical Equipment: Based at Rotocolor and traditional screen	Pigment Producers	Inkjet tech manufacturers	Mechanical Equipment	Pigment Producers	Inkjet tech manufacturers	Mechanical Equipment	Pigment Producers	Inkjet tech manufacturers
4 Italian companies co-located in Castellon with headquarters in Sassuolo (System, Tecnoitalia, Sacmi and Barbieri)	1 Italian producer in Castellon, headquarters in Sassuolo (Coloribbia) Technology: Frits and glazes for Rotocolor and traditional screen	None	0 Sassuolo	0 Sassuolo		4 in Sassuolo cluster (System-Tarozzi, Sacmi, Barbieri)	1 Italian producer in Castellon, headquarters in Sassuolo (Colorobbia)	Mainly spinoffs from big equipment manufacturers in Sassuolo, Intesa (Sacmi) Projecta (Barbieri) Espectra (System): laggards
1 Firm in Castellon (Cretaprint) Technology: Rotocolor	4 world-class frits-glazing firms with headquarters in Castellon (Torrecid, Esmalglass, Ferro and Endeka)* Technology: Frits and glazes for Rotocolor	None	1 Castellon Cretaprint, following Kerajet	1 Castellon (FerroSpain, the firm which spawned Kerajet) was first developed of inks for the inkjet technology, and specifically for Kerajet machine	1 Castellon (Spin-off firm: Kerajet) Kerajet is the only one in the world market with a Patent and has issued the rest for patenting infringement.	1 Firm in Castellon (Cretaprint) Technology: Rotocolor	4 Castellon firms (Ferro Spain, Endeka, Torrecid, Esmalglass)	2 Castellon (Kerajet, Cretaprint) 2 Firms from outside the Sassuolo and Castellon cluster (Durst, Jettable): new entrants from printing technology field, no spin-offs; early new entrants

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