European Planning Studies

ISSN: 0965-4313 (Print) 1469-5944 (Online) Journal homepage: www.tandfonline.com/journals/ceps20

The green-restructuring of clusters: investigating a biocluster's transition using a complex adaptive system model

Ram Kamath, Aitziber Elola & Frans Hermans

To cite this article: Ram Kamath, Aitziber Elola & Frans Hermans (2023) The green-restructuring of clusters: investigating a biocluster's transition using a complex adaptive system model, European Planning Studies, 31:9, 1842-1867, DOI: 10.1080/09654313.2022.2141054

To link to this article: https://doi.org/10.1080/09654313.2022.2141054

Published online: 06 Nov 2022.

EUROPEAN PLANNING STUDIES
2023, VOL. 31, NO. 9, 1842–1867
https://doi.org/10.1080/09654313.2022.2141054

Routledge
Taylor & Francis Group

The green-restructuring of clusters: investigating a biocluster's transition using a complex adaptive system model

Ram Kamath [a], Aitziber Elola[b,c] and Frans Hermans [a]

[a]Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Halle (Saale), Germany; [b]Orkestra - Deusto Foundation, Donostia - San Sebastian, Spain; [c]Deusto Business School, University of Deusto, Donostia - San Sebastian, Spain

ABSTRACT

Bioclusters' promise of helping achieving sustainable bioeconomies has invoked great interest among policymakers and academia. However, bioclusters are not intrinsically sustainable. If they are to fulfil their promise, bioclusters must undergo green-restructuring. While cluster-research has elaborated on green regional development, we need more clarity on how clusters transition to normatively desired states; we need more evidence of how green-restructuring unfolds. In this study, we conduct a longitudinal analysis to demonstrate how a biocluster green-restructures through the interactions of agency, regional and industrial structures, and phenomena at (supra-)national levels. To execute this analysis, we created a novel cluster-evolution framework that treats clusters, and the regional innovation system and sectoral systems of innovation that contain the cluster, as complex adaptive systems. We applied this framework to study the greening of the Basque pulp-and paper-biocluster, over four phases between 1986 and 2019. Our analysis helped us discover patterns of agency, structural dynamics, and of agency-structure interactions and how supra-regional phenomena shaped structures and agency over the four phases. Based on our findings, we recommend policymakers encourage not only green-tech entrepreneurs, but also institutional-entrepreneurs and place-leaders who can help shape both (supra-)regional and industrial structures.

ARTICLE HISTORY
Received 1 April 2022
Revised 14 October 2022
Accepted 21 October 2022

KEYWORDS
Green clusters; bioeconomy; path dependency; agency; place dependency; multiscalarity

1. Introduction

Given the threat of climate change disrupting access to essential resources, society requires a 'green shift'. Regions and countries increasingly view establishing a bioeconomy as a solution to this challenge (Ingrao et al. 2018; Martinez de Arano et al. 2018). The bioeconomy emphasizes biobased production, efficient utilization of renewable biological raw material, and circular-loops (Brunori 2013; Devaney and Henchion 2018).

CONTACT Ram Kamath kamath@iamo.de Leibniz Institute of Agricultural Development in Transition Economies (IAMO), 06120 Halle (Saale), Germany

To achieve regional bioeconomies, authorities are turning to bioclusters such as the Cambridge biocluster in the UK, and the IAR cluster in France (PriceWaterhouseCoopers 2011). Following Porter (1990), we define bioclusters as geographic agglomerations of interconnected organizations, operating in one or multiple bioeconomy sectors: pulp & paper, textiles, biochemicals etc. Bioclusters are expected to foster biobased innovations that can lead to the bioeconomy (Cooke 2002; Marsden 2013). Bioclusters are also drawing interest from academia. This is the result of growing interest in the possible role for industrial clusters in promoting sustainable innovation (Lazzeretti et al. 2019); and in helping regions diversify into green growth-paths (Hassink, Isaksen, and Trippl 2019; Grillitsch and Hansen 2019).

However, bioclusters, are not intrinsically sustainable (Pfau et al. 2014; Purkus et al. 2018). Especially when they operate in sectors such as paper or textiles, bioclusters can be quite dirty (Bergquist and Söderholm 2018). If bioclusters are to help achieve a sustainable bioeconomy, they must undergo green-restructuring. Cluster-restructuring is a complex process. Extant regional and industrial structures tend to encourage innovations that sustain these (unsustainable) structures (Belussi and Sedita 2009). Trying to (de)stabilize these structures will be various actors using different forms of agency (Grillitsch and Sotarauta 2018). Simultaneously, these structures and agency may be shaped by phenomena at National, Continental or Global scales (MacKinnon et al. 2019). Although some recent work has been done on green-restructuring of clusters (see Sjøtun and Njøs (2019), Kamath, Sun, and Hermans (2022)), we need more empirical evidence of how green-restructuring unfolds. In this study, we conduct a longitudinal investigation to demonstrate how a biocluster green-restructured through the interactions of agency, regional and industrial structures and phenomena beyond the region.

We executed this study by creating a novel cluster-evolution framework based on the perspective of Complex Adaptive Systems (CAS). We apply our framework to study the green-restructuring of the pulp-and-paper (P&P) biocluster in the Basque Country (Spain). We chose this biocluster because of the P&P industry's history of environmental issues, the cluster's history of sustainable growth, and the Basque region's strong cluster-based policy structure. Using our framework, we explain how the Basque biocluster moved to greater sustainability between 1986 and 2019. Through this descriptive analysis, we contribute to pivotal debates regarding the roles of agency and place-dependency in cluster-restructuring, and on the multiscalar nature of restructuring.

The rest of this paper is structured as follows. In section two, we describe the debates we contribute to, introduce our cluster-evolution framework, and state the research question we attempt to answer. In the third section, we describe our methodology. In section four, we describe in four discrete time phases, the Basque biocluster's restructuring. In the fifth section, we present our insights and contributions; policy implications from our findings; and avenues for future research.

2. Towards a CAS perspective on cluster-restructuring

Clusters have become a key feature of regional development plans. Clusters also draw scholarly interest from varied fields – Evolutionary Economic Geography (EEG), Sustainability-Transition Studies (STS), and Innovation Studies. While the majority of EEG literature has focused on the characterization of successful clusters, recent years have seen several studies

investigating cluster-evolution (Trippl et al. 2015). Being an emerging practice, there is still a lot of ground to cover in understanding the dynamics of clusters' restructuring.

2.1 Cluster restructuring

EEG has traditionally investigated the evolution of clusters using life-cycle models (which draw from the product life-cycle approach (Utterback and Abernathy 1975)). Generally, these models have the cluster moving through the stages of emergence, growth, maturity, and decline (Martin and Sunley 2011). There are two schools of thought on what governs clusters' 'ageing'. The first school asserts that a cluster's restructuring is synchronized with that of its industry(ies) (Neffke 2009). The model from Ter Wal and & Boschma (2011), for instance, proposes that a cluster co-evolves with the main technologies in the industry, the variety of firm capabilities and the knowledge network of the industry. The argument against this perspective is that while some clusters are able to thrive even if the industry is declining, others struggle despite being in a booming industry. From this argument, came the second school, which propounds that a cluster's restructuring is driven by characteristics unique to the cluster. Models from this school aim to demonstrate how clusters within the same industry can experience different trajectories. For instance, Menzel and Fornahl's (2009) cluster life-cycle model explains how restructuring is shaped by the variation of heterogeneity in capabilities, and population, within a cluster.

2.2 Ongoing debates regarding cluster-restructuring

Life-cycle models stimulated greater interest in investigating the long-term evolution of clusters (Isaksen 2011). However, these models have been criticized for treating cluster-evolution as a deterministic motion from emergence to decline (Frenken, Cefis, and Stam 2015). Regions and clusters may actually restructure along several paths (Isaksen, Tödtling, and Trippl 2018). A cluster may undergo path-extension, where it continually engages in incremental innovation to advance extant industrial activities (leading to eventual decline); it can undergo path-modernization, where the cluster renews regional industries by installing new technologies; the cluster may introduce industrial activities that are new to the region, but are based on extant regional structures, thus undergoing path-branching; the cluster may see path-importation, where foreign firms bring in industries new to the region; and finally, the cluster may engage in path-creation, where completely new industries, based on radical technologies, are introduced.

Martin and Sunley (2011) proposed that a non-deterministic model should factor in contextual influences, and agency effects. They created the 'modified adaptive cycle' model, which is based on viewing clusters as complex adaptive systems. In this model, restructuring emerges from the interaction of agency and structures. Because the CAS perspective treats cluster-evolution as non-deterministic, the authors could propose multiple possible cluster trajectories. Consequently, while preceding models can at most be used to analyse path-extension, this model can examine path-modernization, creation, renewal, importation or branching.

Indisputably, the adaptive life-cycle model furthered our understanding of the openness of cluster-evolution, and how this evolution results from the interaction of agency

and structures. However, this and other life-cycle models still inspire some ongoing debates in EEG. Below, we elaborate on these debates.

2.2.1 The role of place-based structures

EEG scholarship has predominantly focused on how industrial structures shape cluster-evolution. More recently, it began arguing that evolution is influenced by the regional innovation system (RIS) in which the cluster is nested. RIS structures such as incumbent industries, knowledge infrastructure, and regional policy can enable or hinder certain types of evolutionary-paths (Trippl et al. 2020). Isaksen and Trippl (2014) differentiate between three RIS types: the organizationally thick & diversified RIS (metropolitan regions), the organizationally thick & specialized RIS and the organizationally thin RIS. Metropolitan regions have ideal structures for path-branching and/or path-creation. The structures in specialized regions, and in thin regions, will have a proclivity to support incremental innovation. This tendency makes these regions prone to evolving along path-extension or path-modernization. Avoiding lock-in will require path-importation.

In spite of the progress in delineating how place-based structures influence the evolution of clusters and regions, multiple studies have argued that there is still need for greater clarity on the effects of place-dependency (Boschma et al. 2017; Neffke et al. 2018).

2.2.2 The role of agency

Regional and cluster paths may deviate from paths that they were expected to take, given regional pre-conditions (Grillitsch and Sotarauta 2018). It is definitely possible then that clusters within similar RIS experience different paths. This open-ended nature of cluster-restructuring is the outcome of strategic, distributed agency (Dawley 2014). Micro-/actor-level dynamics are, therefore, crucial in explaining restructuring processes (Asheim, Grillitsch, and Trippl 2016). The realization that paths of structural change are constructed by agency (Simmie 2012), led to criticism of extant cluster-evolution models, and of regional development studies, for not paying enough attention to agency (Trippl et al. 2015).

Based on Grillitsch and Sotarauta (2018), actors can use three forms of agency to shape cluster-restructuring: technological-entrepreneurship, institutional-entrepreneurship and place-leadership. Technological-entrepreneurship refers to product or process innovation. Creating an environment conducive for innovation requires institutional-entrepreneurship that maintains, changes, or introduces pertinent institutions. Finally, place-leaders help to align visions, ensure stakeholder participation and guarantee benefits.

2.2.3 The multiscalarity of cluster-restructuring

The third debate surrounding cluster-evolution is that of multiscalarity. The restructuring of nations, regions and clusters can be thought of as a function of the interactions of agency and structures (Mazzucato 2013). However, what is underestimated in this framing, is the effects of 'non-local sources and influences' (Hassink, Isaksen, and Trippl 2019, 1639).

RIS are embedded within governance systems that cross various spatial scales (Patchell & Hayter, 2013). Agency that affects structures may be exercised by actors at various spatial scales (Dawley 2014). This means that regional structures may be the consequence of actions at higher scales. Industrial structures may also be shaped by developments at national and supra-national levels. In other words, the effects regional or industrial structures have on cluster-evolution may be indirect effects of supra-regional phenomena (Ayrapetyan, Befort, and Hermans 2022).

There have been a few studies that demonstrated the multiscalar effects of policy actions (see MacKinnon et al. (2019)), and of extra-regional actor-networks (see Neffke et al. (2018)). However, our knowledge of the multiscalarity of restructuring is still limited (Trippl et al. 2020). For instance, while the effects of multiscalar phenomena on the RIS have been studied, there has not been a lot of emphasis on how the sectoral system of innovation (SSI) (Malerba 2002) is affected, and how it in turn affects agency.

2.3 Green-restructuring of clusters

Clusters were envisaged as a means to achieve economic targets (Porter 1990). However, they are now also being employed to achieve environmental targets. We see regions around the world have started using green-tech clusters, including bioclusters, to instigate greening of their economies (Hansen and Coenen 2015; Stegmann, Londo, and Junginger 2020).

Nevertheless, while EEG literature has elaborated on green regional development, it is yet to ordain a normative focus on clusters. Cluster-research has not sufficiently emphasized how clusters move into greener industries; and EEG lacks discussions on how policy can support this process (Sjøtun and Njøs 2019). The studies that do attempt to clarify how clusters can catalyse sustainability-transitions (such as McCauley and Stephens (2012), Hansen and Coenen (2015)) have come from 'geography of transitions' (GoT). In looking to bridge EEG and STS, GoT emphasizes investigation of how clusters and regions undergo green-restructuring. This has led to studies such as Grillitsch and Hansen (2019), and Trippl et al. (2020), which state that green-restructuring can take different paths: green path-creation by creating new green-technologies, path-importation by bringing in green technology from outside the region, green path-branching from existing industries, and finally, the path-modernization of an existing cluster via the introduction of greener products and processes.

With a few exceptions (such as Sjøtun and Njøs (2019)), most studies on green-restructuring have either made a theoretical contribution or employed computer modelling (e.g. Kamath, Sun, and Hermans (2022)). Consequently, we need greater understanding of how green-restructuring unfolds in reality. Following Grillitsch and Hansen (2019) and Trippl et al. (2020), we can infer that metropolitan regions are best placed to enable green path-creation; specialized regions have structures ideal for green path-branching or path-importation; and peripheral clusters will most probably restructure through green path-importation or path-modernization. What we do not know, however, is whether clusters actually adhere to these expected greening-paths; and whether there are differences between green-restructuring, and 'normal' restructuring. We also need more empirical evidence of how different actors use different forms of agency; and how this agency interacts with structures, supra-regional phenomena, to lay

out the evolutionary path. To address these concerns, and the debates detailed in this section, we conduct a longitudinal analysis of a biocluster's green-restructuring. To conduct this analysis, we create a novel cluster-evolution framework, which we introduce in the sub-section 2.5.

2.4 How clusters restructure

Our cluster-evolution framework is based on the factors discussed in sub-section 2.2 – agency, place-based and industrial structures, and supra-regional phenomena. As a prelude to introducing our framework in the following sub-section, we explain how all these factors interact to guide a cluster's restructuring.

We begin with our definition of a cluster. Drawing a boundary around porous systems like clusters is fundamentally difficult (Martin and Sunley 2003). So, for the sake of simplicity, we define a cluster as the members of the cluster. Following this, we define cluster-restructuring as cluster members transitioning. For instance, clusters will green-restructure as members transition to greater sustainability through cleaner production (by removing non-renewable inputs, introducing circular-loops, adopting clean energy etc.).

2.4.1. Cluster paths emerge from agency

As stated in sub-section 2.2, the development path of a cluster is laid out by agency. Since actors will use their agency to either advance or hinder any restructuring (Grillitsch and Sotarauta 2018), path-development will not be a linear process. Actors in the cluster can use technological-entrepreneurship, institutional-entrepreneurship and place-leadership to construct restructuring-paths.

2.4.2. Structures, agency shape each other

Clusters (and their members) are embedded within both a RIS, and a SSI (Kamath, Sun, and Hermans 2022); which means agency must confront, or conform to, both place-dependency and path-dependency. We define place-dependency as the process of regional structures being reproduced (Trippl et al. 2015); which forces the cluster to follow certain restructuring paths. We define path-dependency as the reproduction of the structures of the SSI; which ensures that the industry and its technologies evolve along a narrow channel (Boschma et al. 2017). Agency can end up being directed by the dependencies, in which case the cluster restructures along expected paths; or it can modify the dependencies, and take the cluster along unexpected paths.

2.4.3. Supra-regional phenomena shape structures, agency

Both regional and industrial structures can be shaped by events such as changes in the macro-level structures at the national, continental or global scales, and black-swan events beyond the region and industry (e.g. global recessions). By influencing the structures of the RIS and/or SSI, these phenomena indirectly shape agency. Supra-regional events may also directly mould agency (Hung and Whittington 2011).

Table 1 provides short descriptions of these factors, and their interactions. Synthesizing the relationships, restructuring-paths eventually emerges from agency. This agency

Table 1. Factors that combine to shape a cluster's restructuring-path, and their interactions.

Factor	Description	Interactions with other factors
Place-dependency	Place-dependency is the process of the regional innovation system's structures being reproduced; which forces the region and clusters to follow certain types of restructuring paths (Trippl et al., 2015).	Place-dependency guides agency, or it is guided by agency. Changes in RIS structures may be the result of multiscalar phenomena
Path-dependency	Path-dependency is the reproduction of the structures of the sectoral system of innovation; which ensures that the industry and its technologies evolve along a narrow channel (Boschma et al., 2017).	Path-dependency guides agency, or it is guided by agency. Changes in SSI structures may be the result of multiscalar phenomena
Agency	A cluster's development path is laid out by agency of three forms – technological-entrepreneurship, institutional-entrepreneurship and place-leadership (Grillitsch and Sotarauta, 2018).	Agency is either guided by dependencies, or guides the dependencies. Agency dynamics may also be the (indirect) result of multiscalar phenomena
Multiscalar phenomena	Multiscalar phenomena are events or processes at various geographical scales beyond the region – national, continental, or global.	Multiscalar phenomena can shape structures and agency (MacKinnon et al., 2019).

may be directed by dependencies, or agency may condition the dependencies. In case of the former, restructuring occurs along paths expected from the structural context; in case of the latter, paths deviate from expectations (clusters in thin regions undergoing path-creation, for example). Finally, structural dynamics or agency may actually be the result of phenomena at (supra-)national scales.

2.5 A CAS-based framework to study the restructuring of clusters

Like Martin and Sunley (2011), we employ a CAS-based cluster-evolution framework. The CAS perspective has multiple characteristics that make it suitable for studying cluster-evolution. Firstly, it treats cluster-evolution as non-deterministic; meaning a CAS framework can accommodate different types of restructuring-paths. Secondly, in a CAS, systemic properties are understood to emerge from the exertion of actor-agency (Epstein and Axtell 1996). Concomitantly, these properties make constituent actors act in certain ways. This means a CAS framework can naturally explain a greener cluster as emerging from the processes of upward-causation (agency shaping structures) and downward-causation (structures shaping agency). Thirdly, CAS are nested systems, which means a CAS can contain a smaller CAS, while being embedded in a larger one (Keshavarz et al. 2010). This means a CAS framework can inherently factor in the effects of supra-regional phenomena on structures and agency.

Our model treats cluster members as part of three overlapping complex adaptive systems[1]: 1) the cluster, 2) the RIS and 3) the SSI. Following the concepts discussed in sub-section 2.2, and their interactions defined in sub-section 2.4, Figure 1 depicts the components and relationships in our framework. We have the regional and industrial structures at the macro-level; and the cluster actors at the micro-level. Then, we have the mutual relationships between actors and the region, and actors and the industry. Cluster members' agency is influenced by the structures of the region, and of the sector (i.e. downward-causation). On the other hand, using the three forms of agency, cluster members can influence the structures (i.e. upward-causation).

The final component of the framework is the external environment, which accounts for influential events and processes at scales beyond the region. We can view the RIS and SSI,

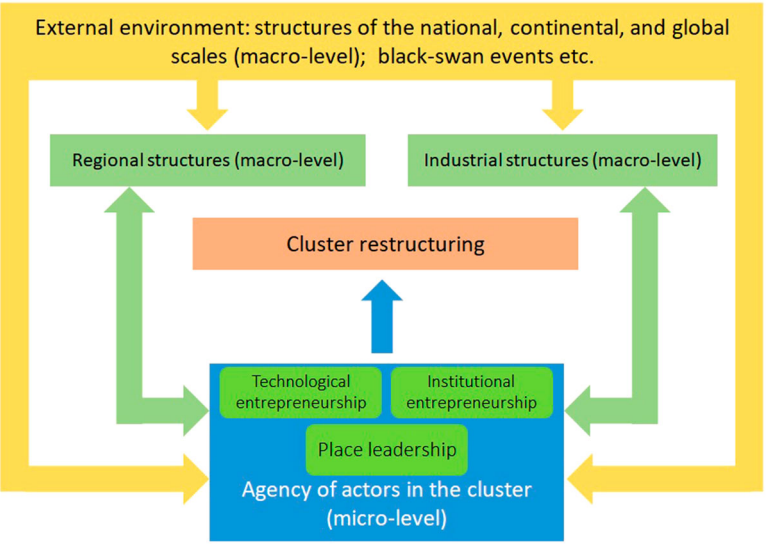

Figure 1. Our cluster evolution framework.

and their structures, as being nested in the external environment; while the cluster (i.e. its members) is nested within the RIS and SSI. In other words, the RIS and SSI are macro-levels nested within the higher macro-level of the external environment, while cluster members are at the micro-level. We can see in figure one that macro-level events in the environment may alter the macro-structures of the RIS and SSI, which then may lead to changes in how cluster members exercise agency at the micro-level. Furthermore, environmental events may also directly shape agency at the micro-level.

The question we attempt to answer in this study is, how does the dynamic interaction of agency, structures, and supra-regional phenomena cause the green-restructuring of a biocluster? With this framework of ours, a cluster's (green-)restructuring emerges from the constituent actors' agency (as depicted in Figure 1). How the region or sector may influence the cluster's evolution, is by shaping actor-agency within the cluster, through the (dynamics of) respective structures. How multiscalar phenomena beyond the region may shape the cluster's transition is by influencing structures, which then influence agency; or by influencing cluster members' agency directly. While structural changes at (supra-)regional scales (and in the industry) result from deliberate agency of actors at these scales, with agency from within the cluster also possibly playing a part, our framework does not explore the role of extra-cluster agency in shaping influential structural dynamics. In other words, the framework only incorporates the end-effect (i.e. the (changes in) structures), and the possible role of agency within the cluster, in engendering the end-effect. This means the framework explains the influence of extra-cluster agency indirectly, by demonstrating the effects of structural change on agency in the cluster, and thus, on cluster restructuring.

3. Methodology

To answer our research question, we applied our framework to the greening of the P&P biocluster in the Basque region of Spain, between 1986 and 2019. Over this period, the

cluster moved to cleaner production by significantly reducing water contamination and GHGs, introducing greater circularity, and creating several biobased innovations. This restructuring was accompanied by the augmentation of revenues and productivity, in spite of the closure of several firms (Interviews; Clusterpapel 2019a).

This cluster is an apt case because it captures the dichotomy between the normative idea of a biocluster, and what happens in reality. Traditionally, P&P production has involved acute water contamination, and significant consumption of energy and toxic chemicals (Bergquist and Söderholm 2018). In making bleached pulp, the use of elemental chlorine severely damages aquatic ecosystems (Thompson et al. 2001). Even though the industry has considerably reduced its environmental impact over the past five decades, it still faces questions over sustainability. With stagnating profits, and growing pressure to improve environmental performance, the industry 'has been seeking renewal under the emerging concept of bio-economy' (Toppinen et al. 2017, 2), by developing new products, processes from forest biomass (Näyhä, Hetemäki, and Stern 2014). Additionally, our choice was influenced by the Basque region's history of pioneering cluster policies (Valdaliso, Elola, and Franco 2016); and it being one of the most innovative regions in Europe (Hollanders and Es-Sadki 2017).

This agglomeration of P&P firms was caused by the abundance of forest biomass, and easy availability of water and hydraulic infrastructure (Elola et al. 2012). The cluster is composed of firms that are industry-followers, not pioneers (Valdaliso, Elola, and Franco 2016; Interviews). These firms are smaller in comparison to its peers in the P&P SSI. Owing to reasons we make clear in section 4, the number of P&P firms in the cluster has gradually declined. In 1973, the cluster had 30 P&P manufacturers. In 2019, this number stood at 16, after dipping to the lowest level of 10 in 2014 (Clusterpapel 2019a). Following our definition of a cluster (in sub-section 2.4), we define the biocluster to be its members – the firms plus the cluster organization. While this cluster consists of biobased companies (P&P firms), and some non-biobased companies (firms making machinery for P&P companies), for pragmatic purposes, we treat the entire cluster as a biocluster. Furthermore, as described in section four, paper-machinery companies also contributed to the cluster's green-structuring.

For the longitudinal analysis, we used the methodology of event-history analysis (EHA) (Poole et al. 2000). An EHA 'conceives of change processes as sequences of events' (Suurs 2009, 29). EHA provides historically rich accounts, which facilitate discovery of agency-structure interplay (Strambach and Pflitsch 2018). Data for the EHA was collected through document analysis, and semi-structured interviews. We looked for interviewees with a history of operation in the region, who were well-versed with the restructuring of the cluster. We used the snowball technique, and documentary data, such as the cluster's latest member-list, and news reports, to identify our interviewees. After one round of document analysis, we conducted a pilot interview with the director of the cluster organization, who was known to one of the co-authors, in December 2018. This pilot interview led to the identification of further candidates, who then led us to other candidates, so on and so forth. In total, we conducted 12 interviews by July 2019. Table A1 in the appendix lists our interviewees, and the documents we analysed.

We used both recurring and ad hoc questions for the interviews. The main themes explored through these questions were the history of the cluster's green-restructuring (influential events, and drivers and obstacles at various geographical levels etc.); the cluster organization's contributions to this restructuring; key collaborative constellations

that drove the cluster's restructuring; the role played by firms, the national government, the EU and other organizations; regional influences on the cluster's green-restructuring (policy, infrastructure, resources etc.); industrial influences on the cluster's green-restructuring (environmental standards, priority for (radical) innovation etc.).

For building the event-history, we coded longitudinal data using the variables in Table 2. These variables were used to operationalize regional and industrial structures, the three forms of agency, and also environmental variables. We built the table initially with some variables identified through secondary data, and STS, EEG literature (Woolthuis, Lankhuizen, and Gilsing (2005), Lawrence and Suddaby (2006), Isaksen and Trippl (2014), Grillitsch and Sotarauta (2018)). The table was further populated as we coded the data. To better organize structural variables, we used an adapted version of Rotmans (2003) domains of systemic change: Policy, Economics (a mix of business and market parameters), KTIR (knowledge, technology, infrastructure and resources), and Culture. We categorized agency events under technological-entrepreneurship, institutional-entrepreneurship and place-leadership.

Coding was carried out through the following steps:

1. We assigned pieces of data to one of the regional domains, to one of the industrial domains, to a form of agency or to environmental phenomena.
2. In case the data represented a variable not contained in Table 2, the table was updated to include this new variable.
3. We arranged the coded data chronologically, and determined sequential relationships.

By iterating the above steps, we discovered the interactions between supra-regional phenomena, structures and agency, which caused the cluster to restructure. By chronologically arranging the coded data, we identified four distinct phases in the Basque biocluster's transition between 1986 and 2019, which we describe in the next section.

4. Results

Although we used Rotmans's (2003) domains to organize variables in Table 2, we won't use them to report the results. Not all domains are important in all phases, and we only report the most important variables in each phase.

4.1 1986–1998: Regional dynamics drive, and sectoral dynamics hinder, greening

We begin in 1986, when Spain liberalized its economy, and joined the European Economic Community (de la Escosura, Rosés, and Sanz-Villarroya 2011). Up till then, lax environmental regulation in the region meant that the firms of the cluster could unabatedly discharge toxic effluents (Valdaliso, Elola, and Franco 2016; Interviews). Images of coloured rivers and dead fish resulted in a very poor societal image for the biocluster (Angulo 2000). With this accession, the Basque Country had to bring its water laws in line with European standards. Facing command-and-control measures from the regional government, and growing environmental awareness in Basque society, cluster firms

Table 2. Variables for operationalizing the cluster evolution framework.

Structures	Place (Region)	Path (Sector)	
Policy	Legislative instruments (e.g. environmental regulations) Financial instruments (tax breaks, subsidies) promoting sustainable innovation	Industrial standards	
Economics	Regional industrial base	Degree of concentration in the industry Importance of sustainability in organizing supply chains (via environmental management system certification)	
Knowledge, technology, infrastructure & Resources	Availability, quality of infrastructure, human-resources in the region	Production processes used in the industry	
	Availability and cost of biomass in the region	Inputs (raw material, chemicals etc.), energy sources commonly used in the industry	
	Availability and cost of inputs (e.g. oil, electricity etc.) in the region	Waste management techniques, and circular loops used in the industry	
	Cost and availability of tertiary services (e.g. waste-management) in the region	Sunk costs, such as expensive production processes	
Culture	Societal priority for environmentally – sustainable growth in the region	Priority for (radical) innovation in the industry	
Agency			
	Technological-entrepreneurship	Institutional-entrepreneurship	Place-leadership
	Introducing circular loops for internal or external valorisation of waste	Creating platforms, institutions, organizations	Convening different actors, negotiating with them, aligning visions
	Switching to greener, biobased energy sources	Forming or modifying formal relationships	Facilitating sharing of resources, technologies and capabilities
	Introduction of greener, biobased production processes and products Introducing EOP solutions for treatment of waste and effluents Switching to sustainable (biological) raw materials	Educating actors in biobased products, processes and business-models	
Environment			
National or supranational policy; Macro-economic developments at the national, supranational or global levels (e.g. market liberalization, recession etc.);			

Based on Rotmans (2003), Lawrence & Suddaby (2006), Woolthuis et al. (2005), Isaksen & Trippl (2014), and primary and secondary case data.

invested in end-of-pipe (EOP) solutions such as water-treatment plants (Angulo 2000; Interviews). Firms also introduced circular-loops – using woodchips and paper waste as raw material (Valdaliso et al. 2008). These were the first documented instances of sustainable technological-entrepreneurship in the cluster.

Events in the SSI, however, retarded further restructuring. Liberalization of the Spanish economy meant that the firms of the biocluster finally became members of the global P&P

SSI. The global recession in the early nineteen-eighties led to progressive concentration, and increasing cost-competition in the SSI (Elola et al. 2012). Owing to their small scale, the Basque firms could not match the prices of larger foreign rivals. Consequently, several firms closed down (Clusterpapel 2018a). For the firms that survived, economic-efficiency and productivity became prime objectives (Valdaliso, Elola, and Franco 2016; Clusterpapel 2018a). The denouement was that investments in sustainability stalled, and the cluster's transition in this phase was not as progressive as that of the rest of the SSI.

In 1991, the Basque government instituted the policy for industrial competitiveness, centred on creating regional cluster organizations (Querejeta and Navarro 2003). The P&P industry, however, refused to form a cluster organization. This was the result of firms' low priority for social capital, which historically precluded any form of collaboration (Valdaliso et al. 2012; interviews).

See Table 3 to find a summary of the dynamics in this phase.

4.2 1998–2004: The cluster organization guides the biocluster's restructuring

In 1998, the manager of the firm of Coinpasa was finally able to convince regional firms to create a cluster organization, the C*luster del Papel* (Ahedo 2004; Clusterpapel 2018a). One key goal for the organization was improving environmental performance (Interviews). The cluster's most deleterious environmental impacts emanated from firms' effluents and sludge (IHOBE 2000). The firms were also beset by inefficient usage of water and energy. In the first phase, the cluster's green shift had fallen behind that of the SSI. For instance, the cluster continued to use elemental chlorine as a bleaching agent, even as most of the SSI had shifted to chlorine free bleaching (IHOBE 2000; Bergquist and Söderholm 2018).

In 1998, the Basque region passed the Environmental Protection Act, following Europe's ratification of the IPPC directive in 1996 (Ministry of the Environment and Territorial Policy 2014). The introduction of the act was accompanied by other changes in the RIS: growing environmental awareness in Basque society, and increasing cost of waste management. Meanwhile, sustainability had started to become a competitive advantage within the SSI – with the passing of the IPPC directive firms without environmental management system

Table 3. Agency and structural dynamics in phase 1.

	Phase 1 1986–1998		
	Place (Region)	Path (Sector)	
Structures	1. Stricter regional command-and-control environmental regulations (+) 2. Rising environmental awareness in Basque society (+) 2. Institution of framework for industrial competitiveness in 1991 (+ for effects in the next phase)	1. Increasing concentration in the market and cost-competition (–)	
Agency	Technological-entrepreneurship 1. Adoption of water-treatment plants(Firms) (+) 2. Using woodchips, paper waste as raw – material (Firms) (+)	Institutional-entrepreneurship	Place-leadership
Environment	1. Spain liberalizing its economy, and joining the European Economic Community (+) 2. The global recession in the early nineteen-eighties (-)		

Variables marked (+)/(–) advanced/retarded the cluster's transition.

(EMS) certifications were struggling to draw customers. All these dynamics contributed to the cluster associating with IHOBE, to identify cleaner production (IHOBE 2000). In collaboration with IHOBE, the firms had the opportunity to break away from the path established in the first phase – path-modernisation through the introduction of EOP solutions, and waste-valorization. IHOBE (2000) suggested that the cluster could install completely new production processes that would prevent production of toxic waste. However, the firms chose to continue along path-modernisation. This decision was made because the P&P industry is one where firms are risk-averse, and are required to invest in expensive processes (Toppinen et al. 2017; Interviews). The issue of high switching costs was further compounded by a place-based heterogeneity – the relatively small size of the Basque firms. Consequently, the cluster firms engaged in various instances of technological-entrepreneurship for modernisation, with the help of the cluster's paper-machinery companies. They introduced circular-loops for valorization of waste; and turned to EOP technologies and retrofitting to reduce water contamination, atmospheric pollution, and use of toxic raw materials (Clusterpapel 2004; interviews). To manage sludge, some cluster firms established formal agreements for external valorisation in cement companies (Angulo 2000; Interviews).

In 1997, Spain liberalized its electricity market (Crampes and Fabra 2005). The uncertainties presented by this event drove the firms to begin using combined heat and power generation (CHP) (IHOBE 2000; Interviews). Through CHP, the cluster firms reduced their GHG-emissions and power costs considerably. It also meant the cluster finally started emulating the SSI, which was on its way to become the third largest industrial user of CHP in Europe (Minett 2006).

This phase saw two instances of place-leadership from the cluster organization. The organization coordinated with cluster firms, regional forestry companies, regional technology providers, and with P&P firms in Scandinavia, to explore possibilities of using waste biomass as fuel (Interviews). This campaign led some firms to adopt biomass as CHP fuel (Clusterpapel 2005). Secondly, the cluster organization saw an opportunity to convert toxic sludge into bricks, and launched negotiations with the concrete industry and with the Basque government (Clusterpapel 2005). With their improved sustainability, the number of cluster firms with EMS certification jumped from 7% to 25% by the end of this phase (Clusterpapel 2005).

See Table 4 to find a summary of the dynamics in this phase.

4.3 2004–2014: Formally embracing sustainable development

In 2004, the cluster organization reached a 'sustainable development' agreement with the Basque government, whereby cluster firms committed to moderate effluents, increase valorisation, adhere to IPPC standards and to attain EMS certification (Clusterpapel 2004; interviews). This agreement was possible thanks to the establishment of the Basque Country's Environmental Sustainability Strategy for 2002-2020, which was instituted in accordance with the 2001 EU Strategy for Sustainable Development (Ministry of the Environment and Territorial Policy 2014). Following the agreement, the program for valorizing sludge with the concrete industry, initiated in phase two, was institutionalized (Gobierno Vasco 2005). By 2008, 60% of sludge was internally or externally valorized. The cluster also invested heavily in retrofitting and EOP solutions to reduce the contamination of water, and to improve energy-efficiency (Gobierno Vasco 2005; El Diario Vasco

Table 4. Agency and structural dynamics in phase 2.

	Phase 2 1998–2004		
	Place (Region)	Path (Sector)	
Structures	1. Institution of the Basque environmental sustainability strategy for 2002–2020 (+) 2. Increasing cost of managing toxic waste in the region (+) 3. Growing environmental awareness in Basque society (+)	1. EMS certifications starting to become non-negotiable in organizing supply-chains in the SSI (+)	
Agency	Technological-entrepreneurship 1. Adoption of EOP solutions, retrofitting processes for water treatment, minimizing atmospheric pollutants and toxic raw materials (Firms) (+) 2. Adoption of CHP. Adoption of biomass as CHP fuel (Firms) (+) 3. Internal, external valorisation of waste (Firms) (+)	Institutional-entrepreneurship 1. Formation of a cluster organization (Firms) (+) 2. Establishing agreements with cement companies, for valorisation of waste (Firms) (+)	Place-leadership 1. Convincing firms to form a cluster organization (Manager of Coinpasa) (+) 2. Guiding firms in the adoption of biomass as fuel (Cluster organization) (+) 3. Coordinating negotiations for sludge-valorisation in brick and concrete industries (Cluster organization) (+)
Environment	1. Europe's ratification of the IPPC directive in 1996 (+) 2. Spain liberalizing its electricity market in 1997 (+)		

Variables marked (+)/(−) advanced/retarded the cluster's transition.

2008). Significantly, the cluster completely shifted to chlorine free bleaching, which vastly reduced the cluster's impact on the region's waterways (Clusterpapel 2011). Furthermore, owing to rising regional electricity prices, the cluster expanded its CHP capacity and ramped up usage of waste biomass as fuel (Lezana 2009).

However, the biocluster's restructuring was retarted in the second half of this phase. In 2006, the 2000 EU water framework directive was translated into the Basque water law, which required firms to install best available technologies (BAT) for lowering water contamination (Laguardia 2006). While this legislation improved the cluster's overall sustainability, not all firms could afford BATs, and they ended up paying fines that affected them financially. In the aftermath of the 2008 recession, the construction industry in the region nosedived. As a result, all programs of converting sludge into bricks and cement were suspended (Interviews). In 2013, Spain stopped paying premium prices for the clean-electricity produced using CHP (El Diario Vasco, 2014). The recession, and the removal of electricity premiums, severely affected firms' margins. Consequently, they halted further investments in CHP (and other environmental technologies), closed multiple CHPs, and also lowered clean-power production (El Diario Vasco, 2014; Interviews). Meanwhile, in the SSI, EMS certifications had become mandatory in establishing supply-chains. All these macro-level changes contributed to the closure of multiple (unsustainable) firms in this phase (Interviews; Clusterpapel, 2019a).

In spite of these difficulties, firms' actions (along with higher recycling of paper in the region) caused the cluster's carbon emissions per ton of product to fall considerably. The cluster also achieved 100% EMS certification, and could continue being part of global supply-chains (Ereño & Sancho, 2010; Clusterpapel, 2015).

See Table 5 to find a summary of the dynamics in this phase.

4.4 2014–2019: The Basque country formally embraces shifting to a bioeconomy

In 2015, the Basque country formally embraced a shift to the bioeconomy, inspired by the European Horizon2020 bioeconomy work program of 2014. Subsequently, the government organized an event to envision a Basque bioeconomy (Innobasque, 2019). By 2018, the region had decided to focus on a forest-based bioeconomy. Utilization of forest resources is deeply ingrained in Basque culture, with the sector employing 20,000 people, and representing 1.5% of GDP (Martinez de Arano et al. 2018). This thematic choice placed the P&P biocluster at the forefront of the region's planned transition. Cluster firms were involved in multiple biobased innovation ventures in this phase. In a notable case, the cluster firms Papelera Aralar and Voith created Araflush, claimed to be the world's first completely biodegradable hygienic wipe (Aranguren, 2017). To manufacture Araflush, Voith invented a novel biobased production-process (Papel Aralar, 2015; Interviews). Between 2014 and 2016, IHOBE financed two projects where firms attempted to produce biofuel from waste (IHOBE, 2017; Interviews). While both projects were abortive (Interviews), they are noteworthy because the cluster had started to reflect the trend in the global SSI, of P&P firms installing biorefineries to produce next-generation biofuels (Bergquist & Söderholm, 2018).

Table 5. Agency and structural dynamics in phase 3.

Phase 3 2004–2014			
	Place (Region)	Path (Sector)	
Structures	1. Institution of the Basque environmental sustainability strategy, and Basque water law (+). 2. Increasing cost of electricity in the Basque country (+) 3. Improved recycling of paper-waste in the region (+)	1. EMS certifications becoming non-negotiable in organizing supply-chains in the SSI (+)	
Agency	Technological-entrepreneurship 1. EOP, retrofitting and BATs to improve energy-efficiency, to reduce water contamination (Firms) (+) 2. Adoption of ECF or TCF bleaching (Firms) (+) 3. Expanding cogeneration capacity, greater usage of biomass fuel (Firms) (+) 4. Internal valorisation of waste (Firms) (+) 6.Halting investments in CHP, and other environmental improvements (Firms) (−)	Institutional-entrepreneurship 1. Entering into the sustainable development agreement in 2004 (Firms and cluster organization) (+) 2. Institution of agreements with the concrete industry, for valorisation of sludge (Cluster organization) (+) 3. Suspension of agreements for external valorisation of sludge, in 2008 (Firms) (−)	Place-leadership
Environment	1. The EU establishing the water framework directive in 2000, and the sustainable development strategy in 2001 (+) 2. The global recession of 2008 (−) 3. Spain removing premiums for green-electricity, in 2013 (−)		

Variables marked (+)/(−) advanced/retarded the cluster's transition.

From 2018, the cluster's biobased initiatives were formally shaped by the region's planned shift to the bioeconomy. Neiker-Tecnalia, the research agency defining the roadmap for the region's forest-bioeconomy, organized the event 'Bioeconomy in Euskadi: challenges and opportunities', where cluster firms discovered possible new biobased business models (Euskadi.eus, 2018). Subsequently, the cluster organization introduced a bioeconomy working group (in collaboration with Neiker-Tecnalia), which identified six new wood-based products the firms could create (Clusterpapel, 2018b; Interviews). In 2018, the region financed multiple projects where firms collaborated with Neiker-Tecnalia to create cellulose-based plastic (Interviews).

Over the last two phases, the cluster reduced the consumption of water, gas and electricity; and lowered water contamination and sludge production (Clusterpapel, 2019b). Crucially, this greening was accompanied by economic performance; revenues had almost increased to pre-2008 levels, the export rate was close to its highest, and productivity had improved markedly from 2008 (Clusterpapel, 2019a). In spite of the progress made over three decades, the cluster still faces different challenges. In 2019, the proportion of cluster firms with EMS certification fell to 89% (Clusterpapel, 2019b). Secondly, the cluster was yet to meet annual targets it committed to in 2016, for valorizing sludge (Euskadi.eus, 2018; Interviews). Towards resolving these issues, the cluster has committed itself to a future of innovation based on forest-biomass (Murcia, 2018).

See Table 6 to find a summary of the dynamics in this phase.

4.5 The dynamics behind the restructuring of the Basque biocluster

Based on the above phases, we now discuss the patterns of agency dynamics, structural dynamics, and multiscalar interactions. Figure 2 is a timeline that depicts the interactions led to the Basque biocluster's transition.

Concerning agency, we observed that the three forms of agency were exercised by diverse actors over the four phases. In phase one, we only saw firms exercising only technological-entrepreneurship. Phase two saw firms exercising both technological-entrepreneurship and institutional-entrepreneurship. This phase also saw three instances of place-leadership (once by the manager of Coinpasa, and twice by the cluster organization). In phase three, there were several instances of technological-entrepreneurship by firms. Along with the cluster organization, they also engaged in a few instances of institutional entrepreneurship. Phase four saw further instances of technological-entrepreneurship by firms. However, while the instances in phases one to three pushed the cluster along green path-modernisation (as firms made their processes incrementally greener through retrofitting etc.), technological-entrepreneurship in phase four had more to do with green path-creation, as firms laid the foundations of industries based on new technologies (bioplastics, biobased production processes, biofuels). This disruptive technological-entrepreneurship was encouraged by the cluster organization's institutional-entrepreneurship, and a research organization's institutional-entrepreneurship and place-leadership (and by place-dependency dynamics looking to support biobased innovation). From this summary, we infer institutional-entrepreneurship and place-leadership were as important as technological-entrepreneurship. We also see that the two most active, most influential actors were the firms, and the cluster organization. Over the four phases, firms' technological-entrepreneurship combined with the cluster

Table 6. Agency and structural dynamics in phase 4.

	Phase 4 2014–2019		
	Place (Region)	Path (Sector)	
Structures	1. The Basque government designating the transition to the bioeconomy an official mission in 2015 (+) 2. Financial instruments from IHOBE, Basque government for biobased innovation projects (+) 3. Robust regional forestry industry and infrastructure, easy availability of forest-based biomass (+)		
Agency	Technological-entrepreneurship 1. Creation of cellulose-plastic (Firms + Neiker-Tecnalia) (+)	Institutional-entrepreneurship 1. Educating firms of possible biobased products and business models (Neiker-Tecnalia + Cluster organization) (+)	Place-leadership 1. Coordinating with Basque firms and clusters, to define the region's forest-bioeconomy roadmap (Neiker-Tecnalia) (+)
	2. Introduction of a novel biobased production-process for wipes (Firms) (+)	2. Introduction of a bioeconomy working group within the cluster (Cluster organization + Neiker-Tecnalia)	
Environment	1. EU establishing a Horizon2020 work program for the bioeconomy in 2014 (+)		

Variables marked (+)/(−) advanced/retarded the cluster's transition.

organization's institutional-entrepreneurship and place-leadership to cause the emergence of a greener cluster. Following the characteristics of the framework detailed in sub-section 2.5, we have only included in our analysis, agency from organizations and individuals within the cluster, and from the research agency, which worked within the cluster.

Concerning structural dynamics, we observed that regional structures shaped agency more often than industrial structures. On this basis, we can argue that place-dependency was the more influential dependency. In phase one, regional dynamics drove firms to begin prioritizing sustainable production (through path-modernisation). Industrial dynamics, however, limited the transition that could have been achieved. While the dependencies generally worked in separation over the cluster's greening, in phase two,

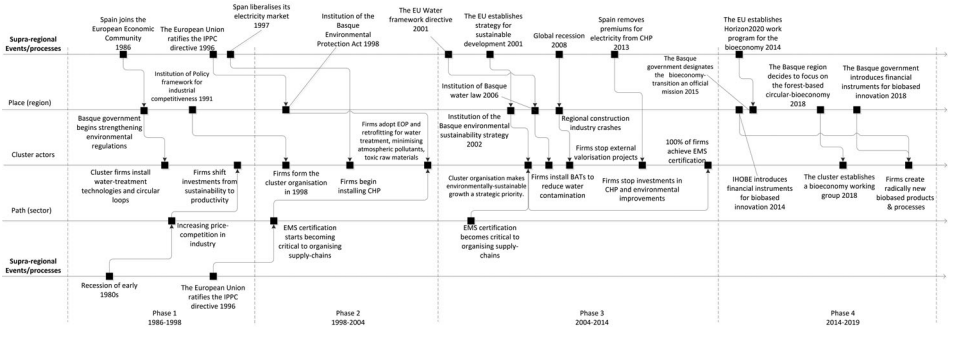

Figure 2. A timeline showing how agency, structures and supra-regional phenomena interacted during the cluster's green-restructuring.

we saw an instance where they complemented each other. The dependencies combined to direct actor-agency to continue innovating for greening through modernisation, rather than innovating for greening through path-creation. In phase three, place-dependency was the main structural driver of the cluster's restructuring. Regional dynamics (such as the institution of the Basque environmental sustainability strategy) caused actors to exercise agency that advanced greening. In the fourth phase, once again, place-dependency was the key structural driver; regional dynamics encouraged actors to embrace the bioeconomy, and engage in biobased innovation for path-creation.

We can attribute place-dependency shaping agency more often to two reasons. Firstly, the cluster is predominantly composed of relatively small industry-follower firms. This place-based heterogeneity meant that the firms had to play catch-up with the green-restructuring of the SSI (for instance, with the adoption of chlorine free bleaching, CHP, biorefining etc.). Secondly, the heterogeneity in terms of the sub-sectors the firms operated in, in their attitudes towards innovation, and resources they possessed, meant that path-dependency rarely affected every firm identically (interviews). With place-dependency, this heterogeneity was not as important, because new regional policy, increasing costs for waste-management etc. affected all firms similarly.

Regarding agency-structure interactions – in complex adaptive systems, the relationship between agency and structures is a bidirectional one. However, in this case, structures were driving agency for most of the restructuring process (i.e. for the first three phases). The inability of agency to proportionally shape structures was caused by the relatively smaller scale, and hence, limited agency, of this biocluster's firms (Valdaliso et al. 2016; Interviews). It was because of this limited agency that the firms in the biocluster were pushed by the dependencies to follow green path-modernisation, in spite of the Basque region being one of the most innovative metropolitan regions in Europe, offering ideal conditions for green path-creation. In phase four, cluster actors combined the three forms of agency to produce innovations that finally disrupted this path, and sowed the seeds of green path-creation. While these instances of agency were instigated by place-dependency, they have started shaping the dependencies. For instance, the biodegradable wipes produced by Aralar, and the biobased production-process invented by Voith, are being emulated by other, larger firms in the P&P SSI (interviews). The innovations also played a key role in shaping the region's shift to the forest-bioeconomy.

Finally, regarding multiscalarity of the cluster's greening, we found that several supra-regional phenomena were influential (see Figure 2). There were two supra-regional events that shaped agency through their effects on industrial structures – both occurring in phase one (the recession of the early nineteen-eighties, and the introduction of the EU IPPC directive). Spread over the four phases, there were five events that shaped agency through their effects on regional structures. In two cases, supra-regional events circumvented structures, and acted directly on agency; firstly when Spain liberalized its electricity market, and firms started using CHP (phases one and two); secondly when Spain removed premiums for green-electricity, and firms stopped investements in CHP (phase three).

5. Discussion

This study was conducted with the goal of advancing understanding of how and why bioclusters undergo green-restructuring. We achieved this goal by creating a novel cluster-evolution

framework, and then executing a longitudinal analysis of the Basque P&P biocluster's transition. In conducting an empirical study, we have furthered knowledge from preceding studies on green-restructuring, which have predominantly been of a theoretical or modelling nature. The characteristics of our framework allowed us to make contributions to ongoing debates around the multiscalarity of restructuring, and around the roles of agency and place-dependency. We discuss our insights and contributions here.

5.1 The empirics of green-restructuring

Our first contribution to cluster-research is that we conducted an empirical investigation of a cluster's green-restructuring. A central argument for us using a CAS-based model, is that it offers a non-deterministic view of cluster-evolution. With this perspective, path-development becomes an ongoing process, and clusters may change restructuring-paths. This view is all the more important because of the urgent need to decarbonize different types of clusters at distinct 'life' stages (Geels et al., 2017). Being located in a highly innovative region, we would have expected the Basque biocluster to green through path-creation. However, this cluster turned out to be an exemplar of clusters that do not adhere to such expectations. The non-determinism of our framework allowed us to demonstrate how (and why) the biocluster greened through path-modernisation for most of its life; and how it finally started greening through path-creation at a later stage. Of course, we cannot state how common such deviations are, with this singular case.

The findings of our empirical investigation bring us to another important question – whether there is a fundamental difference between 'normal' restructuring and green-restructuring? The discussion regarding the differences is especially important for bioclusters, since the concept of the bioeconomy, much like that of sustainable development, is a contested one (Wilde & Hermans, 2021). Furthermore, truly decoupled growth of clusters is quite difficult (Kamath et al., 2022). One of the differences between restructuring and green-restructuring could be the deliberate destabilization/destruction of unsustainable systemic structures (Turnheim & Geels, 2012; Trippl et al., 2020). Within our case, we did see deliberate destabilization; for example, the regional government introducing command-and-control regulation in phases one and three (following EU requirements), and the removal of unsustainable firms from supply-network in the P&P SSI, in phases two and three. These examples suggest that greening-paths are different from economic restructuring-paths. However, since we only investigate one case, this is not sufficient evidence. While we used our framework to analyse green-restructuring of a biocluster, it can possibly be used to study (green-)restructuring of other types of clusters. This presents an opportunity for future case-analysis using the framework, to establish the distinctions and similarities between greening and economic restructuring. The challenge here is identifying what changes to the macro-level and micro-level variables are required for this analysis.

There are also other avenues for future research. We can explore how the framework can be modified to include components for the analysis of meso-level (i.e. the level between macro and micro) processes such as the formation and modification of actor-networks. We can also investigate how to include components that represent individual actors' capabilities (as functions of their resources and attitudes). The challenge here will be expanding the framework while limiting how much more complicated it becomes.

5.2 The multiscalarity of green-restructuring.

Since our CAS-based framework can analyse interactions within nested systems, we were able to discover influential multiscalar interactions in the Basque cluster's greening. We showed that phenomena at the national, continental and global scale can act either directly on agency and greening or through their effects on structures. These phenomena could be relatively predictable structural changes at these scales (like the institution of national policies) or black-swan events (like global recessions). Studies in the past have elaborated how higher-scale processes affect place-dependency. What this study did differently is that it also demonstrated how these processes affect path-dependency; and how SSI dynamics in turn affect agency.

We did not see any instances of agency from beyond the cluster in our analysis. However, this does not mean our framework disregards the role of higher-scale actions (while over-emphasizing the actions of cluster members). Structural dynamics that affected agency within the cluster emerge (partly) from regional, supra-regional agency. For example, modifying the laws of the region requires institutional-entrepreneurship from regional (and national) policymakers. While we did not explore the extra-cluster entrepreneurial processes behind influential structures effects, we did demonstrate the influence of these processes on the cluster's greening, by illustrating how the structural dynamics they engendered affected agency within the cluster, and thus, its restructuring.

Whereas we chose to club all supra-regional scales into one 'external environment' component, we must note that the framework can be modified to have separate components for events and structures in the National Innovation System (NIS) (Freeman, 2002) and Global Innovation System (GIS) (Binz & Truffer, 2017). This choice of a single component was made to minimize the complexity of the framework, but it does lead to vagueness. While this was not such a critical issue in our case, since there were not many instances of upward-causation, inclusion of separate NIS and GIS components will be necessary when analysing clusters known to exert strong influence on national structures, and global value-chains.

5.3 Structures-agency interactions, and policy-implications

We learnt that regional or cluster-based idiosyncrasies can render path-dependency not as effective as place-dependency, in shaping green-restructuring. We demonstrated how regional structures can either act separately from industrial structures or combine with them, to facilitate or hinder greening. Place-dependency and path-dependency combined to force this cluster to take a modernisation path, instead of a creation path, for most of the restructuring process. It could be possible in other cases that the dependencies combine to prevent even path-modernisation, and cause an unsustainable lock-in.

The policy implication here is that policymakers aiming to drive green-restructuring should not just encourage technological entrepreneurs, but also institutional entrepreneurs and place-leaders who can help shape both supra-regional, and industrial structures (which governments may not have a lot of control over). From our analysis, we infer that institutional-entrepreneurship and place-leadership can be as important as technological-entrepreneurship in the greening process. So much so that technological-entrepreneurship may not be possible without the other forms of agency. We saw

how several instances of technological-entrepreneurship – adoption of biomass as CHP fuel, and valorisation of waste in the cement industry (in phase two), and also the innovations that disrupted path-modernisation (in phase four) – were made possible by institutional-entrepreneurship and place-leadership. Policymakers tend to have a techno-economic focus, especially with regards to the bioeconomy (Bogner & Dahlke, 2022); but techno-entrepreneurs themselves see the need for institutional-entrepreneurs and place-leaders (Wilde & Hermans, 2021). Regional governments can themselves play this role or they can follow the Basque government, and establish cluster organizations. We saw how the cluster organization helped advance the Basque cluster's restructuring, by connecting it to the regional government, to foreign firms, and to other industries as well. In essence, durable green-restructuring requires intermediary-actors (Kivimaa, 2014) that build the necessary institutional support at various administrative levels, and help cause bottom-up changes in industrial structures, if required.

Note

1. Like with clusters, both the SSI and RIS can be viewed as CAS. Innovation systems are composed of actor networks and structures (Malerba, 2005), they exhibit characteristics of CAS. For instance, because of dependencies between actor behaviour and systemic institutions (Trippl et al. 2015), innovation systems exhibit the property of emergence (Martin & Sunley, 2007). Innovation systems also display non-linear dynamics (because of path-dependency), and non-determinism (because of their non-tractable nature) (Grillitsch & Sotarauta, 2018).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Bundesministerium für Bildung und Forschung (BMBF) [grant number 031B0020].

ORCID

Ram Kamath http://orcid.org/0000-0003-0910-7771
Frans Hermans http://orcid.org/0000-0003-3394-9012

References

Ahedo, M. 2004. "Cluster Policy in the Basque Country (1991–2002): Constructing 'Industry–Government' Collaboration Through Cluster-Associations." *European Planning Studies* 12 (8): 1097–1113. doi:10.1080/0965431042000289232

Angulo, C. 2000. "*Pasta y papel para exportar* [Pulp and Paper for Export]." https://elpais.com

Aranguren, P. 2017. "*Las toallitas higiénicas que ni atascan ni contaminan tienen label guipuzcoano* [The Hygienic Wipes that Neither Block Nor Contaminate Have the Gipuzkoa Label]." https://www.diariovasco.com

Asheim, B, M. Grillitsch, and M. Trippl. (2017). Regional Innovation Systems: Past - Present – Future. In *Handbook on the geographies of innovations*, edited by R. Shearmur, C. Carrincazeaux, & D. Doloreux. Cheltenham: Edward Elgar.

Ayrapetyan, D., N. Befort, and F. Hermans. 2022. "The Role of Sustainability in the Emergence and Evolution of Bioeconomy Clusters: An Application of a Multiscalar Framework." *Journal of Cleaner Production* 134306. doi:10.1016/j.jclepro.2022.134306

Belussi, F., and S. Sedita. 2009. "Life Cycle vs. Multiple Path Dependency in Industrial Districts." *European Planning Studies* 17 (4): 505–528. doi:10.1080/09654310802682065

Bergquist, A., and K. Söderholm. 2018. "The Greening of the Pulp and Paper Industry: Sweden in Comparative Perspective." In *Technological Transformation in the Global Pulp and Paper Industry 1800–2018*, edited by T. Särkkä, M. Gutiérrez-Poch, and M. Kuhlberg, 65–87. Cham: Springer.

Binz, C., and B. Truffer. 2017. "Global Innovation Systems—A Conceptual Framework for Innovation Dynamics in Transnational Contexts." *Research Policy* 46 (7): 1284–1298. doi:10.1016/j.respol.2017.05.012

Bogner, K., and J. Dahlke. 2022. "Born to Transform? German Bioeconomy Policy and Research Projects for Transformations Towards Sustainability." *Ecological Economics* 195: 107366. doi:10.1016/j.ecolecon.2022.107366

Boschma, R., L. Coenen, K. Frenken, and B. Truffer. 2017. "Towards a Theory of Regional Diversification: Combining Insights from Evolutionary Economic Geography and Transition Studies." *Regional Studies* 51 (1): 31–45. doi:10.1080/00343404.2016.1258460

Brunori, G. 2013. "Biomass, Biovalue and Sustainability: Some Thoughts on the Definition of the Bioeconomy." *EuroChoices* 12 (1): 48–52.

Clusterpapel. 2004. "*Contribución Ambiental de las empresas del Sector de Pasta y Papel al Desarrollo Sostenible 2004–2006* [Environmental Contribution of Pulp and Paper Firms to Sustainable Development 2004–2006]." https://www.ihobe.eus/

Clusterpapel. 2005. "*Memoria 2004* [Report for 2004]." http://www.clusterpapel.com

Clusterpapel. 2011. "*El papel es un producto medioambientalmente sostenible* [Paper is an environmentally sustainable product]." http://www.elpapeltedavida.com

Clusterpapel. 2015. "*Informe Annual 2014* [Annual report 2014]." http://www.clusterpapel.com

Clusterpapel. 2018a. "*Basque Paper Directory*." http://www.clusterpapel.com

Clusterpapel. 2018b. "*Informe responsabilidad social 2017* [Social Responsibility Report 2017]." http://www.clusterpapel.com

Clusterpapel. 2019a. "*Basque paper directory 2019*." http://www.clusterpapel.com

Clusterpapel. 2019b. "*Cooperación Sectorial 2018* [Sectoral Cooperation 2018]." http://www.clusterpapel.com

Cooke, P. 2002. "Biotechnology Clusters as Regional, Sectoral Innovation Systems." *International Regional Science Review* 25 (1): 8–37. doi:10.1177/016001760202500102

Crampes, C., and N. Fabra. 2005. "The Spanish Electricity Industry: Plus ca Change." *The Energy Journal* 26: 127–153. doi:10.5547/ISSN0195-6574-EJ-Vol26-NoSI-6

Dawley, S. 2014. "Creating New Paths? Offshore Wind, Policy Activism, and Peripheral Region Development." *Economic Geography* 90 (1): 91–112. doi:10.1111/ecge.12028

de la Escosura, L., J. Rosés, and I. Sanz-Villarroya. 2011. "Economic Reforms and Growth in Franco's Spain." *Revista de Historia Económica-Journal of Iberian and Latin American Economic History* 30 (1): 45–89. doi:10.1017/S0212610911000152

Devaney, L., and M. Henchion. 2018. "Consensus, Caveats and Conditions: International Learnings for Bioeconomy Development." *Journal of Cleaner Production* 174: 1400–1411. doi:10.1016/j.jclepro.2017.11.047

El Diario Vasco. 2008. "*Las empresas del clúster del papel de Euskadi facturaron 625 millones, un 4,7% más en 2007* [The Companies in the Euskadi Paper Cluster had a Turnover of 625 Million, 4.7% More in 2007]." https://www.diariovasco.com

El Diario Vasco. 2014. *Una reforma que puede dar la puntilla al sector vasco del Papel* [A Reform that Could Topple the Basque Paper Sector]." https://www.diariovasco.com

Elola, A., J. Valdaliso, S. López, and M. Aranguren. 2012. "Cluster Life Cycles, Path Dependency and Regional Economic Development: Insights from a Meta-Study on Basque Clusters." *European Planning Studies* 20 (2): 257–279. doi:10.1080/09654313.2012.650902

Epstein, J., and R. Axtell. 1996. *Growing Artificial Societies: Social Science from the Bottom up*. Cambridge, MA: MIT Press.

Ereño, I., and A. Sancho. 2010. *Mejorando la sostenibilidad del papel* [Improving the Sustainability of Paper] [Presentation Given to the Basque Paper Cluster]. Bilbao: Factor CO2.

Euskadi.eus. 2018. "*Euskadi aspira a ser referente en bioeconomía forestal en el sur de Europa* [Euskadi Aspires to be a Reference in Forest Bioeconomy in Southern Europe]." http://www.euskadi.eus

Freeman, C. 2002. "Continental, National and sub-National Innovation Systems—Complementarity and Economic Growth." *Research Policy* 31 (2): 191–211. doi:10.1016/S0048-7333(01)00136-6

Frenken, K., E. Cefis, and E. Stam. 2015. "Industrial Dynamics and Clusters: A Survey." *Regional Studies* 49 (1): 10–27. doi:10.1080/00343404.2014.904505

Geels, F., B. Sovacool, T. Schwanen, and S. Sorrell. 2017. "Sociotechnical Transitions for Deep Decarbonization." *Science* 357 (6357): 1242–1244.

Gobierno Vasco. 2005. "*Avances y retos de los Acuerdos Ambientales Voluntarios en la Comunidad Autónoma del País Vasco - Logros 2004* [Progress and challenges of Voluntary Environmental Agreements in the Autonomous Community of the Basque Country - Achievements 2004]." http://www.euskadi.eus/

Grillitsch, M., and T. Hansen. 2019. "Green Industry Development in Different Types of Regions." *European Planning Studies* 27 (11): 2163–2183. doi:10.1080/09654313.2019.1648385

Grillitsch, M., and M. Sotarauta. 2018. *Regional Growth Paths: From Structure to Agency and Back* (No. 2018/1). Lund: Lund University, CIRCLE-Center for Innovation, Research and Competences in the Learning Economy.

Hansen, T., and L. Coenen. 2015. "The Geography of Sustainability Transitions: Review, Synthesis and Reflections on an Emergent Research Field." *Environmental Innovation and Societal Transitions* 17: 92–109.

Hassink, R., A. Isaksen, and M. Trippl. 2019. "Towards a Comprehensive Understanding of new Regional Industrial Path Development." *Regional Studies*, 1–10.

Hollanders, H., and N. Es-Sadki. 2017. *Regional Innovation Scoreboard 2017*. Brussels: European Commission.

Hung, S., and R. Whittington. 2011. "Agency in National Innovation Systems: Institutional Entrepreneurship and the Professionalization of Taiwanese IT." *Research Policy* 40 (4): 526–538. doi:10.1016/j.respol.2011.01.008

IHOBE. 2000. "*Libro blanco para la minimización de residuos y emisiones: pasta y papel* [White Paper for the Minimisation of Residual Waste and Emissions of Pulp and Paper]." https://www.ihobe.eus

IHOBE. 2017. "*Iniciativas empresariales de economía circularen el País Vasco: Descripción de 36 proyectos* [Circular Economy Business Initiatives in the Basque Country: Description of 36 Projects]." https://www.ihobe.eus

Ingrao, C., J. Bacenetti, A. Bezama, V. Blok, P. Goglio, E. Koukios, M. Lindner, et al. 2018. "The Potential Roles of BioEconomy in the Transition to Equitable, Sustainable, Post Fossil-Carbon Societies: Findings from This Virtual Special Issue." *Journal of Cleaner Production* 204: 471–488. doi:10.1016/j.jclepro.2018.09.068

Innobasque. 2019. "*Infoday Horizonte 2020: Seguridad alimentaria, agricultura y silvicultura sostenibles, investigación marina, marítima y de aguas interiores y bioeconomía* [Info-day Horizon 2020: Food Security, Sustainable Agriculture and Forestry, Marine and Maritime and Inland Water Research and the Bioeconomy]." https://www.innobasque.eus

Isaksen, A. (2011) Cluster Evolution. In *Handbook of Regional Innovation and Growth*, edited by P. Cooke, B. Asheim, R. Boschma, R. Martin, D. Schwartz and F. Tödtling, 293-302. Cheltenham: Edward Elgar.

Isaksen, A., F. Tödtling, and M. Trippl. (2018). Innovation Policies for Regional Structural Change: Combining Actor-Based and System-Based Strategies. In *New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons*, edited by A. Isaksen, R. Martin, and M. Trippl, 221–238. Cham: Springer International Publishing.

Isaksen, A., and M. Trippl. 2014. *Regional Industrial Path Development in Different Regional Innovation Systems: A Conceptual Analysis (No. 2014/17)*. Lund: Lund University, CIRCLE-Center for Innovation, Research and Competences in the Learning Economy.

Kamath, R., Z. Sun, and F. Hermans. 2022. "Policy Instruments for Green-Growth of Clusters: Implications from an Agent-Based Model." *Environmental Innovation and Societal Transitions* 43: 257–269. doi:10.1016/j.eist.2022.04.003

Keshavarz, N., D. Nutbeam, L. Rowling, and F. Khavarpour. 2010. "Schools as Social Complex Adaptive Systems: A new way to Understand the Challenges of Introducing the Health Promoting Schools Concept." *Social Science & Medicine* 70 (10): 1467–1474. doi:10.1016/j.socscimed.2010.01.034

Kivimaa, P. 2014. "Government-affiliated Intermediary Organisations as Actors in System-Level Transitions." *Research Policy* 43 (8): 1370–1380. doi:10.1016/j.respol.2014.02.007

Laguardia, I. 2006. "*Los fabricantes de pasta y papel y la nueva Ley de Aguas* [Pulp and Paper Manufacturers and the New Water Law]." https://www.diariovasco.com

Lawrence, T., and R. Suddaby. 2006. "Institutions and Institutional Work." In *Handbook of Organization Studies*, edited by S. Clegg, C. Hardy, and W. Nord, 215–254. London: Sage.

Lazzeretti, L., F. Capone, A. Caloffi, and S. Sedita. 2019. "Rethinking Clusters. Towards a new Research Agenda for Cluster Research." *European Planning Studies* 27 (10): 1879–1903. doi:10.1080/09654313.2019.1650899

Lezana, C. 2009. "*Papresa construirá una planta de cogeneración eléctrica en Errenteria* [Papresa Will Build an Electric Cogeneration Plant in Errenteria]." https://www.diariovasco.com

MacKinnon, D., S. Dawley, M. Steen, M. Menzel, A. Karlsen, P. Sommer, G. Hansen, and H. Normann. 2019. "Path Creation, Global Production Networks and Regional Development: A Comparative International Analysis of the Offshore Wind Sector." *Progress in Planning* 130: 1–32. doi:10.1016/j.progress.2018.01.001

Malerba, F. 2002. "Sectoral Systems of Innovation and Production." *Research Policy* 31 (2): 247–264. doi:10.1016/S0048-7333(01)00139-1

Malerba, F. 2005. "Sectoral Systems of Innovation: A Framework for Linking Innovation to the Knowledge Base, Structure and Dynamics of Sectors." *Economics of Innovation and New Technology* 14 (1-2): 63–82. doi:10.1080/1043859042000228688

Marsden, T. 2013. "Sustainable Place-Making for Sustainability Science: The Contested Case of Agri-Food and Urban–Rural Relations." *Sustainability Science* 8 (2): 213–226. doi:10.1007/s11625-012-0186-0

Martin, R., and P. Sunley. 2003. "Deconstructing Clusters: Chaotic Concept or Policy Panacea?" *Journal of Economic Geography* 3 (1): 5–35. doi:10.1093/jeg/3.1.5

Martin, R., and P. Sunley. 2007. "Complexity Thinking and Evolutionary Economic Geography." *Journal of Economic Geography* 7 (5): 573–601. doi:10.1093/jeg/lbm019

Martin, R., and P. Sunley. 2011. "Conceptualizing Cluster Evolution: Beyond the Life Cycle Model?" *Regional Studies* 45 (10): 1299–1318. doi:10.1080/00343404.2011.622263

Martinez de Arano, I., B. Muys, C. Topi, D. Petenella, D. Feliciano, E. Rigolot, and R. LLano-Ponte. 2018. *A Forest-Based Circular Bioeconomy for Southern Europe: Visions, Opportunities and Challenges: Reflections on the Bioeconomy*. Joensuu: European Forest Institute (EFI).

Mazzucato, M. 2013. *The Entrepreneurial State. Debunking Public vs. Private Sector Myths*. London: AnthemcPress.

McCauley, S.., and J. Stephens. 2012. "Green Energy Clusters and Socio-Technical Transitions: Analysis of a Sustainable Energy Cluster for Regional Economic Development in Central Massachusetts, USA." *Sustainability Science* 7 (2): 213–225. doi:10.1007/s11625-012-0164-6

Menzel, M., and D. Fornahl. 2009. "Cluster Life Cycles—Dimensions and Rationales of Cluster Evolution." *Industrial and Corporate Change* 19 (1): 205–238. doi:10.1093/icc/dtp036

Minett, S. 2006, October. "Pulp and Paper Industry CHP in Europe." *Paper presented at the International Seminar on Energy & Forest Products Industry*, Rome.
Ministry of the Environment and Territorial Policy. 2014. *Environmental Framework Programme of the Basque Country 2020*. San Sebastian: Ministry of the Environment and Territorial Policy.
Murcia, J. 2018. "*El auge del e-commerce esquiva a la industria vasca del papel* [The Rise of E-Commerce Evades the Basque Paper Industry]." https://www.diariovasco.com
Näyhä, A., L. Hetemäki, and T. Stern. 2014. "New Products Outlook." In *Future of the European Forest Based Sector: Structural Changes Towards Bioeconomy*, edited by L. Hetemäki, 43–54. Joensuu: European Forest Institute.
Neffke, F. 2009. *Productive Places: The Influence of Technological Change and Relatedness on Agglomeration Externalities*. Utrecht: Utrecht University.
Neffke, F., M. Hartog, R. Boschma, and M. Henning. 2018. "Agents of Structural Change: The Role of Firms and Entrepreneurs in Regional Diversification." *Economic Geography* 94 (1): 23–48. doi:10.1080/00130095.2017.1391691
Papel Aralar. (Producer). 2015. "*ARAFLUSH. 100% flushable paper for wet wipes* [YouTube Video]." https://www.youtube.com
Pfau, S., J. Hagens, B. Dankbaar, and A. Smits. 2014. "Visions of Sustainability in Bioeconomy Research." *Sustainability* 6 (3): 1222–1249.
Poole, M., A. Van de Ven, K. Dooley, and M. Holmes. 2000. *Organizational Change and Innovation Processes: Theory and Methods for Research*. Oxford: Oxford University Press.
Porter, M. 1990. "The Competitive Advantage of Nations." *Harvard Business Review* 68 (2): 73–93.
PriceWaterhouseCoopers. 2011. *Regional Biotechnology: Establishing a Methodology and Performance Indicators for Assessing Bioclusters and Bioregions Relevant to the KBBE Area: Final Report*. Brussels: PWC.
Purkus, A., N. Hagemann, N. Bedtke, and E. Gawel. 2018. "Towards a Sustainable Innovation System for the German Wood-Based Bioeconomy: Implications for Policy Design." *Journal of Cleaner Production* 172: 3955–3968. doi:10.1016/j.jclepro.2017.04.146
Querejeta, M., and I. Navarro. 2003. "La política de clusters en la Comunidad Autónoma del País Vasco: una primera valoración [Cluster Policy in the Autonomous Community of the Basque Country: A First Assessment]." *Ekonomiaz: Revista Vasca de Economía* 53: 90–113.
Rotmans, J. 2003. *Transition Management*. Assen: Van Gorcum.
Simmie, J. 2012. "Path Dependence and new Technological Path Creation in the Danish Wind Power Industry." *European Planning Studies* 20 (5): 753–772. doi:10.1080/09654313.2012.667924
Sjøtun, S, and R. Njøs. 2019. "Green Reorientation of Clusters and the Role of Policy:'The Normative'and 'the Neutral'route." *European Planning Studies* 27 (12): 2411–2430. doi:10.1080/09654313.2019.1630370
Stegmann, P., M. Londo, and M. Junginger. 2020. "The Circular Bioeconomy: Its Elements and Role in European Bioeconomy Clusters." *Resources, Conservation & Recycling: X* 6: 100029. doi:10.1016/j.rcrx.2019.100029
Strambach, S., and G. Pflitsch. 2018. "Micro-dynamics in Regional Transition Paths to Sustainability-Insights from the Augsburg Region." *Applied Geography* 90: 296–307. doi:10.1016/j.apgeog.2017.04.012
Suurs, R. 2009. *Motors of Sustainable Innovation: Towards a Theory on the Dynamics of Technological Innovation Systems*. Utrecht: Utrecht University.
Ter Wal, A., and R. & Boschma. 2011. "Co-evolution of Firms, Industries and Networks in Space." *Regional Studies* 45 (7): 919–933. doi:10.1080/00343400802662658
Thompson, G., J. Swain, M. Kay, and C. Forster. 2001. "The Treatment of Pulp and Paper Mill Effluent: A Review." *Bioresource Technology* 77 (3): 275–286. doi:10.1016/S0960-8524(00)00060-2
Toppinen, A., S. Pätäri, A. Tuppura, and A. Jantunen. 2017. "The European Pulp and Paper Industry in Transition to a bio-Economy: A Delphi Study." *Futures* 88: 1–14. doi:10.1016/j.futures.2017.02.002
Trippl, M., S. Baumgartinger-Seiringer, A. Frangenheim, A. Isaksen, and J. Rypestøl. 2020. "Unravelling Green Regional Industrial Path Development: Regional Preconditions, Asset Modification and Agency." *Geoforum; Journal of Physical, Human, and Regional Geosciences* 111: 189–197.

Trippl, M., M. Grillitsch, A. Isaksen, and T. Sinozic. 2015. "Perspectives on Cluster Evolution: Critical Review and Future Research Issues." *European Planning Studies* 23 (10): 2028–2044. doi:10.1080/09654313.2014.999450

Turnheim, B., and F. Geels. 2012. "Regime Destabilisation as the Flipside of Energy Transitions: Lessons from the History of the British Coal Industry (1913–1997)." *Energy Policy* 50: 35–49. doi:10.1016/j.enpol.2012.04.060

Utterback, J., and W. Abernathy. 1975. "A Dynamic Model of Process and Product Innovation." *Omega* 3 (6): 639–656. doi:10.1016/0305-0483(75)90068-7

Valdaliso, J., A. Ceberio, M. Aranguren, and S. García. 2008. *Los orígenes históricos del clúster del papel en el País Vasco y su legado para el presente* [The Historical Origins of the Paper Cluster in the Basque Country and Its Legacy for the Present]. San Sebastian: Eusko Ikaskuntza.

Valdaliso, J., A. Elola, M. Aranguren, and S. López. 2012. "Social Capital, Knowledge, and Competitiveness: The Cases of the Basque Paper and Electronics/ICT Clusters." In *Interactive Learning for Innovation. A Key Driver Within Clusters and Innovation Systems*, edited by B. Asheim, and M. D. Parrilli, 161–180. London: Palgrave Macmillan.

Valdaliso, J., A. Elola, and S. Franco. 2016. "Do Clusters Follow the Industry Life Cycle? Diversity of Cluster Evolution in old Industrial Regions." *Competitiveness Review* 26 (1): 66–86. doi:10.1108/CR-02-2015-0006

Wilde, K., and F. Hermans. 2021. "Innovation in the Bioeconomy: Perspectives of Entrepreneurs on Relevant Framework Conditions." *Journal of Cleaner Production* 314: 127979. doi:10.1016/j.jclepro.2021.127979

Woolthuis, R., M. Lankhuizen, and V. Gilsing. 2005. "A System Failure Framework for Innovation Policy Design." *Technovation* 25 (6): 609–619. doi:10.1016/j.technovation.2003.11.002

Appendix

Table A1. The interviewees, and documents from which data was collected

No.	Organization, designation	Date
1	Cluster organization, Director	December 2018
2	Pulp and paper company, CEO Cluster organization, Former Director	January 2019
3	Pulp and paper company, General Manager	January 2019
4	Agricultural Research and Development Agency, General manager	January 2019
5	Pulp company, CEO	January 2019
6	Pulp and paper company, CEO Cluster organization, Former Director	January 2019
7	Regional cluster development agency, Divisional Head	January 2019
8	Pulp and paper company, Plant Manager	February 2019
9	Cluster organization, Former Director	February 2019
10	Regional Environmental Management Agency, Coordinator	February 2019
11	Climate consultancy, Managing Director	February 2019
12	Paper-machinery company, Senior Vice President	July 2019
No.	Document analysed	–
1	Journal Articles: Ahedo (2004), Crampes & Fabra (2005), Elola et al. (2012), Minett (2006), Querejeta & Navarro (2003), Valdaliso et al. (2008, 2012, 2016)	–
2	Reports from the Cluster Organization, Clusterpapel (2004, 2005, 2011, 2015, 2018a, 2018b, 2019a, 2019b)	-
3	News reports: Angulo (2000), Aranguren (2017), El Diario Vasco (2008, 2014), Innobasque (2019), Lezana (2009), Murcia (2018), Papel Aralar (2015)	–
4	Reports from regional agencies: Ereño & Sancho (2010), Euskadi.eus (2018), Gobierno Vasco (2005), IHOBE (2000, 2017), Ministry of the Environment and Territorial Policy (2014)	–