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Do clusters follow the industry life cycle?

Diversity of cluster evolution in old industrial regions

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Abstract

Purpose – This paper aims to examine whether in old industrial regions, the trajectory of clusters follows that of their corresponding industry or deviates from it and which are the factors that account for cluster evolution. This paper deals with the issue of how established clusters either renew or transform themselves in such regions and how they adapt to changes in their corresponding international industries.

Design/methodology/approach – This research paper draws from in-depth case studies on six industrial clusters, takes a longitudinal perspective and uses a multi-level and qualitative analysis. Based on existing literature, the paper suggests and exploratory analytical framework with four alternative scenarios for cluster evolution and three broad factors: cluster knowledge base, social capital at cluster and region-level and public policies.

Findings – Clusters do not always follow the life cycle of its dominant industry. The paper clearly shows a diversity of cluster evolution across clusters and even within clusters (at subcluster level). This study suggests that cluster knowledge diversity and heterogeneity allow to broaden the scope of evolutionary trajectories available; the same goes for social capital at cluster and region levels.

Research limitations/implications – The main limitation of this paper lies in its qualitative approach that makes its conclusions more suggestive than conclusive. In any case, further research on other Basque clusters may corroborate or question its findings.

Originality/value – The paper offers an empirical and longitudinal study on cluster evolution, very much needed to the ongoing theoretical discussion on this issue. So far, there are very few empirical studies on cluster evolution with this perspective. At the same time, it presents a theoretical framework to analyse diversity of cluster evolution in old industrial regions that builds on Menzel and Fornah's (2010) model.

Keywords Basque country, Cluster, Life cycles

Paper type Research paper

1. Introduction

Although it is widely recognised that cluster life cycles can differ from their dominant industry and/or technology life cycles, currently, there is still little empirical research assessing how and why the life cycles of clusters differ from those of their respective dominant industries (Fornahl *et al.*, 2015). We aim to analyse in this paper whether in old

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industrial regions, the trajectory that clusters follow mirrors that of their corresponding industry or deviates from it and which are the factors that account for cluster evolution. In particular, we deal with the issue of how established clusters either renew or transform themselves in such regions and how they adapt to changes in their corresponding international industries (Tödtling and Trippl, 2004; Trippl and Tödtling, 2008).

The empirical base of this paper draws from in-depth longitudinal case studies on six industrial clusters of the Basque Country: papermaking, maritime industries, machine tools, energy, electronics and information and communication technologies (ICTs) and aeronautics. Based on this sample, and using selected quantitative and qualitative data amenable to comparison, we have attempted to, first, make a comparative assessment of the evolutionary trajectory of every cluster since c.1980 and, second, to examine whether the cluster life cycle follows that of its dominant industry or deviates from it. In this period, this old industrial region had to face up to the challenges of three economic crises (the first half of the 1980s, the early 1990s and the last one that started in 2008), a widespread and, in some sectors, radical technological change, and an increasing economic openness and globalisation.

The paper has five parts. In the first one, we discuss the theoretical literature on cluster life cycles and present the analytical framework we have developed to classify cluster trajectories in relation to the trajectories of their corresponding industries. Then, we explain in Section 2 the methodology and data used. This is followed, in Section 3, by a presentation of the six clusters studied and a stylised analysis of the competitive trajectory of every cluster from the late 1970s onwards. Afterwards, in Section 4, we discuss how established clusters have adjusted to the evolution of their dominant industries and, if so, how they have been able to renew or transform themselves, and suggest some driving factors of their evolution. Finally, we offer some conclusions.

2. Cluster life cycles: beyond the industry life cycle

Like a product, an industry also follows cyclical development patterns. Klepper (1997) distinguishes three different stages of an industry life cycle:

(1) an embryonic stage with small output;

(2) a growing stage; and

(3) a mature stage with a decline in the number of companies and employees.

This seems to indicate a deterministic industrial path. However, similarly to what has been described for cluster life cycles (Menzel and Fornahl, 2010), industries might also be able to adapt or renew themselves.

At first glance, it might seem obvious that cluster life cycles tend to co-evolve with the life cycle of its dominant international industry and technology. The cluster life cycle, then, would only be the local expression of its industry. However, both theoretical and empirical studies indicate that clusters do not necessarily follow the life cycles of their dominant industries, as, first, there are other factors that work at cluster and regional levels, and, second, different clusters that belong to the same industry life cycle follow different evolutionary paths. That is, some clusters are able to escape from the tyranny of the industry life cycle and from lock-in situations while others cannot (Bergman, 2008; Menzel and Fornahl, 2010; Martin and Sunley, 2011; Ter Wal and Boschma, 2011; Suire and Vicente, 2014). And the same goes for

the regions where these clusters are located (Martin and Sunley, 2006 and 2011; Martin, 2010).

Clusters, therefore, can be viewed as complex adaptive systems (Martin and Sunley, 2011) made up of different components (companies, suppliers, institutions […]), with different characteristics, that interact with each other in a systemic way (Menzel and Fornahl, 2010, p. 20). The population of clustered firms and other organisations is heterogeneous in terms of knowledge and capabilities (Ter Wal and Boschma, 2011) and, hence, clusters "do not develop evenly and as a whole" (Martin, 2010; Menzel and Fornahl, 2010, p. 224).

Regardless of whether the authors support the stylised life-cycle model (Trippl and Todtling, 2008; Bergman, 2008; Menzel and Fornahl, 2010) or the adaptive life-cycle model (Martin and Sunley, 2011), all stress that maturity and decline is one among many possible trajectories of cluster evolution. Menzel and Fornahl (2010, pp. 218-219) point to three other scenarios: adaptation (within the sustainment phase), renewal (that would lead the cluster to a new growth phase) and transformation (that would lead the cluster to a radically new phase of emergence) (Figure 1).

As to the driving factors of cluster evolution different than those related to the industry and technology life cycle, all authors point to the cluster knowledge base, although with different emphasis and focus: cluster knowledge diversity and heterogeneity (Menzel and Fornahl, 2010); knowledge embedded in the clustered firms' capabilities (Maskell and Malmberg, 2007); firms' capabilities and networks within the cluster and outside, including cluster absorptive capacity (Giuliani, 2005; Ter Wal and Boschma, 2011; Elola *et al.*, 2012); structural properties of cluster knowledge networks (Suire and Vicente, 2014); and knowledge embedded in the region where the cluster is located (Bergman, 2008; Trippl and Tödtling, 2008; Martin and Sunley, 2011). Other

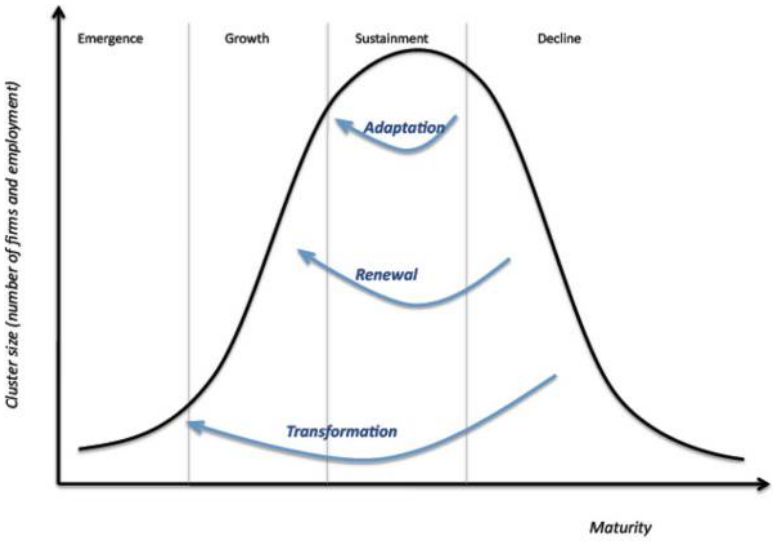


Figure 1.
Diversity of cluster evolution trajectories

Source: Authors' elaboration, from Menzel and Fornahl (2010: Figure 4)

empirical studies also suggest the role of local demand, factor conditions, entrepreneurship and the inflow of external knowledge and technology, along with historical legacy in cluster origins; and path dependent mechanisms linked to both cluster and region evolution (social capital, development of cluster specific factors and public policies) in cluster development (Van der Linde, 2003; Belussi and Sedita, 2009; Elola *et al.*, 2012; Brenner and Mühlig, 2013).

Social capital, in particular, is widely understood as conducive to the promotion of intellectual capital, collective learning and the creation and transfer of knowledge both inside and outside the firm's and cluster's borders (Nahapiet and Ghoshal, 1999; Lawson and Lorenz, 1999; Maskell, 2001; Westlund, 2006; Malecki, 2012). Cluster and business associations are regarded as institutions that promote inter-firm cooperation within and between clusters, build up social capital and increase cluster absorptive capacity (Carbonara, 2002; Molina-Morales, 2002; Giuliani, 2005; Valdaliso *et al.*, 2011; Niu *et al.*, 2012).

With regard to public policies, some authors have suggested the role of cluster policies and science, technology and innovation (STI) policies in facilitating cluster renewal and avoiding lock-in situations (Tödtling and Trippl, 2004; Trippl and Tödtling, 2008; Brenner and Schlump, 2011; Uyarra and Ramlogan, 2012).

Finally, clusters affect and are affected by their external environment and their trajectory co-evolves with that of the region where they are located. Regional knowledge bases, competences and assets shape the scope of evolutionary trajectories available for clusters and industries there, and may result in higher economic diversification or specialisation (Boschma, 2004; Asheim and Gertler, 2005; Martin and Sunley, 2006; Nefke *et al.*, 2011).

Martin and Sunley (2006) suggested five possible trajectories of regional development other than that of lock-in and decline: indigenous creation, heterogeneity and diversity, transplantation (of a new industry or technology) from elsewhere, diversification into technologically related industries and upgrading of existing industries. With a particular focus on old European industrial regions, Trippl and Tödtling (2008) proposed three types of cluster-based renewal related to three distinct regional development paths: incremental change (innovation-based adjustment of mature clusters), diversification (new clusters in established industries) and radical change (new high technology clusters). These types may coexist within a given region[1].

Following the above discussion, and given that our study attempts to assess cluster evolution in old industrial regions facing a new phase of widespread technological change and increasing global competition, we have opted for displaying the alternative cluster evolutionary trajectories in the phases of sustainment and decline of Figure 1, taking into account the "degree of evolution" in both the cluster (measured by the number of firms, employment and production, and other qualitative indicators related to cluster knowledge) and its dominant industry (measured by the rate of technological change, its market trends and its business structure) (Figure 2). We suggest four distinctive paths for existing clusters in old industrial regions:

(1) *Sustainment and maturity (and eventual decline, adaptation or renewal)*: Clusters follow the life cycle of the dominant industry that is not changing noticeably (although the situation might change in the future).

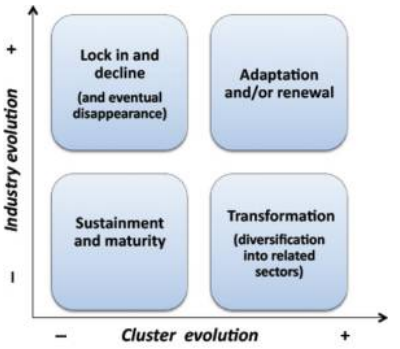


Figure 2.
Alternative cluster evolutionary trajectories in old industrial regions

Source: Authors' elaboration

(2) *Lock-in and decline (and eventual disappearance)*: Clusters are not able to adapt to the technological change undergoing in the dominant industry and, consequently, they become locked-in, decline and eventually disappear.

(3) *Adaptation and/or Renewal*: Clusters are able to adapt to the evolving technological trajectory of the dominant industry by renewing and/or transforming their knowledge base, in a process that goes hand in hand with the technological evolution of the dominant industry.

(4) *Transformation*: Clusters are able to escape from declining or mature industries by applying their knowledge base to enter into related (and more dynamic) sectors, some of them even new to the region.

3. Data and methodology

The economic evolution of the Basque Country from the early 1980s until 2008 has been described as "a regional transformation success story" (OECD, 2011): an old industrial European region that, building on its regional base of resources and capabilities and using innovative cluster and STI policies, successfully managed to cope with the severe economic crisis and industrial restructuring in the 1980s by renovating and upgrading some of its mature industries and by promoting new high-technology ones (Aranguren *et al.*, 2012a; Birch *et al.*, 2010 for a comparative assessment).

This paper draws on in-depth longitudinal studies on six Basque industrial clusters particularly representative of the industrial development of the region in the nineteenth and twentieth centuries: papermaking, maritime industries, machine tools, energy, electronics and ICTs and aeronautics[2]. Along with the detailed information of every case study, we have used quantitative data to undertake the comparative assessment:

- data series of gross value added, working hours and employment for the industrial sectors most representative of every cluster from 1982 onwards[3];
- data series of turnover, exports, employment and number of firms for every cluster given by its respective cluster association[4]; and
- data on exports at cluster and subcluster level and its share over world exports for the period from 1995 to 2012 (most of this information is not included in the paper

due to tight space requirements, but can be provided by the authors if requested)[5].

The task of matching every cluster with any of these possible scenarios faces at least three important methodological problems. First, how to deal with the co-evolutionary and thus systemic relationship between industry and cluster life cycles? Given that our sample of clusters is mostly comprised of "followers" rather than "leaders" of their respective industries (with the exception of some firms of the energy cluster), we have taken the factors related to the technology and industry life cycle at international level (e.g. technological change, demand, industry structure) for granted (e.g. as given, although it does not mean that they are not important) and focused instead on how the Basque clusters adapt to them and which are the factors at play at both cluster and regional level[6].

Second, cluster (and region) knowledge base has been regarded as the main factor of cluster evolution. However, the problem of how to measure such an intangible factor – either qualitatively or quantitatively – continues to be under discussion. As mentioned above, cluster knowledge base is integrated by three different knowledge sources:

(1) those that come from the strategic and dynamic capabilities of the clustered firms;

(2) those that stem from other firms and institutions in the region; and

(3) those that come from global sources.

R&D expenditures over turnover, R&D employees and human capital levels may be taken as proxies for firms' and region's capabilities (Sources 1 and 2). Firms' and cluster's degree of internationalisation, measured by the ratio of exports over turnover, may be a proxy for both firms' capabilities and cluster openness, and linked to the latter, for the degree of cluster absorptive capacity of external knowledge (Sources 1 and 3). As to the cluster knowledge diversity and heterogeneity (Source 1), we have adopted the following indicators as proxies:

- the number of industries represented in the cluster, the number of public research organisations (PROs) involved; and
- cluster size (e.g. the number of companies and organisations).

Knowledge diversity and heterogeneity at regional level (Source 2) can be measured by the sector distribution of gross domestic product (GDP), with particular attention to manufacturing activities with high and medium-high technological content and knowledge-intensive business activities, and the extent of related variety in exports[7]. Finally, the existence of cluster associations and other mechanisms of collaboration has been taken as a proxy for social capital and thus the existence of intra-cluster knowledge linkages and networks (Sources 1 and 3).

Third, assuming that clusters are complex adaptive systems made up of different components (companies, suppliers, institutions […]), with different characteristics, and that clusters as a whole do not develop uniformly, the assignment of a given cluster to one of the trajectories is based on taking the trajectory of the key clustered firms as a representative of that of the whole cluster.

The variety of sources used in the six case studies, the multi-level and qualitative analysis adopted and the aforementioned methodological problems, makes our comparative assessment a descriptive and exploratory study (Yin, 2003; Eisenhardt and Graebner, 2007; for a similar methodology, see Bresnahan *et al.*, 2001; Feldman, 2001; Shin and Hassink, 2011; Zettinig and Vincze, 2012). However, given the need of more empirical and, in particular, longitudinal studies on cluster evolution (Boschma and Fornahl, 2011; Fornahl *et al.*, 2015), our study can contribute to the ongoing theoretical discussion on this issue.

4. Cluster evolution and transformation in the Basque Country since c.1980

The origins of the six clusters under consideration can be traced back to different points in time. The clusters of maritime industries, papermaking and machine tools have a long history that goes back to the nineteenth century (and even farther in the first two cases) and have followed an entire life cycle of emergence, development, maturity and decline or renewal. The energy cluster dates back to the first years of the twentieth century, linked to the spread of electricity in the region and comprises not only the activities of production and distribution of energy but the manufacturing of energy equipment and related services as well. The clusters of electronics and ICTs and aeronautics correspond to younger industries that appeared in the 1940s-1950s and in the 1990s, respectively, and are still in a development phase (Aranguren *et al.*, 2012a, pp. 125-145).

From the late 1970s onwards, the Basque industry faced up a severe economic crisis that went hand in hand with an intense process of globalisation and technological change. Mature industries in which the region had long specialised, such as iron and steel, metal products, shipbuilding, machinery and electrical equipment were hit hardest by the combination of a falling demand and a fiercer competition from emerging countries. Besides, Basque firms had lived for decades serving a domestic market highly protected from foreign competition and were scarcely used to compete abroad, but after Spain's integration into the European Economic Community in 1986, this scenario changed radically. In spite of this adverse situation, the Basque industry managed to survive, change and grow. Although the share of industry over the GDP of the country diminished with respect to that of the early 1980s (from 43 per cent in 1980 to 22 per cent in 2012), the Basque country still ranks among the most industrialised regions of the European Union (Navarro *et al.*, 1994; Aranguren *et al.*, 2012a, pp. 145-181).

In 2012, the clusters of energy, maritime industries and electronics and ICTs comprised over 300 firms each, while those of machine tools, aeronautics and papermaking were quite smaller. According to employment and turnover figures, the biggest cluster was that of energy, followed by electronics and ICTs and maritime industries and machine tools (Table I)[8].

In the late 1970s, the Basque *papermaking cluster* comprised about 30 manufacturing firms of paper and pulp (with an average size smaller than their foreign competitors), plus c.50 firms of paper products, and a small number of manufacturers of machines and equipment for this industry. As a result of the domestic and international crisis of the late 1970s, demand and prices collapsed (while labour, energy and capital costs increased), and competition became fiercer. Besides, the internationalisation process in this industry since the 1980s made paper and pulp global commodities, increased cost competition worldwide and reduced prices and brought about a process of business

Table I. Main figures of the six Basque clusters c.2012

Cluster	Firms	Employment	Turnover	Exports	R&D expenditures	Exports/ turnover (%)	R&D/ turnover (%)
Aeronautics and space	60	4,142	771	694	195	90.0	25.3
Electronics and ICT	289	11,900	2,950	1,210	122	41.0	4.1
Maritime industries	350	6,430	985	837	n.a.	85.0	n.a.
Paper making[a]	20	1,650	614	302	n.a.	49.2	n.a.
Energy	350	23,336	15,943	n.a.	253	c.36	1.6
Machine tools[b]	108	5,762	1,107	846	n.a.	76.4	5.0

Notes: SPRI, *Observatorio de Coyuntura Industrial* 2013-I; and ACE, *Panorama del Clúster de Energía del País Vasco 2011*, for the energy cluster; Data on turnover, exports and R&D expenditures, in million euros; Otherwise is stated, figures refer to facilities located in the Basque Country; [a]Figures refer to 2010 and to the firms affiliated to the cluster association, that represents about 50% of the whole cluster; [b]R&D/turnover ratio corresponds to 2011

consolidation that resulted in the creation of larger multinational groups to benefit from economies of scale (Whiteman, 2005; Valdaliso *et al.*, 2008).

As happened in other European countries, some of the pulp and papermaking firms of the Basque cluster, unable to compete, broke down and exited from the sector. The survivors specialised in a smaller product range, invested in new machinery and equipment and became more international. Some of them were merged into big multinational groups. Employment figures fell between 1982 and 1993, then slightly grew in the second half of the 1990s and later stabilised until 2008 (Valdaliso *et al.*, 2008). Between 1995 and 2008, both sectors maintained their competitive position in terms of exports, while that of the Basque manufacturers of pulp and paper products did not change noticeably in the former case or even diminished in the latter one. But all of them saw its share over world exports decline between 2008 and 2012.

On the eve of the international maritime crisis of the 1970s, the Basque *cluster of maritime industries* comprised two big shipyards, highly specialised in the manufacturing of big standardised merchant vessels (tankers and bulk carriers) for the world market, along with about ten medium shipyards, more flexible and with a larger product range, and a bigger number of small shipyards and firms in auxiliary and related industries and services. The collapse of the international shipping market after 1974 hit hardest the largest Basque shipyards specialised in the type of ships most affected by the crisis and by the increasing competition of East Asian nations. They disappeared or, after a substantial reconversion, specialised in other type of vessels (Valdaliso, 2003). The small and medium shipyards, on the contrary, due to their wider product range and their higher flexibility, specialised in differentiated market niches, where Asian shipbuilders could not compete. This strategy of product differentiation, together with a strong commitment to innovation, helped those shipyards to survive and even grow, although with heavy cuts in employment.

During the 1980s and 1990s, the auxiliary and related industries (marine engines, parts and equipment) underwent a period of creative destruction: many companies disappeared, while others, either incumbent ones or start-ups, promoted by former technicians from the closed shipyards and/or companies, introduced innovative products and solutions, broadened their product range and went international (Valdaliso *et al.*, 2010). Between 1998 and 2008, a period of expansion in the world shipbuilding industry (Stopford, 2009, p. 625), sales, exports, employment and number of firms grew, particularly from 2005 to 2008, and declined afterwards, except the latter one, that remained stable.

The *machine tool cluster* faced up a severe crisis between 1976 and 1985 due to the sharp reduction of the Spanish market, significant cost increases and the appearance of new lower cost Asian competitors in the segment of conventional machine tools (with low technological content). On top of that, Basque manufacturers had to cope with the introduction of numerically controlled machine tools and, more generally, microelectronics in this industry (Urdangarín and Aldabaldetrecu, 1982; Mazzoleni, 1999). The collapse of the Spanish market forced Basque manufacturers to go abroad: between 1970 and 1980, the ratio of exports over production grew from 25 to more than 60 per cent (Check, 1985). By mid-1980s, Basque firms had a low scale of production, a narrow product range, and a competitive strategy that was halfway between cost and product differentiation. Unable to compete with lower-cost/high-scale manufacturers such as Taiwan and South Korea, they decide to upgrade their products making

higher-quality goods, as manufacturers with a similar plant size were doing in Germany and Italy (Calabrese, 1993; Monitor Company, 1993). Basque firms merged into larger groups and invested heavily in R&D resources and facilities (Calabrese, 1993; Soraluze, 2012).

In terms of firms and employment, and with regard to the figures of the early 1970s, the sector, that witnessed a new international crisis in the early 1990s, experienced a steady decline until c.1995. The number of firms continued to decline until 1995 and then remained stable, while that of employees that had decreased until 1995 tended to grow until 2002 and to slightly diminish henceforth. Sales and exports showed an upward trend between 1996 and 2008 that followed that of the world industry, then diminished sharply until 2010 (CECIMO, 2011). During this period, the cluster has gone international either by the increasing share of exports over sales or by the establishment of facilities abroad. Its competitive position over those years, in terms of world exports' share, remained fairly stable.

On the eve of the oil crisis of 1974, the *Basque energy cluster* comprised two big firms in electricity (Iberdrola) and oil refining (Repsol-Petronor), and several small and medium firms in the sectors of electrical parts and equipment, power electronics (transmission and distribution of electricity) and engineering. From the 1980s onwards, the cluster went through a phase of renewal and reorientation, linked to the diversification of traditional energy sources (substitution of gas natural for oil) and the diffusion of renewable energies such as wind and solar energies. The development of these new sectors not only brought about new markets for incumbent firms in this cluster (electric and electronic equipment, engineering) but it also opened up new windows of opportunity for firms in related industries and clusters as well, such as aeronautics, shipyards and marine equipment manufacturers. Iberdrola entered the wind energy business in 2001 and very soon it became a global leader in terms of wind power capacity. Another younger firm of this cluster, Gamesa, diversified from aeronautics into wind turbines manufacturing in the 1990s, became a key partner of Iberdrola (to which it supplied about 60 per cent of the wind turbines installed in its wind farms) and ranked among the global top five turbine manufacturers from 2003 onwards. Both companies lead global value chains [global value chains (GVCs), henceforth] in the wind energy sector into which several firms of the Basque cluster have joined (Elola *et al.*, 2013a). The expansion of the manufacturing activities of the energy cluster since the mid-1990s helps to explain the growth of employment in the electric and electronic equipment industries and their internationalisation both in terms of exports and of their facilities worldwide.

The *electronics cluster* had to cope with the technological divide brought about by the introduction of the microchip and the transition from analogue to digital electronics that happened in the 1980s. This opened up a window of opportunity for this sector, as microelectronics spread across different sectors from industry to services. The incumbent firms of this cluster completed the transition to digital technologies, reinforced their control over the Spanish market and started or increased their export orientation. Many new small firms, either spin-offs of incumbent firms and technological centres or start-ups, were created in the 1980s and the 1990s, not only in electronics but in the expanding sector of information and communication technologies as well (López *et al.*, 2008; Valdaliso and López, 2008; Valdaliso *et al.*, 2011). Most of these

new firms were born global, and maintained a strong commitment to innovation and internationalisation ever since (Valdaliso, 2010; Valdaliso *et al.*, 2011).

The creation of the Basque *aeronautics cluster* took place in the late 1980s linked to the initiatives of two big firms from other industries that entered the sectors of aerospace engines (Sener-ITP) and aerospace vehicles (Gamesa, later Aernnova) as Tier-1 suppliers of global leaders. Technological change in aeronautics and deregulation in air transport in the 1980s lowered entry barriers and increased modularity, paving the way to the creation of GVCs lead by airframe and engine manufacturers. Driven initially by Sener-ITP and Gamesa, many firms entered this cluster in the 1990s, either old companies from sectors in crisis (special steels, foundries, automotive parts) or new firms oriented to manufacture parts in metallic alloys, carbon fibre and composites. Later on, some of them moved upwards within the GVCs, becoming Tier-1 suppliers of the global leaders too (Lopez *et al.*, 2012; Elola *et al.*, 2013b). The main figures of the Basque aeronautics cluster (number of firms, employment, turnover and exports) experienced a steady growth between 1995 and 2013. Another significant feature of this cluster is high degree of internationalisation. Between 1997 and 2013, the number of firms' facilities located outside the Basque Country went from 2 to 76 (HEGAN, 2007; and Annual Report 2013). In 2013, Basque firms had 52 facilities located in the rest of Spain and 24 worldwide, that accounted for 43 per cent of turnover and 67 per cent of employment (HEGAN, Annual Report 2013).

5. Discussion

Do Basque clusters follow the trajectory of their respective dominant international industries? Based on our theoretical model presented in Section 1 and on the empirical evidence shown in Section 3, we have attempted to place every cluster in one of the four possible evolutionary trajectories. This has not been an easy task because, as we stated before, clusters are not internally homogeneous.

First, several subclusters that correspond to industries with different trajectories may coexist within a given cluster. Subcluster mapping was initially made according to exports, thanks to a conversion table provided by the Institute for Strategy and Competitiveness of Harvard Business School that matches HS6 harmonised system of export codes and cluster categories[9]. But there are other factors that reinforce this distinction, such as the different rate of technological change across the different dominant industries within every subcluster; or the previous trajectories of some of those subclusters, their relative importance and visibility reflected, for instance, in the creation of business associations (and hence, political influence)[10]. Due to these reasons, we have opted for splitting the energy cluster into oil and gas, on the one hand, and renewable energies and manufacturing of energy equipment, on the other. And the same goes for the electronics and ICTs cluster, separated into electronics and ICTs, and even for the papermaking and maritime clusters, with an increasingly diverging performance between producers of pulp and paper or ships, on the one hand, and manufacturers of equipment for their respective industries, on the other.

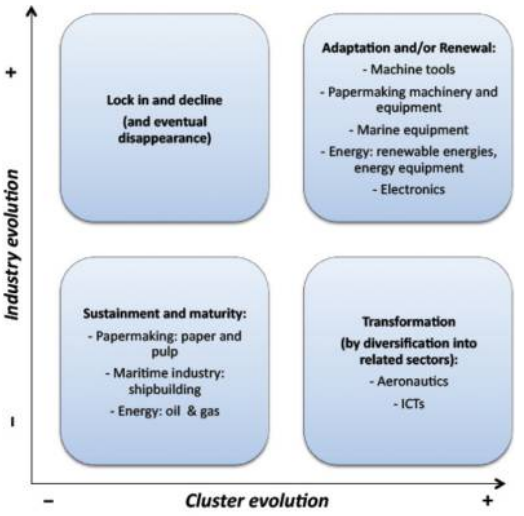
Second, clustered firms may differ in terms of their degree of adjustment to the industry life cycle. We establish the cluster evolutionary trajectories, and therefore, its assignment to one of the four possible scenarios described in Figure 1, based on the development of the cluster's core of firms and organisations. However, there are some clustered firms that deviate from that path and may stay either in an earlier stage (and

even, become locked-in and disappear) or partially escape from the industry life cycle by diversifying into new sectors[11].

At first glance, it seems that four out of the six clusters studied have followed the evolution of their respective dominant industries (Figure 3). Over the period analysed in this paper, the Basque papermaking and maritime industries clusters followed the life cycle of their dominant (mature) industries and managed to maintain its competitive position by becoming more cost-efficient (papermaking), specialising into niche markets (shipbuilding) and innovating and going international (papermaking and marine equipment). The same goes for the subcluster of energy production, where the leading firms in oil and gas have increased their size by a sustained strategy of internationalisation (combined sometimes with other of M&A abroad) and, in the case of electricity, by entering in the new sector of renewable energies, an emerging market for manufacturing and engineering firms of this cluster too. The machine tools cluster, and the subclusters of energy equipment and electronics were able to renew and transform themselves thanks to a combined strategy of innovation and internationalisation developed by a core group of medium size firms (some of them strongly linked to the large energy-producing firms).

There are, however, two new clusters that have appeared and developed in the Basque Country in the period under study: those of aeronautics and ICTs, linked to the new windows of opportunity brought about by technological change in those industries. The aeronautics cluster was not created from scratch; its foundations relied on the base of knowledge, resources and capabilities of incumbent firms of other related sectors (special steels, automotive, engineering) (López *et al.*, 2012). With regard to the ICTs subcluster, it started in the 1980s linked to the diffusion of microelectronics, software and telecommunication technologies that speeded up in the 1990s (López *et al.*, 2008).

Our findings fit well with the typology of cluster-based renewal of old industrial regions proposed by Trippl and Tödtling (2008, p. 207). With different degrees of



Source: Authors' ellaboration

Figure 3.
Evolutionary trajectories of Basque clusters from c.1980 onwards

innovation, the clusters of papermaking, maritime industries, machine tools and energy, would be good examples of "innovation-based adjustment of mature clusters"; while those of aeronautics and ICT would fit, respectively, into the "diversification" and "radical change" types.

As to the driving factors behind cluster evolution, we briefly discuss the impact of the following three factors mentioned in Section 2: cluster knowledge base, social capital and public policies.

Cluster knowledge base depends on the capabilities (and strategies) of the clustered firms, the cluster absorptive capacity and networks, and the region's capabilities. So far, we do not have a homogeneous quantitative indicator of the relative strength of the firms' knowledge base in every cluster, although the ratio of R&D expenditures over turnover may be a first proxy (Table I). Besides, in-depth case studies point to a higher R&D intensity and a relatively stronger knowledge base in the machine tools, electronics and ICT, energy and aeronautics clusters (large or medium firms with in house R&D units) than in the papermaking and maritime clusters (except for a few firms, particularly those that diversified into the emerging sector of renewable energies) (Lopez *et al.*, 2008, 2012; Valdaliso *et al.*, 2008, 2010, 2014).

The business strategies of the clustered firms – insofar as they are the result of their existing resources and capabilities – may be another proxy for the cluster knowledge base and have been identified as one of the driving factors of Basque clusters evolution (Elola *et al.*, 2012a; Valdaliso, 2013). The clusters of machine tools, maritime industries and electronics and ICTs comprise small- and medium-sized enterprises that have largely followed a combined strategy of product differentiation, innovation and internationalisation; the same goes for the subcluster of manufacturing of papermaking equipment and machinery. The presence of large firms is much more important in the other three clusters, but they have played a very different role. The large papermaking firms, some of them owned by MNEs, followed a strategy of price competition based on scale economies and cost efficiency. In the energy cluster, a few large firms in the oil refining, natural gas and electricity have played a tractor role for the SMEs specialised in energy equipment manufacturing that, in its turn, have followed the same strategy pointed for the SMEs of the machine tools and electronics and ICTs clusters. As to the aeronautics cluster, its origins and development are strongly linked to the efforts of two large anchor firms well positioned in the industry's GVCs. In any case, again, the type of industry (and technology) does matter, as it defines the scope of business strategies available for the clustered firms. For example, the "commoditisation" of paper in the global market forced papermaking firms to follow a cost competition strategy, while in other sectors, the strong market segmentation (machine tools, shipbuilding) or the fast pace of technological change (energy equipment, electronics and ICTs, aeronautics) broadened the scope of business strategies available (Elola *et al.*, 2013a, 2013b; Valdaliso, 2010; Valdaliso *et al.*, 2011, 2012b).

Some authors have stressed that the dynamic growth of clusters depends on their absorptive capacity, which has two dimensions:

(1) the intra-cluster knowledge system (based on the firms' knowledge base, the existence of regional communities of knowledge and technicians, the strength of their universities and technological centres); and

(2) the extra-cluster knowledge system (based on the relationship of leading clustered firms with foreign sources of knowledge, cluster insertion in GVCs, foreign direct investment of MNEs) (Giuliani, 2005).

With the exception of the papermaking cluster, the selected clusters benefited from a strong research and educational infrastructure in the region (technological centres, training schools and universities) closely related to their needs of qualified workers, researchers and technological solutions (Valdaliso *et al.*, 2011, 2012b). Besides, the Basque Country ranks relatively well among the European regions in terms of R&D and innovation indicators and educational levels (OECD, 2011; Aranguren *et al.*, 2012a). The six clusters appear to be well connected with foreign sources of knowledge, although by means of different channels: multinational enterprises in the papermaking cluster, internationalisation processes lead by leading firms (either SMEs, as in the machine tools, maritime industries, electronics and ICTs clusters or large enterprises, as in the energy cluster), and insertion of the large firms and SMEs of the aeronautics cluster into GVCs (Elola *et al.*, 2013b; Valdaliso *et al.*, 2011).

Another proxy to cluster diversity is the number of industries and sectors that it encompasses. The clusters of energy and electronics and ICTs were those with a larger number of subclusters according to exports, i.e. 10 and 6, respectively, whereas machine tools, aeronautics, maritime industries and papermaking were quite more specialised, with 1, 2, 3 and 4, respectively[12]. Additionally, clusters larger in size comprise many firms with a great diversity of technologies and knowledge, as our clusters of electronics and ICTs, maritime industries and energy show.

In terms of knowledge diversity at the regional level, the Basque Country maintained over this period a relative specialisation in industry – particularly in metal advanced manufacturing activities with medium-high and high technological content – and business services much higher than the average level of Spanish and European regions (NUTS2 level) (Eurostat, 2010; Aranguren *et al.*, 2012a, pp. 160-161, 174-175; Orkestra, 2013, p. 48). With regard to the related variety of regional exports, the estimation made for 2007 ranked Basque territories among the top ten Spanish provinces with a higher score (Boschma *et al.*, 2012). Although the causal relationship between these regional indicators and clusters' performance is not proved, however, it seems clear enough that Basque clusters counted on a regional base of knowledge and capabilities that might facilitate their renewal and adaptation.

Several studies have pointed out that social capital has enhanced both knowledge creation and absorptive capacity within and between clusters in the Basque Country, and have emphasised the key role played by cluster associations in this regard (Valdaliso *et al.*, 2011 and 2012a; Aragón *et al.*, 2012). However, the level of social capital, grossly measured by the representativeness and recognition of the cluster association, differs across our sample of clusters studied. It is relatively high in the machine tools, maritime industries, electronics and ICTs and aeronautics and relatively low in the papermaking one. As to the energy cluster, the strong business relations that exist between the large energy-producing firms and the manufacturing SMEs, act as a substitute for the minor role of the cluster association[13]. Cluster associations were not only drivers of social capital formation but they promoted inter-firm collaboration in human capital formation, R&D and internationalisation as well. Its role was more

important in those clusters comprising exclusively of SMEs that were not large enough to face those challenges alone.

Last, but not least, public policies applied in the Basque Country since the 1980s onwards have facilitated cluster-based renewal. The regional government showed a strong commitment in the 1980s to keep and restructure the traditional industries by a retooling strategy based on the creation and development of a technological infrastructure (technology centres and parks), a policy of R&D promotion (in house and external) and a strong emphasis on human capital formation. This policy was maintained in the 1990s, but combined with others: a cluster policy aimed at promoting the creation of several cluster-based initiatives in the six (and many other) clusters studied; and the first attempts to promote diversification into other sectors that did not exist in the region, such as aeronautics, telecommunications and creative industries. This strategy of industrial diversification (a "de-locking" mechanism according to Martin and Sunley, 2006) continued throughout the 2000s, but then with a clear stress on science-based sectors (bios, nanotechnologies and advanced manufacturing). Regional and national energy policies and strategies have encouraged the renewal and transformation of the Basque energy cluster, driven by renewable energy technologies (Aranguren *et al.*, 2012b).

6. Conclusions

In this paper, based on the evidence of the Basque Country, we contribute to the literature on cluster life cycles and on cluster evolution in old industrial regions. We specifically add new insights to the research on the relationship between cluster life cycles and the trajectory of its corresponding industry, by introducing an exploratory analytical framework with four different evolving scenarios for established clusters in the maturity phase of its life cycle depending on how clusters adapt themselves to the changes underwent by the region and by their dominant industries at international level; and with three driving factors at cluster and region-level: knowledge base, social capital and public policies. Our work contributes to the existing research in three different ways.

First, building on Menzel and Fornahl's (2010) theory, we develop a new framework to analyse how clusters evolve in the maturity phase of its life cycle. This framework seems particularly well suited to old industrial regions with many clusters in that situation. Mature clusters' trajectories will depend not only on the size and heterogeneity of knowledge but on the evolution of the underlying industry as well. If the industry is not changing noticeably (lower part of our framework), clusters can either remain within the industry's trajectory (sustainment and maturity) or they can transform themselves. This will usually imply moving to a different industry that might be either nascent or established. On the other hand, if the industry itself is changing very fast, the clusters have to change accordingly or they will become locked-in, and then decline or eventually disappear. Therefore, technology and industry do play a significant role in cluster evolution and clusters tend to co-evolve with their dominant industries. However, clusters are not only a local representation of the world industry, and their evolution may differ from the evolution of their dominant industry.

Second, our study contributes to the existing literature on cluster life cycles by adding new empirical evidence on the evolution of clusters and their respective dominant industries in old industrial regions. In our specific case, four out of the six

clusters studied followed the evolution of their respective dominant industries: some evolved in line with their dominant (mature) industries and managed to maintain their competitive position (papermaking and maritime industries), and others were able to renew and transform themselves (machine tools and energy). There are, however, two new clusters that have appeared and developed in the Basque Country in the period under study, aeronautics and ICTs. Our paper does not include examples of locked-in clusters because its empirical base draws on current established clusters in the region (but there are some examples of clusters that disappeared).

Third, with regard to the driving factors of cluster evolution, our study suggests, in a very exploratory way, a positive relationship between the size and heterogeneity of the cluster knowledge base and its possibilities of escaping from maturity and lock-in scenarios, by adapting to the rate of industry evolution, by renewing its base of resources and capabilities and/or by transforming themselves and diversifying into new sectors that did not exist in the region. In general, the larger the cluster and region knowledge base, the greater is the scope of adaptation possibilities of the clustered firms. Social capital, as an enhancer or knowledge creation and absorptive capacity, may also have played a positive role. Knowledge requirements will be more important for clustered firms to keep pace with industries moving through phases of rapid technological change or to diversify into new sectors and clusters that might even not exist in the region. In our sample, public policies helped this strategy of cluster transformation by diversification into new sectors such as ICTs and aeronautics in the 1990s.

Finally, our study raises some implications for policymakers, as it highlights some elements that policies should focus on to promote cluster competitiveness. First, policies should foster the creation and development of social capital by promoting the development of inter-firm networking and collaboration and community building through the support of cluster associations. Second, policies should also be oriented to increase the knowledge base and absorptive capacity of clusters, through the promotion of innovation and R&D activities (of firms and other agents of the regional innovation system) and internationalisation.

Notes

1. In fact, the research and innovation strategies for smart specialisation (RIS3) recently adopted by the European Commission (modernization or retooling, extending into related sectors and radical foundation of new industries) (Foray, 2013) are not that new, and may be seen with other names in several European regions in the past three decades (Trippl and Tödtling, 2008; Aranguren *et al.*, 2012b).
2. López *et al.* (2008) and (2012); Valdaliso *et al.* (2008), (2010) and (2014); and ongoing research on the machine tool cluster. Preliminary results of this meta-study can be found in Elola *et al.* (2012) and Valdaliso *et al.* (2012b).
3. EUSTAT, *Industrial Statistics* and www.eustat.es. The sectors are (in brackets, their codes of the national classification of economic activities A84 according to the CNAE-93): papermaking (21/21), machine tools (39/29.401), shipbuilding and other transport equipment (such as aircrafts, but not aircrafts engines) (47-48/35.1-35.5), electricity and oil refining (52 and 23/40.1 and 23) and office and computing machines, electric and electronic parts and equipment (42-43-44/30-31-32).

4. Cluster associations were created in the 1990s due to the cluster policy implemented by the Basque Government, see Aranguren *et al.* (2009) and (2012a).
5. "Subclusters are subgroups of industries within the cluster" (Porter, 2003, p. 563). Data series on cluster and subcluster exports between 1995 and 2012 are taken from Orkestra http://tools.orkestra.deusto.es/klusterbolak/regions/
6. Our assessment of the evolution of the international industry to which the cluster belongs is based on Basque cluster associations' annual reports, world or European industry associations' reports, world outlooks for their respective sectors and secondary literature.
7. Following Orkestra (2013), we assume the existence of a positive relationship between the relative importance of both sectors in a region and its competitive position. According to Frenken *et al.* (2007), the existence of related variety reduces the risks of excessive specialization and broadens the scope of regional development trajectories.
8. Notice, however, that both figures refer to facilities located in the Basque Country, what diminishes the overall importance of the most internationalised clusters – e.g. aeronautics, energy, machine tools and electronics and ICTs – whose firms have facilities dispersed in the rest of Spain and worldwide that accounted for, respectively, 62, 62, 49 and 44 per cent of their total employment for 2011.
9. See[5] We distinguish the following subclusters: aircraft and aircraft engines (aeronautics); electrical and electronic components, electronic components and assemblies, communications equipment, specially office machines, computers and peripherals (electronics and ICTs); porcelain, carbon and graphite components, electrical capacitors, electric energy, crude petroleum, hydrocarbons, oil and gas machinery, nuclear reactors, petroleum processing, transformers and turbines and turbine generators (energy); shipbuilding and repairing and marine engines (maritime industries); machine tools and accessories (machine tools); paper mills, paper industries machinery, pulp and waste paper and paper products (papermaking).
10. For instance, the Basque electronics industry had its own business association that later on transformed into a cluster association and included ICTs firms, López *et al.* (2008) and Valdaliso and López (2008). In the energy cluster, the companies of the two aforementioned subclusters belonged to different industry associations.
11. Some firms of the Basque cluster of maritime industries, such as Guascor, have partially diversified their product and client portfolio by moving into new and more dynamic sectors like that of renewable energies. The same went for Gamesa, a firm that started in the 1970s manufacturing metal products, then moved in the early 1990s to aeronautics and finally diversified into the wind energy sector (López *et al.*, 2012; Elola *et al.*, 2013a), and for many small suppliers of Gamesa in the Basque Country (Valdaliso *et al.*, 2014). These trajectories can also be seen in other European regions, see Fornahl *et al.* (2012).
12. So far, the number of subclusters attending to the analysis of exports is a more accurate proxy for diversity than the number of four-digit CNAE-93 sectors. The 15 four-digit CNAE-93 codes of the papermaking cluster, for example, can be grouped into the four aforementioned sectors, see Section 2 and [3] and [5].
13. In 2012, firms affiliated to cluster associations accounted for more than 90 per cent of turnover and employment of the whole population of firms in the aeronautics, machine tools and electronics and ICTs; between 80 and 90 per cent in the maritime industries; about 75 per cent in the energy cluster; and about 50 per cent in the papermaking one, see Table I for references.

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