HOW DOES AN INNOVATIVE CLUSTER IN A PERIPHERAL AND MARGINALLY INNOVATIVE REGION WORK?

KNOWLEDGE EXCHANGE AND POLICY EVALUATION IN A NORWEGIAN BIOTECHNOLOGY CLUSTER

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How does an innovative cluster in a peripheral and marginally innovative region work? Knowledge exchange and policy evaluation in a Norwegian biotechnology cluster

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ABSTRACT

This project is an exploratory study of the Inland bioeconomy landscape and its relationship with regional development, with a specific focus on the collaboration between Small and Medium-Sized Enterprises (SMEs) and Higher Education Institutions (HEIs) in the biotechnology sector in Norway. Through the lens of Regional Innovation Systems (RISs) in combination with novel approaches to the analysis of clusters, this case-based research analyzes the enablers and barriers contributing to SME and HEI collaboration for knowledge transfer. In-depth interviews and surveys with one of Norway's Centers of Expertise (NCE), Heidner Biocluster and its members, reveal the nuanced role of geographic and other forms of proximity in fostering university-industry collaborations.

The project emphasizes the importance of proximity for SMEs in the biotechnology sector, demonstrating that geographic proximity may benefit larger, more established SMEs, though it is not as important for smaller, more internationally focused ones. It further highlights how innovation clusters exemplify effective place-based leadership in peripheral RISs, contributing to the Inland region's transition to a circular bioeconomy through strategic cluster governance and administration. Doing so, the project further contributes to broader knowledge on the dynamics of RISs, offering insights into the conditions under which collaboration between the private sector and academic institutions can thrive, thereby enhancing regional competitiveness and innovation. These findings extend to policymaking, strategic planning, and research on the implementation of the bioeconomy.

SAMMENDRAG

Dette prosjektet er en utforskende studie av bioøkonomilandskapet i Innlandet og dets forhold til regional utvikling, med et spesifikt fokus på samarbeid mellom små og mellomstore bedrifter (SMB) og høyere utdanningsinstitusjoner (HEI) innen bioteknologisektoren i Norge.

Med utgangspunkt i regionale innovasjonssystemer (RIS) i kombinasjon med nye tilnærminger til analyse av klynger, undersøker denne casestudien drivere og barrierer som påvirker samarbeid mellom SMB og HEI for kunnskapsoverføring.

Dyptgående intervjuer og spørreundersøkelser med Heidner Biocluster, ett av Norges NCE-programmer (Norwegian Centers of Expertise), og dets medlemmer, avdekker den nyanserte rollen geografisk og annen form for nærhet spiller i å fremme samarbeid mellom universiteter og næringsliv.

Funnene viser at geografisk nærhet kan være fordelaktig for større, mer etablerte SMB, mens det ikke er like avgjørende for mindre, mer internasjonalt orienterte bedrifter. Videre fremheves det hvordan innovasjonsklynger eksemplifiserer effektiv stedbasert ledelse i perifere RIS, og hvordan dette bidrar til Innlandets overgang til en sirkulær bioøkonomi gjennom strategisk klyngeledelse og administrasjon.

Studien bidrar til bredere kunnskap om dynamikken i RIS og gir innsikt i betingelsene for vellykket samarbeid mellom privat sektor og akademiske institusjoner. Dette styrker regional konkurranseevne og innovasjon. Funnene har implikasjoner for politikkutforming, strategisk planlegging og forskning på implementering av bioøkonomi.

PREFACE

This Industrial PhD was established between Norse Biotech AS, The Research Council of Norway, and the University of Inland Norway. The project owner, Norse Biotech AS, is a biotechnology organization based in Inland, Norway, focused on biomass utilization. Norse Biotech AS's vision is to contribute to the transition of the bioeconomy of the Inland region by developing a range of products and patents based on local biomass and to stimulate collaborations with regional firms, higher education organizations, and research institutes.

Norse Biotech AS's collaborations, formed as a member of multiple clusters and as a project partner with local universities and research institutes, created the basis for this Industrial PhD. For a small startup in the biotech sector, these collaborations were key at all stages of its product development and research. Interest in exploring the mechanisms of those collaborations formed the foundation for this research project.

As a project manager at Norse Biotech AS and a PhD candidate at the INTOP (Ph.d. i innovasjon i tjenesteyting i offentlig og privat sektor) program at the University of Inland Norway (INN), I was fortunate to be surrounded by passionate, experienced experts. At Norse Biotech AS, I had the privilege of working with a small, international team made up of chemists, farmers, and entrepreneurs, who were truly passionate about the development of new biobased products and the world class technology behind it. At the Inland School of Business and Social Sciences I was grateful to work with a group of leading academics who introduced me to a variety of new concepts around economic geography, evolutionary economic geography, and regional studies. I was also fortunate to be able to contribute to the regional research project REDINN, be a member of the NORSI research institution, and be based at The Game School at INN. All three were instrumental in providing me opportunities to present and receive feedback on my research, attend courses and conferences, and inspire me with greater motivation and enthusiasm for the field.

A special thank you to Danelle du Plessis, Ole Van Allen, Dr. Ray Chrisman, Dr. Werner Christie, Rune Langerud, and the teams at the NCE Heidner Biocluster, the

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Hamar, 22.11.2024

John Eugene Chrisman

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Chrisman, J. E., Chrisman, R., & Fundusa, Z. (2023). New processing concepts and cluster technologies: Catalysts for a faster and more efficient transition to a circular bioeconomy and biobased carbon materials. *Chimica Oggi* - *Chemistry Today*, *41*(5), 51–55.

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1. INTRODUCTION

1.1 The Knowledge Imperative in Innovation

In recent years, the need for sharing knowledge between research institutions and industry has emerged not only as an approach for turning research into viable businesses, but also as a strategy for businesses themselves to innovate, using external knowledge sources to maximize their own economic value (European Commission, 2007, p.8). Such knowledge transfer, which involves the process of identifying, gathering, and sharing technical and relational knowledge, skills, and competences between research institutions and businesses (European Commission, 2007, p. 6), has become so central to industrial innovation, that the European Commission itself identified knowledge transfer as one of the ten key areas for action within their broad-based innovation strategy for the EU. The centrality of knowledge transfer has led to the emergence of numerous approaches to facilitate the transfer of knowledge from institutions to industry (Calignano & Fitjar, 2017).

1.1.1 Knowledge Flows in and Through RISs and Innovation Clusters

In Norway, programs contributing to industrial innovation both at the national and regional levels have aimed to promote innovation through R&D activities to increase their value creation and competitiveness in the market. These programs are implemented through innovation clusters at the regional level – interconnected businesses, research institutions, and other organizations that collaborate to foster innovation and competitiveness by facilitating knowledge transfers (Delgado et al., 2016). It is these collaborations, and how to optimize them, that have formed a core element of cluster programs.

Such cluster programs are most often implemented at the regional level within earmarked Regional Innovation Systems (RISs), where knowledge flows and exchange take place as a dynamic and interconnected process, to enable different orders of innovation and regional business development by providing critical infrastructure and frameworks (Tödtling & Trippl, 2011). Innovation in various forms is the key to increased value creation and growth, and emerges both through interactions among actors (e.g., firms and other organizations) and their engagement with the broader structures (RISs) they operate in (Hauge et al., 2009, p. 125). Within one such RIS, the Inland bioeconomic development region (see section 1.2.3 for a description of the Inland RIS), two notable clusters have been established: the Norwegian Wood Cluster (NWC), organized as a cooperative which focuses on the forest and timber industry, and the NCE Heidner Biocluster, focused on green bioeconomy and sustainable food production across various industries such as breeding, biotechnology, feed development, and residual raw materials. Recognized as one of Norway's Centers of Expertise (NCE), the Heidner Biocluster illustrates how the uptake and management of targeted policy-driven directives that prioritize research, collaboration, and knowledge exchange can produce successful outcomes which are especially important in peripheral regions with low levels of innovation and R&D. Focusing on NCE status risks overshadowing smaller emerging clusters or shifting the cluster's focus from regional to national concerns. However, in the case of the NCE Heidner Biocluster, the status reflects its documented increase in member collaborations and its continued focus on the bioeconomy, which remains strongly rooted in the regional context.

Clusters are especially important in regional path development within the Inland RIS, working to advance the transition to a circular bioeconomy in this peripheral region (see sections 1.2.3 and 2.2.1 for more on Inland RIS path development). To achieve this, clusters must serve as strong place-based leaders to foster knowledge flows and collaboration among RIS actors. This vision is reinforced by *Innlandsporteføljen* (2023), the county's strategic document outlining a 2030 vision of Inland as a circular green growth region, which emphasizes the importance of innovation clusters:

> We have seen that the future of business development lies in co-locating companies and people to share resources, infrastructure, expertise, and energy. This applies both to industrial processes and to cities, in order to create arenas

that facilitate innovation and new developments. To scale and industrialize several new green projects, we need to focus on hub development in central hubs in Inland. 'Good for businesses' and 'good for the planet.' This is especially true for industry and the forest-based bioeconomy (p. 10).

Facilitating co-location to create innovation arenas and foster new path development is thus a central task of industrial innovation clusters driving bioeconomic development in the Inland RIS.

1.1.2 Challenges to Collaboration in Peripheral Regions

Given their location in a peripheral region operating outside of areas with centralized resources, clusters based in the Inland RIS face unique challenges. Unlike clusters administered close to the capital city of Oslo, Inland-based clusters are located farther away from venture capitalist funding, large universities, and high-tech businesses. As such, they are unable to rely on the geographic closeness of organizations and knowledge assets (Jasimuddin et al., 2015). Instead, clusters in this region must pursue growth and development through alternative paths than those in high-tech metropolitan areas. This may be achieved by sourcing their financial investments, expertise, and knowledge from both foreign and domestic immigrants, so-called return migrants or by relying on a stronger policy role from governments and collaborations with more distant partners (Asheim et al., 2019, p. 90).

More Knowledge Needed on Dimensions of Proximity in Peripheral Regions

Yet, as highlighted by Vale et al. (2023), research often overlooks transitions in peripheral regions and, when they are addressed, the regions themselves are seen to be full of limitations. Instead of taking up a deterministic view of peripherality that sees such regions as vulnerable and inferior, more attention should be directed to the potential of these regions as “generative contexts” for innovation and climate-related transitions, as noted in select studies from the field of Economic Geography and Regional Studies (Vale et al., 2023). To address this gap, this research project examines the role of industrial innovation clusters and the collaborations that occur in building new capabilities to support transitions to the circular bioeconomy in peripheral regions.

In addition to the need for more generative studies on peripheral regions, the cluster literature further reflects a preoccupation with knowledge transfer traditionally understood as being a result of spillovers due to the close geographic proximity of SMEs in each cluster (Malmberg & Power, 2005). This, however, ignores other, more nuanced conditions that could potentially facilitate collaborations and subsequent knowledge transfers among cluster members and other stakeholders. Critiquing this singular focus on geographic location, Boschma (2005) proposes four additional dimensions of proximity (cognitive, organizational, social, and institutional) that should be considered in addition to geographical proximity.

This is especially important in peripheral regions since too much or too little of any of these five dimensions of proximity can negatively affect innovation and interactive learning and lead to “lock-in” – meaning there is not enough flexibility or openness – or to a lack of coordination between the actors in an organization. Following Boschma’s (2005) call for a dynamic approach when analyzing proximity, this project addresses proximity among clustered biotech firms in a peripheral region beyond its traditional geographic understanding to contribute to research that creates a better understanding of the combination of dimensions and conditions that lead to improved interactive learning.

1.1.3 What can Cluster Policy Research Contribute to the Knowledge Imperative in Peripheral Regions?

The implementation of biotechnology clusters and the adoption of policy measures specifically aiming to stimulate coordination, networking, and knowledge exchange have been shown to lead to positive outcomes in terms of new industrial and development paths (Isaksen & Jakobsen, 2017; Tödtling & Trippl, 2018). Since they are central to understanding the establishment, maintenance, and growth of RISs, how knowledge exchanges and flows are optimally conducted (i.e., the combinations of conditions that lead to increased collaborations) should be further analyzed to identify and promote the collaborative mechanisms that best facilitate such exchanges in peripheral regions. Investigating the role of an industrial cluster such as the NCE Heidner Biocluster as a mechanism of knowledge diffusion facilitated by collaborations within localized systems (RIS) thus represents a critical approach to better inform policy guidance.

It is exactly this peripherality of the NCE Heidner Biocluster, i.e., being located in a marginally innovative region and geographically distant from the core areas of the country, that motivated the approaches taken in this project, which includes investigating knowledge flows with both co-located and distant partners, knowledge bases influencing spatial patterns of collaborations, effectiveness of cluster policy aimed at improving networking, as well as the related research questions and results discussed in the articles (see also chapter 5 for further discussion).

1.1.4 Geographic Concepts and Approaches

This project's examination of knowledge exchange and policy implementation in a Norwegian peripheral biotechnology cluster draws on concepts and approaches from the field of policy studies and Economic Geography (see Figure 1). This section will clarify and systematize the main geographical and other approaches that have informed the conceptual and empirical analyses and position this research project within the field. The theoretical background of this project – which includes relevant, varied, and layered strands of literature such as (innovation) systems thinking, RIS, place-based leadership, and cluster policies – will be described in detail in chapter 2.

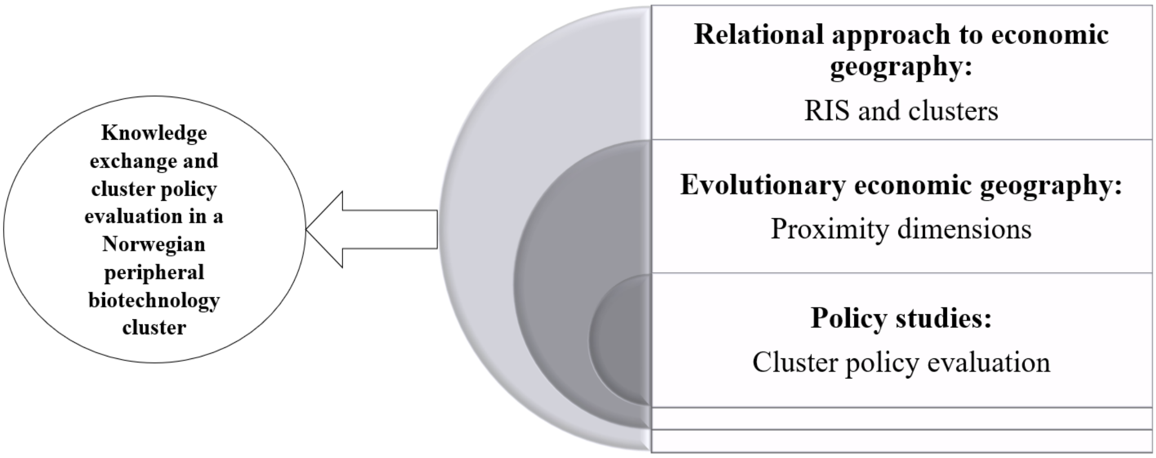

Figure 1: Geographical Approaches

First, this research explicitly adopts a relational approach to the study of cluster policy and regional development. In this regard, it was inspired by a key strand of literature, Relational Economic Geography (Bathelt & Glückler, 2011), according to which firms and other economic actors do not act in isolation but exchange critical knowledge – considered a prerequisite for innovation – with partners located at different geographic scales (Bathelt & Glückler, 2003; Boggs & Rantisi, 2003). The key concepts used are economic dynamics in regional areas (i.e., RIS and clusters; e.g., Asheim et al., 2019; Cooke, 2001; Giest, 2021; Isaksen & Trippl, 2016; Porter, 1998; Reve & Jacobsen, 2001; Wilson et al., 2022) and are eminently relational, consisting of systems of different actors, networks, and institutions.

In this regard, this project combines the relational study of cluster policy in a peripheral and marginally innovative RIS with a specific successful approach to the study of collaborations in regions, namely how different dimensions of proximity (geographic, social, cognitive, organizational, and institutional) can potentially lead to mutual learning (knowledge exchange) and related positive effects in clusters or entire regional areas. These dimensions of proximity were originally theorized by Boschma (2005) and form part of a key strand of literature in Evolutionary Economic Geography (EEG), according to which the capabilities and competencies of existing firms can determine different development paths and in which a critical element such as time plays a key role. That is, EEG scholars argue that economic landscapes, including clusters, are not static, but rather evolve over time and can draw on different elements of new or complementary knowledge from both co-located and more distant partners (Boschma & Martin, 2010). Based on this, a dynamic approach that considered two moments in time was taken in Paper 3, with the aim of determining whether a networking policy initiated by cluster management could have led to increased collaborations in the target biotechnology cluster and for what type of firms.

Building on these considerations, this research project turned toward the study of cluster policy evaluation, a topic that – despite some notable exceptions (e.g., Calignano, 2017; Calignano et al., 2018; Maffioli et al., 2016) – has not received adequate attention from economic geographers and regional research (see Wilson et al., 2022, in this regard). Drawing on previous policy studies (e.g., Schmiedeberg, 2010), this project seeks to address this gap, by adopting new methodological tools such as qualitative comparative analysis (QCA) and contributing to the above-mentioned relational and evolutionary approaches in the geographic study of regional development and cluster policy.

1.1.5 Research Questions

To reveal the mechanisms that would inform such a cluster policy, this research project is interested in developing conceptual and empirical knowledge on optimal cluster policy (see Figure 2) and the role of cluster governance therein as it is applicable to biotechnology clusters participating in the transition to the circular bioeconomy in peripheral regions in the following way:

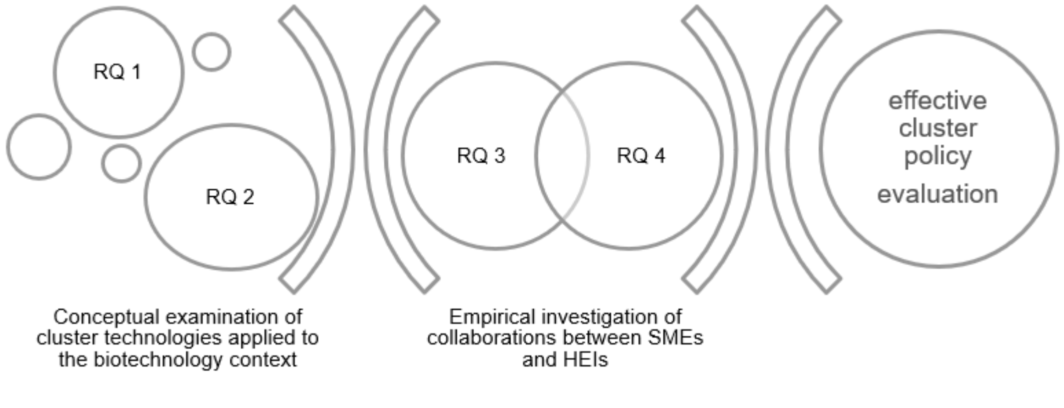

Figure 2: Examining Policy and Governance

Conceptually examining the potential role of industrial clusters applied to challenges faced in the biotechnology sector, the first two research questions ask,

1. How can cluster policies facilitate process development and commercialization in the biotechnology sector towards achieving the transition to a circular bioeconomy?
2. How can enhanced knowledge flows and effective governance accelerate a key innovation process in biotechnology clusters shifting towards biobased alternatives?

Empirically investigating the role of cluster management in how enhanced collaborations between SMEs and HEIs take place, the next two research questions ask,

3. What are the possible effects of indirect policy measures carried out by the cluster administration? and what are the characteristics of the targeted SMEs that primarily benefit from these policies?
4. What drives collaboration between SMEs and HEIs?
   What are the main enabling factors and barriers that SMEs in biotechnology encounter when collaborating with HEIs?
   What roles do different forms of proximity and innovation modes (STI vs. DUI) have in shaping university-industry (U-I) interactions?

1.1.6 A Snapshot from the Periphery: The Role of an Industrial Cluster in the Inland Bioeconomic RIS

Posing these questions across four papers, this research project reveals the generative role of industrial cluster organizations and relations in building new capabilities in peripheral regions transitioning to the bioeconomy. In explicating this role, the NCE Heidner Biocluster revealed several interesting features that position it as a productive intervention in technical yet peripheral fields.

First, industrial clusters can provide important organizational solutions to technical problems in transitioning to the circular bioeconomy. Several technical challenges, such as a lack of access to biobased materials, mean that biotechnology firms experience long wait periods to product commercialization. Exploring the potential role of industrial clusters, especially the role of features like proximity and knowledge exchange, this research project found that the way clusters are organized and managed can have a big impact on their ability to help organizations transition to a circular bioeconomy. This means that the very technical challenges experienced by biotech firms in transitioning to a circular bioeconomy can potentially be addressed by organizational solutions provided by cluster technologies (the utilization of clusters as a key part of systemic solutions to technical challenges).

Second, "softer" structural elements have a bigger part to play in fostering collaborations among cluster members than is often acknowledged. There are many structural elements that can influence collaborations between SMEs and HEIs in peripheral industrial clusters including, for example, human capital (in the form of, for example, the number of PhDs at an SME) or the amount of money that is spent on R&D. However, empirical analysis of the NCE Heidner Biocluster highlights the importance of "softer" structural elements such as age and level of trust – relational elements that may help SMEs overcome their lack of human capital or lower R&D spending. This suggests that "softer" structural elements may be positioned as potentially important features to develop when attempting to form new collaborations (Wilson et al., 2022).

Third, clustered SMEs in peripheral regions have a generative character that is conducive to transitions to the bioeconomy in the Inland RIS. While peripheral regions are often overlooked given their assumed limitations in terms of path dependency and economic stagnation, this project makes the case that these regions can and should be recognized for their ability to develop the needed capabilities to foster collaborations. Examining the mechanisms that help clustered SMEs collaborate optimally, this project delineates how different forms of proximity affect collaborations between SMEs and HEIs in the periphery. It finds that even in a single sector, like the biotechnology sector, a firms' behavior is unique and its characteristics like age, size, and degrees of satisfaction can impact its ability to collaborate when faced with peripherality. This suggests that industrial clusters operating in the periphery should be placed higher on the list of importance when developing policies aimed at transitions to the bioeconomy.

1.2 Background: The Role of SMEs and RISs in Bioeconomic Development

This section outlines the larger imperative of bioeconomic path development (sections 1.2.1 and 1.2.2) alongside the perspective of a small SME (section 1.3) located in an RIS in the Inland region of Norway (section 1.2.3), providing the case, context, and premise for this industrial research on the analysis of clusters.

1.2.1 Understanding Global Bioeconomy Development: Definitions, Aims, and Challenges

Both internationally and regionally, research into implementing a bioeconomy to move from fossil-based economies to greener, more sustainable ones has become more pressing. Governing bodies worldwide, particularly in the United States and Europe, are investing a growing number of resources into facilitating this transition through various policy strategies and agendas. The European Union is a key driver of this transition, primarily through the European Green Deal and its new Circular Green Economy Action Plan, a comprehensive program that promotes sustainable production, consumption, and reduced waste and resource use. Targeted initiatives such as REPowerEU emphasizes energy innovation and efficiency to move away from fossil-based sources and The Green Deal Industrial Plan, focuses on creating zero emission products and improving technologies to further accelerate this transition (European Commission, n.d.).

While definitions of the bioeconomy vary across institutions and governing bodies, it entails the development of an economy based on the sustainable use of renewable resources to develop new processes and products in a circular economy (Teräs et al., 2014, p. 11). To encapsulate the areas of focus within the bioeconomy, the European Commission (2018) defines the bioeconomy in their action plan as follows:

> The bioeconomy covers all sectors and systems that rely on biological resources, animals, plants, micro-organisms and derived biomass, including organic waste – as well as their functions and principles. It includes and

> interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries, and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy, and services (p. 27).

Central to the development of new processes and products in bioeconomic development is the inclusion and interlinking of “all sectors and systems” throughout production. However, at an international, national, and even regional level, interested bodies looking into selected elements and processes related to the bioeconomy often only focus on individual aspects thereof. In their review of bioeconomic research, Gabrielle et al. (2018) demonstrate that the scientific literature on bioeconomy systems in general, and biomass feedstock production in particular, focus on a “one product and/or one resource” (Gabrielle et al., 2018, p. 41) approach. Such an approach neglects the inherent nature of any given bioeconomy as a system of elements and processes, thereby overlooking the system and its complexity (Robledo-Abad et al., 2017).

1.2.2 Implementing the Bioeconomy: National Perspectives

In Norway, the systemic approach required for developing a burgeoning bioeconomic sector is evident in the cross-sectional national programs supporting innovation. Launched in 2016, the national bioeconomy strategy, Familiar Resources – Undreamt of Possibilities, aimed to foster the knowledge exchange needed “to encourage sustainable, bioeconomy-oriented industrial development” (Hallén, 2016). Building on this, the Norwegian Ministry of Climate and Environment’s National Strategy for a Green Circular Economy (2021) outlines current initiatives to position Norway as a leader in the circular economy by promoting cross-industry collaboration and leveraging national and regional strengths. Key policy objectives include utilizing local and regional resources and industry structures to develop a circular economy and advancing a development pathway for circular solutions within the bio-based sectors to replace non-renewable resources, contributing to climate targets and sustainable value creation. Through these policies, the Norwegian government thus closely aligns itself with EU policies like the Green Deal to promote bioeconomic circularity, with implementation led by the Research Council of Norway (RCN), Innovation Norway, and the Industrial Development Cooperation of Norway (SIVA), translating national policy into practice.

A key feature of the Norwegian bioeconomy policy is its cross-sectional nature, in that "the strategy attaches great importance to cooperation across sectors, industries and subject areas, and highlights the importance of research" (Mekjan, 2016, p. 1). According to the Director General of the Research Council, Arvid Hallén, this key underpinning in the Norwegian bioeconomy policy necessitates a broader, more interdisciplinary approach and stresses the benefits of working across disciplines with partners from diverse fields and sectors (Hallén, 2016). Such a cross-sectional approach reinforces the OECD's assessment that successful innovation requires a focus on the application of new knowledge and business models across sectors (OECD, 2009, p. 11) and that implementing the bioeconomy necessitates an approach that will involve a broad range of system-level changes and innovations to succeed (Teräs et al., 2014, p. 11).

1.2.3 Localizing the Bioeconomy: The Inland Region of Norway

Norway's largest region, Inland County, is located north of the capital city Oslo in the south-eastern part of the country. Due to its favorable climate conditions, nutrient-rich soil, and advantageous proximity to the country's largest freshwater lake, Mjøsa, this region is the leading agricultural and forestry area of Norway. The area around lake Mjøsa hosts the majority of private sector value creation and most of the regions' population growth (*Innlandsportfølje*, 2023). Depending on the elevation, potatoes, cereals, and grasses are among the most common crops produced. These favorable soil conditions also produce some of the highest quality pine and spruce timber in the region, making up nearly a quarter of Norway's forest resources (County Government of Hedmark, 2015, p. 3). From these industries, the Inland region has developed a strong tradition of value production from raw materials.

With such traditional industries securely in place, there has, from a regional perspective, been a strong push for the implementation of the bioeconomy within industries across the region – particularly those focused on agricultural activities and the extraction of natural forest-based resources (Bråtå et al., 2015). Among others, the lumber industry has enjoyed significant development through intensified research, digitalization, and innovative policy changes. The implementation of novel sustainable forest regeneration practices and the development of innovative technology used in local harvesting and bioenergy production has proved especially effective in maintaining its competitive edge. Today, the lumber industry is seen by the government as a priority area, providing significant employment in an area that has seen its population decline (Nilsen et al., 2024). Such developments are made possible by the region's understanding that increased growth and improved resource utilization can be realized in both traditional industries and emerging bioeconomic industries. This has led to an increased focus on value creation, jobs, and enhanced competitiveness in local value chains (County Governor of Inland, 2015, p. 7).

However, while recent reports indicate growth, further intensification is required. To advance bioeconomic path development, the county plans significant investments in energy infrastructure based on four value propositions: establishing the greenest land-based industries, becoming a national hub for agricultural technology, developing leading circular biohubs, and developing a Tech Valley (*Innlandsportfølje*, 2023). These regional goals build on existing conditions in the Inland bioeconomic area, positioning it as a Regional Innovation System (RIS) with the necessary conditions to support investment into bioeconomic path development.

Characteristics of the Inland RIS

This drive towards a regional bioeconomy is underpinned by the Bioeconomy Strategy for the Inland Region 2017-2024 (2015), which has recently been followed up by *Innlandsporteføljen* (2023), outlining the regional government's plans to establish leading circular biohubs. These hubs are networks of industries and actors that sustainably utilize biological resources, fostering cross-sector collaboration in areas such as agriculture, food production, bioenergy, and waste management. These initiatives build on earlier efforts to strengthen cooperation between stakeholders in the bioeconomic innovation sector (R&D institutions, business, and funding agencies) and are grounded in the conditions that characterize the Inland bioeconomic area as a Regional Innovation System (RIS).

"In a broad sense, RISs encompasses all regional economic, social and institutional factors that affect the innovativeness of firms" (cf. Lundvall, 1992). More specifically, the RIS concept can be used as an analytical tool to analyze the innovation strengths and weaknesses of a region, and – partly based on this – as a tool for developing and assessing spatially targeted systemic innovation policies (Tödtling, Trippl & Desch, 2022, p. 2142). Taking up this analytical perspective, Asheim et al. (2016) characterize the core of an innovation system as comprised of two interacting subsystems: exploration and exploitation. The "knowledge exploration" subsystem captures actors exploring and generating new knowledge and includes universities, public and private research institutions, technology transfer organizations, policy agencies, and other educational and mediating organizations. The "knowledge exploitation" subsystem consists of firms, both large and small, within or outside clusters, that apply this knowledge for innovation purposes. For these interactions to qualify as an innovation system, linkages must be systemic and long-term in nature (Asheim et al., 2016; Asheim 2019). Cooke (2004) further uses these subsystems to define an RIS as "interacting knowledge generation and exploitation subsystems linked to global, national and other regional systems" (Cooke, 2004, p. 3) providing a framework to characterize the Inland bioeconomic development area as a Regional Innovation System.

The Inland region of Norway exemplifies an RIS through its dual focus on exploration and exploitation. Knowledge creation (exploration) can be documented through the activities of the local university, the University of Inland Norway; established private and public R&D institutes such as Eastern Norway Research Institute and SINTEF; and a robust private consultancy sector with consultancies such as The Assessment Company AS and Mindset AS that consult on areas such as sustainability, firm structuring, and process improvement. On the exploitation side, the region benefits from a strong industrial base, encompassing sectors such as forestry, biotech, metalwork, food processing, tourism and energy production. Regional strengths further include the forestry sector, which is positioned to contribute to Europe's circular building materials agenda, supporting goals of waste reduction and sustainable construction. These established industries and resources provide a strong foundation for innovation and is further supported by key advantages such as ample industrial space connected to strong transport networks and a skilled workforce, making long-term RIS development highly promising (*Innlandsporteføljen*, 2023). Moreover, despite low levels of absolute R&D, the region benefits from relatively high levels of R&D spending in the private sector, which accounts for over half of total R&D spending, with industrial R&D accounting for more than two thirds (*Innlandsporteføljen*, 2023).

One of the key strengths of the Inland RIS is its robust public-private partnerships, with frequent collaboration between public authorities (e.g., Innovation Norway), businesses, and research institutions. Notable collaborations include partnerships between the private R&D sector (e.g., SINTEF) and businesses as well as collaborations between the University of Inland Norway (INN) and private biotech firms (e.g., Norse Biotech AS). The regional bank Sparebankstiftelsen exemplifies this collaborative tradition, serving as a key actor by investing in R&D projects, the University of Inland Norway (INN), and business development initiatives.

The transition to a circular bioeconomy is progressing in Norway, with the business sector systematically incorporating circular solutions into green competitive roadmaps across various industries based on the conditions provided by local RISs. Solutions to regional path development are supported by national policy that helps county municipalities serve as drivers, mediators, and facilitators in implementing circular bioeconomy initiatives through investments in the development of relevant expertise (Norwegian Ministry of Climate and Environment, 2019, p. 7). Building on the Inland RIS, that already boasts more than 200 innovation projects across the county, regional authorities have identified growth areas for development of the region's circular

economy through the *Innlandsporteføljen* (2023) report. At present, the county is prioritizing investments in the RIS by addressing key challenges in, among others, the biotech sector, like funding, scaling and infrastructure. Plans include establishing circular biohubs to promote resource reuse and leveraging business incubators like Klosser (located in Hamar) to support biotech development, scale green innovations, and strengthen value chains. In terms of general investment in the RIS, the county is focusing on developing clean energy infrastructure to support green industry growth. While short-term efforts will emphasize renewable energy expansion, particularly solar power and energy efficiency, longer term plans aim to address grid capacity challenges and develop value propositions for energy intensive green industries.
The initiatives proposed to develop the Inland RIS is based on the belief that:

> Innlandet has unique conditions for succeeding in the bioeconomy. The county has access to world-class knowledge, technology, and renewable resources in forestry and agriculture (*Innlandsportefølje*, 2023, p. 39).

Building on these assets, the Inland RIS seeks to modernize traditional industries like forestry and farming, aligning with Asheim's (2019) description of new path development, which aims to "diversify the economy into technologically more advanced activities that move up the ladder of higher knowledge complexity compared to the present level in the region" (Asheim, 2019, p. 13). A notable example is Norse Biotech AS (see section 1.3 below), which repurposes waste material from forests and fields. Leveraging an international team of scientists, the company develops innovative extraction processes to create a new class of products and contribute to the circular bioeconomic development.

1.3 The SME Perspective: Norse Biotech AS and the Bioeconomy

One SME that falls within the purview of this regional bioeconomic strategy is Norse Biotech AS (the project owner for this industrial research). Norse Biotech AS was created in 2015 to participate in the transition of the local bioeconomy of the Inland region by a small team of American and Norwegian scientists, farmers, plant breeders, and business developers interested in producing innovative and sustainable products.

For Norse Biotech AS, a significant part of this effort is the development of valuable uses for as many components of local biomass as possible to replace finite fossil-based resources which are a key source of global warming gas emissions.

1.3.1 Developing Localized Bio-based Processing Technologies and Products

Within this profile, Norse Biotech AS aims to develop processing strategies for the optimal utilization of biomass throughout the entire value chain. This use of biomass for sustainable production follows broader principles of the circular bioeconomy that aims to ensure the continuing supply of resources required to maintain our modern way of life (for more on the circular bioeconomy, see Paper 1 & 2 in the Appendix). For Norse Biotech AS, a significant part of this approach is the utilization of new manufacturing concepts and the minimization of manufacturing wastes, including energy and materials.

To this end, it has developed what is referred to as a biorefinery – a bio-based processing system where most all components are converted to usable products – that is designed with the locally produced biomass in the Inland region in mind (for more on the transition from fossil-based refineries to biorefineries, see Paper 1 in the Appendix). The goal of Norse Biotech AS is to produce lower volume, high value products like what is done in pharmaceutical production by using the general refinery concept of minimizing energy use and raw material waste which will reduce climate impact. This approach meets the primary objectives and main strategies for developing a competitive and sustainable bioeconomy.

Norse Biotech AS has developed a product roadmap based on this process concentrating on a variety of feedstocks available in the Inland region: from pine needles and birch bark left over from timber production (forestry waste) to potato tops that remain after harvesting (agricultural waste). Using these feedstocks, it first aims to capture valuable small molecules and to subsequently extract the residual biopolymers, lignin, cellulose, and hemicellulose and convert them into high value uses.

1.3.2 SMEs and Challenges in the Transition to the Bioeconomy

Like other SMEs transitioning to the bioeconomy, Norse Biotech AS requires new knowledge and business models as well as a cross-sectional approach involving a broad range of innovations and collaborations to succeed (OECD, 2009; Tëras et al., 2014). As an SME in a capital intensive, competitive biotechnology industry, Norse Biotech AS requires specific and sustained coordination, networking, and knowledge exchange with select collaborative partners that can meet its needs in a way that is time- and cost-effective.

Among others, Norse Biotech AS needs access to avenues for (1) raising capital, specifically collaborations with local business networks and incubators to provide the expertise to identify local, regional, national and EU funding opportunities and (2) project partners to access raw feedstock materials. It is further developing (3) prototypes that need to be tested in collaborative, cost-effective ways. Norse Biotech AS also intends to develop (4) new manufacturing processes which require the latest high-tech equipment and knowledge networks that could reduce the cost needed to develop new equipment on one's own. Finally, it is (5) searching for new customers and access to market opportunities in a variety of industries and applications for its product extractions.

Figure 3: Understanding SME Needs in the Transition to the Circular Bioeconomy.

The needs of Norse Biotech AS point to several key areas that require coordination with collaborative partners. However, SMEs in areas of bioeconomic development often report that they struggle to establish collaborations with stakeholders and research institutions. For example, with regards to university-industry (U-I) linkages, research on regional projects in Italy report that SMEs struggle at multiple points –

from the planning to the closing phases – while initiating collaborations (Bertello et al., 2021). In Australia, biotechnology firms face challenges in gaining access to intellectual property (Molloy, 2021) with collaborations made especially challenging by differences in organizational culture between SMEs in the electronics sector and potential partners external to the sector (Collier et al., 2011). Financial challenges of negotiating technology and university linkages for SMEs in Brazil (Silva et al., 2019), and unrealistic expectations set up at the start of the collaboration in health technology in Europe have also been reported (Austin et al., 2020). Norse Biotech AS faces similar challenges to those reported, specifically how to understand its role, the opportunities, and technologies in the existing regional network of biomass producers and how to establish better relationships with research institutes.

2

2. THEORECTICAL BACKGROUND AND APPROACH

As outlined in the background of chapter 1, the Inland region is affected by national and international policies advancing green innovation initiatives. The region responds to these changes and challenges which calibrates the innovation ecosystem (the RIS) in different ways. This project aims to understand how the innovation system (developing RIS) and the individual actors (individual SMEs and HEIs) *are coordinated* (through the place-based leadership of cluster administration, governance and policy) and mutually reinforce each other during this process of regional diversification (path development towards green innovations, i.e., the bioeconomy).

Within this context, the growing complexity of innovation processes and the diverse knowledge bases that underpin them become particularly important. As Asheim (2007) notes, organizations must not only enhance their internal capabilities, but also establish robust regional partnerships to remain competitive, both nationally and internationally, as these partnerships support collective learning, regional innovation and diversification. This need for collaboration highlights the systemic interdependency of RISs and clusters, as well as the critical role of regional factors. For the Inland region to successfully implement the bioeconomy (path development towards green innovations), a cross-sectional approach involving system-level changes, innovations, and partnerships are required (Teräs et al., 2014). Consequently, this research project approaches Inland's diversification through bioeconomic development as a complex system of interconnected, region-specific processes within the RIS that depends on place-based coordination activities that can be facilitated by innovation clusters.

First, section 2.1 presents Systems Thinking as a framework for understanding the complexity of RISs, followed by section 2.2 discussing how the RIS approach helps to make sense of knowledge exchange in the Inland context. Next, section 2.3 focuses on the central concept of this research, industrial clusters, exploring their role as a strategic tool for operationalizing the RIS (section 2.3.1) and the cluster administration as place-based leaders in fostering coordination and collaboration for regional diversification (section 2.3.2). Finally, section 2.4 offers critical reflections on how clusters, as place-based leaders, can optimally function as mechanisms of knowledge flows and exchange within localized systems and how this can be further supported through cluster policy and its analysis, constituting a framework for analyzing clusters in this project.

2.1 Systems Thinking: Approaching Complexity in Innovation Contexts

Sverdrup et al. (2022) emphasize the growing importance of understanding the dynamism of relationships in an increasingly complex world, noting that "the need to understand events, processes and connections is greater than ever" (p. 7). Systems Thinking addresses this need by focusing on the interdependence of elements within a broader context. Defined as the "principles of organization" or "theory of self-organization," it adopts a "systemic" or "holistic" approach to understanding how seemingly isolated parts function as an integrated whole (Haraldsson, 2004, p. 4). Holistic thinking, central to Systems Thinking, thus reflects its roots as a "science of wholeness" (Haraldsson, 2004, p. 5). In this project, applying a holistic lens to cluster policy involves examining how elements like SMEs, HEIs, cluster administration etc., interact within the RIS to optimally support regional diversification, recognizing the whole exceeds the sum of its parts.

Systems Thinking is valuable when confronting the "complex behaviors" inherent in bioeconomic transitions as it can be used to "better predict them and, ultimately, adjust their outcomes" (Ross & Wade, 2015, p. 670). Accordingly, Ross and Wade (2015, p. 670) argue that such a systems thinking approach is essential for policymakers as it can be useful across a variety of different fields (e.g., regional innovation systems), contexts (e.g., industrial development in Inland), and situations (e.g., cluster policy development). Moreover, Systems Thinking and qualitative comparative analysis

(QCA) are also complementary, with QCA serving as an effective methodological tool for understanding complex systems, making it a suitable choice for examining cluster members data for Paper 3 (Calignano & Winsents, 2023).

2.2. The Inland Bioeconomy: A Regional Innovation System

Systems thinking offers a framework for understanding the nature and the behavioral characteristics of multi-node systems, such as the Inland bioeconomy, and provides a practical way to define systemic problems and design solutions for them (Galanakis et al., 2000, p. 1). Applying a systems approach to the research context, the Inland bioeconomy can be further defined as an innovation system that functions at a regional level, thus a Regional Innovation System (RIS).

An Innovation System

The systems approach has been found to be comprehensive for facilitating sustainable innovation management for competitive advantage and provides a framework to approach the study of innovation management for a sustainable bioeconomy (Adams et al., 2006; Galanakis et al., 2000; Kong & Li, 2007; O'Connor, 2008; Shen et al., 2009). Operating under the term "innovation systems," this approach greatly influenced the theoretical development of today's RIS. This is because innovation systems approaches move away from linear thinking in innovation, whereby a step-by-step process moves a product or invention along a developmental path towards the market, to a process involving more complexity with many actors and an understanding of the connections among those actors, i.e., a more open approach to innovation. Importantly, innovation systems acknowledge that innovation can be achieved through a variety of ways, not only as an output of R&D spending. A shift in the 1980's to an innovation systems approach began to affect policies that focused more on the movement of knowledge among those working in innovation fields. This shift also impacted policies that look at the whole system from academic institutions to firms to explore the connections facilitating knowledge among them (Asheim et al., 2016, p. 46).

A Regional Level Inquiry

In addition to the complexity that the innovation approach brings to understanding and examining the Inland bioeconomy, this innovation system further functions in a localized way. As researchers and other interested parties develop frameworks to gain a better understanding of the bioeconomy as a system, they approach it from a regional level:

> Considering that a social-ecological system at local/regional level is recognized as an appropriate level to deal with the particularities of the social and ecological contexts of action, we focus on bioeconomy systems in a given biophysical, social, technical and economic context: the territorial context (Wohlfahrt et al., 2019, p. 899).

A regional perspective on innovation in and development of existing industry paths to stimulate new industrial growth thus rests on the understanding that path development is strongly rooted in the existing economic structure of the region (Isaksen & Jakobsen, 2017, p. 355). Moreover, a systems approach to proposed regional innovations provides a basis for the application of practical and established industry practices that can be utilized in the execution of innovations in the bioeconomy sector (Jofre, 2011, p. 5). For the Inland bioeconomy, this means that existing industry paths, like the established forestry and agricultural industries, are considered when executing innovations in the local bioeconomy thus functioning as a Regional Innovation System.

2.2.1 Regional Innovation Systems: Promoting Knowledge Exchange

The RIS approach is defined as "the institutional infrastructure supporting innovation within the production structure of a region" (Asheim & Coenen, 2005, p. 1177) and has been an essential part of European regional policy since the 1990s (Asheim et al., 2019, p. 9). Asheim et al. (2019) argue that, even within the context of increased globalization, the RIS approach continues to be the most used analytic framework. This is because RISs allow for more knowledge spillovers and trustful collaborations between organizations than national innovation approaches (Asheim et al., 2019, p.

30). As such, it is projected to remain vital (1) in designing innovation policies to increase inclusiveness, competitiveness, and sustainability; (2) in implementing these policies; and (3) to evaluate the successes of said policies (Asheim et al., 2019, p. 9). This longevity is due to a key structuring element of the RIS approach–knowledge linkages–and signals its significance in understanding the development of different RISs and the way they facilitate interactions (Asheim et al., 2019).

Consequently, substantial academic research has been devoted to understanding the "nature and spatial dimension of knowledge flows that shape the learning activities and innovation success of firms, industries, and regional economies'" (Asheim et al., 2019, p. 114) within RISs. Throughout the 1980s and 1990s, research focused on the number of knowledge linkages found at the local level over the non-local level and emphasized the importance of the geographical proximity of collaborators for knowledge flows. This research surmised that innovation is predominantly the outcome of knowledge circulation at local levels and includes culture, trust, and social capital, which are all influenced by proximity (Healy & Morgan, 2012).

However, more recent research has shifted focus to the interconnection between globalization, innovation outcomes, and knowledge flows and how they are all connected globally. Covering topics from global innovation networks to the migration of skilled workers, this research aims to better understand how interaction operates on non-local levels (Asheim et al., 2019, p. 115). This global perspective has been critical of earlier scholarship on RISs, clusters, and other industrial zones for exaggerating the effect that the region alone has on innovation development (Bunnell & Coe, 2001). Instead, Archibugi and Michie (1997) conclude that, in understanding:

> technological change it is crucial to identify the economic, social, political and geographical context in which innovation is generated and disseminated. This space may be local, national or global. Or, more likely, it will involve a complex and evolving integration at different levels of local, national and global factors (Archibugi & Michie, 1997, p. 122).

The Role of Knowledge Exchange in Defining RIS Path Development

Both the origin and direction of knowledge flows are significant factors in determining the way RISs develop and the nature of their eventual competitiveness. Such RIS evolution is often broken down into two models: organic and planned. Organic RIS evolution begins with firm-level innovations and inventions that help create new paths in a specific region. These paths are built on extant knowledge and competence from entities such as universities. The planned model starts at the system level and adapts the RIS to the needs of new organizations, industries, technologies, etc. as they enter the regional economic area (Asheim et al., 2019, pp. 92-93). With planned RIS evolution, the region can also define how development will take place. Isaksen and Trippl (2016) describe three types of planned RISs: organizationally thick and diversified, which have a diversified industrial structure and many organizations; organizationally thick and specialized, which refer to RISs that have developed clusters that all operate in only a few industries; and organizationally thin RISs that operate without strong clusters or acquired knowledge or support.

Understanding the Inland bioeconomy as a planned, organizationally thick, and specialized RIS creates new opportunities for examining how its knowledge flows and exchanges take place as a dynamic and interconnected process. Since they are central to the understanding of the establishment, maintenance, and growth of a given RIS, these knowledge flows and exchanges must be further analyzed to identify and promote the mechanisms that best facilitate optimal exchanges and enable different orders of innovation and growth.

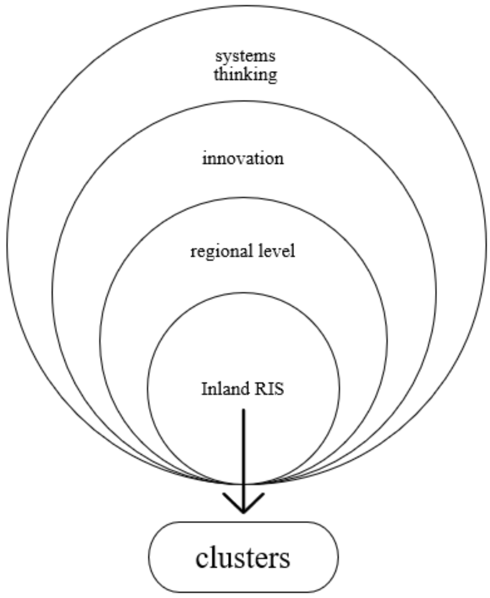

Figure 4: The Inland Bioeconomy: A Regional Innovation System Operationalized through Innovation Clusters

2.3 Operationalizing the RIS with Innovation Clusters

Studies indicate that RISs often grow in tandem with innovation clusters– concentrations of interconnected companies and institutions in a particular field (Porter, 1998)–and that industrial cluster development will organically impact regional knowledge and policy systems (Asheim et al., 2019, p. 91). Optimized knowledge flows and exchanges in RISs are then predominantly understood to be realized through the development of innovation clusters supported by cluster policy – making clusters an essential part of operationalizing the RIS. Similarly, the configuration of the RIS has a significant impact on the development and growth of a cluster, suggesting that regional policy and its associated culture and infrastructure must also be discussed when examining cluster growth (Trippl et al., 2017). Based on this understanding, the Research Council of Norway encourages the simultaneous development of RISs and clusters between industry, education, and research institutes and works to link these local, place-based entities to national and international research programs (Asheim et al., 2019, p. 26).

Following from this literature, this research project set out to conceptually explore the application of innovation clusters to the challenges that SMEs like Norse Biotech AS face in the Inland RIS in its transition to the circular bioeconomy through two conceptual papers (see chapter 4, Publications; chapter 5, Discussion). These conceptual discussions provide the premise for examining cluster policy as an evaluation tool in the empirical part of this research project (Papers 3 & 4) and necessitates a closer look at clusters at the level of policy (2.3.1) and how these policies can be effectively executed regionally (2.3.2).

2.3.1 Cluster Policy Development in Europe and Norway

Examining clusters at the level of governance, as proposed above, i.e., looking at clusters with the goal of evaluating how well the cluster itself is being managed, requires an exploration of their functioning at the policy level. Cluster formation, largely taking place at the regional level, stems from several political and policy developments in Europe.

Beginning in the early 1990s, European policymakers showed increasing interest in the development of industrial districts, clusters, and local production systems (see Obadic, 2013, p. 23 for distinctions between these related concepts). New policies were introduced to improve public and private sector collaborations and thereby develop networks of sector-specific businesses. To this end, new frameworks were introduced to increase the knowledge base at different levels. These policy changes coincided with a period of political decentralization that saw power shift away from national governments – while some aspects of the industrial policy were moved to the international level, others settled more locally at the regional level (Obadic, 2013, p. 24). Roelandt and Den Hartog (1999) attribute this shift to developed nations transitioning from direct to indirect incentivization approaches. This, in turn, resulted in systemic irregularities within networks that had to be addressed through several public actions, among them public intervention in cluster policy. By the late 1990s, these shifts led to the adoption of cluster policies in roughly half of European countries (Obadic, 2013, pp. 23-24).

Norway has a long history of industrial policy focused on supporting individual businesses through public support. Businesses can apply for support by demonstrating innovation or societal contributions, with funding often enabling projects that would otherwise not be realized without their costs being offset. Such public financing is delivered through channels such as Innovation Norway, which provides expertise and capital support to promote exports and sustainable business development (Innovation Norway, 2020); the Norwegian Research Council, which supports research and innovation projects across multiple sectors (The Research Council of Norway, n.d.); and SIVA, who contributes to the infrastructure and development of business incubators, catapult centers and business gardens (Siva SF, 2020) throughout the country (Jakobsen & Røtnes, 2012).

Realizing that these publicly funded innovation projects were often conducted as part of a collaboration between businesses, research centers, and academic environments, Norwegian industrial policy also turned towards a more collaborative model during the mid-1990s. This shift was reinforced by wider academic research highlighting the benefits of such collaborations for businesses in larger groups (Krugman, 1991; Porter, 1990; Reve & Jacobsen, 2001). As Giest (2021) explains, the benefit of collaborative clusters lies in the innovative way knowledge flows are organized and managed. On the one hand, structured cluster management facilitates knowledge exchange through collaborative *capacity-building activities* that include (1) defining a shared vision and allocating joint resources to this end; (2, 3) developing formal structures of regular communication, support, and collaboration amongst members and external partners; and (4) establishing financing powers to allocate to shared projects. On the other hand, *absorptive capacity-building activities* facilitate the establishment and continuous development of both intra- and extra-cluster knowledge systems, increasing knowledge spillovers due to geographic proximity. As a result, cluster policy, particularly through its function as a knowledge management mechanism, came to be understood as linked to performance.

Established as a mechanism for effective knowledge exchange, Norway implemented cluster policy through its national cluster program, which began in 2002. It has since been used to support the development of a variety of clusters with financial and other services in multiple sectors – the former provided through The Norwegian Ministry of Trade and Labor and The Ministry of Local Government and Innovation. Through a range of public policy interventions, the Norwegian innovation cluster program has evolved and today consists of a strategy executed at four distinct certification levels: Arena (introductory or entry-level), Arena Pro, Norwegian Centre of Expertise (NCE), and Global Centres of Expertise (GCE). Its purpose is to increase innovation, growth, and new business opportunities within its 39 clusters, each with its own regional specificities (Innovation Norway, 2019).

2.3.2 Understanding Effective Cluster Administration through Place-based Leadership

To understand how cluster administration can effectively implement cluster policy to meet regional challenges, this project posits that cluster administration should be conceived of as a form of leadership that is spatially situated, or place based. Place-based leadership can be defined as "the mobilization and coordination of diverse groups of actors to achieve a collective effort aimed at enhancing the development of a specific place" (Sotarauta, 2021, p. 152). A place leader is "an actor having a position to assess a path development process from a more comprehensive angle than the other actors, and mobilize and pool resources, competencies and powers" (Sotarauta et al., 2020, p. 96). While such leaders may be individuals from the local community, government or business sectors, organizations such as non-profits, clusters or business incubators can also act as place-based leaders if they hold a similar position of influence and trust within the community.

Place-based leadership and the activities involved in administrating a cluster such as the NCE Heidner Biocluster strongly overlap as "both forms of leadership are based on mobilizing existing potentials and coordinating and harmonizing a multitude of interests to foster knowledge and technology transfer, exploit synergy effects and thus create added value and generate wealth" (Ganske & Carbon, 2023, p. 8). Ganske and Carbon (2023) argue that effective cluster administrators need the trusted, relatable bottom-up personality traits of a place-based leader to be successful: a leader that works to develop trust amongst cluster members or local stakeholders and a common vision and identity for the place or cluster. Ganske and Carbon (2023) argue that this is because “Place Leaders, through their leadership competencies, are better able to face the challenges of the multi-layered and partly competitive environment prevailing in a cluster than a cluster management that is not a Place Leader and lacks this leadership personality for a successful bottom-up approach” (p. 8). In this view, the presence of place leaders within cluster management is essential for successful cluster development.

Place-based Leaders Mitigate Challenges of Peripheral Regions

Effective place-based leaders can help peripheral regions like Inland overcome developmental challenges by promoting innovation policies that drive localized industrial diversification. Leveraging their understanding of “place-specific” conditions, such leaders can identify prospects for diversification, address barriers, and promote connectedness that foster collaborative networks (Grillitsch & Asheim, 2018). The NCE Heidner biocluster administration exemplifies this by actively working across sectors to leverage the strengths of the region, promoting its resources and expertise to drive innovation and growth (personal communication with cluster management, 3 May 2024). The cluster administration identified sustainable food production as its focus area, building on the previously established breeding companies and research labs in the region. This aligns with national and international focus areas on food security and traceability, reducing antibiotic resistance, and improving food production. Effective place-based leaders further support peripheral regions, particularly those with underdeveloped resources, capabilities, and communication networks, through understanding and communicating local requirements and conditions to stakeholders (Grashof, 2021).

Fostering Collaboration through Trust and Consensus-building

One of the primary roles of a place-based leader is to facilitate cross-sector collaboration among stakeholders, such as businesses, government, and education institutions. Unlike traditional top-down leadership models that often characterize business or government, these collaborations are typically less hierarchical (Sotarauta & Beer, 2017). Place-based leaders accomplish this by overcoming barriers through trust and consensus-building, reinforcing shared goals and interests. They also act as gatekeepers, connecting knowledge networks and encouraging collaboration within and beyond the region, including international partnerships (Ebbekink & Lagendijk, 2013; Lucena-Piquero & Vincente, 2019). While traditional cluster strategies like those proposed by Porter (1998) are based on specialization within a single sector, diversified place-based specialization allows regions to identify strategic sectors for collaboration. For instance, the NCE Heidner biocluster, originally established through collaboration among breeding organizations, now focuses on creating value through broader collaborations (NCE Heidner Biocluster, 2020). The cluster has diversified from its origins in plant and animal breeding to include cross-sector members such as BIR AS, working in waste disposal and the creation of feed from home-based vegetable waste, and Agdir Drift AS, an organization that creates software for better farm field management (NCE Heidner Biocluster, 2020) These efforts demonstrate the cluster's ability to develop competitive advantage through broader, cross-sector partnerships (Asheim et al., 2017).

Effective Communication

Effective communication is an important trait for place-based leaders and involves the ability to clearly articulate a vision for the area, introduce new ideas in an accessible way, and effectively engage with stakeholders like cluster members (Sotarauta, 2014; Sotarauta & Beer, 2017). Equally important is to understand and address local issues that may spark debate, enabling place-based leaders to build consensus effectively. The origins of the NCE Heidner Biocluster exemplify these traits. In the 1980s, government discussions highlighted concerns that the Inland region was lagging behind the oil-producing western regions, leading to a perception of being left in the "oil shadow" and primary industries such as forestry and agriculture were viewed as overly "simple." In response, local members of government and business leaders emphasized the region's long-standing expertise in biological research conducted at local HEIs and research institutions. With the 1990s growth in genetic research, leaders successfully positioned the Inland region as a hub for genetic engineering and biotechnology. Leveraging the goodwill and attention from the 1994 Lillehammer Olympic games, the region launched the BioInn network, followed by the BioHus research hub, which eventually culminated in the establishment of the NCE Heidner Biocluster (Hamar historielag, 2024). Exemplifying its role as a place-based leader, this progression highlights the cluster's effective communication of a unifying vision, mobilizing stakeholders, and building a foundation for regional innovation.

Governance

Place-based leaders work to create a shared vision among shareholders, potentially enabling the development of more effective policies and funding opportunities. Such alignment can be achieved through creating opportunities for dialogue among diverse stakeholders from local government to private enterprises. This allows collaborators to combine resources, share knowledge, and establish common objectives. Place-based leaders must then guide stakeholders towards a common vision, while navigating existing policy constraints. Adopting long-term strategies and goals can help address existing policy challenges (Broadhurst et al., 2020). The NCE Heidner Biocluster navigates such policy constraints through its Biotown conference, where cluster members and food industry representatives discuss local challenges with politicians and other industry experts. Locally, the cluster administration attends National Norwegian parliamentary seminars to advocate for investments in biotechnology as well as promoting green transitions through its media channels and at conferences (NCE Heidner Biocluster, 2020). Additionally, in 2024, select Heidner administration members were elected as representatives to *Horizon Europe's cluster 6: Food, bioeconomy, natural resources, agriculture and environment,* opening opportunities to give input on what topics and content should be prioritized at influential levels of governance (NCE Heidner Biocluster, 2020).

Promoting Knowledge Exchange and Support for Innovation

Beyond good communication and encouraging collaboration, place-based leaders connect regional stakeholders to global knowledge networks, such as international universities and research centers (Grillitsch & Asheim, 2018). By tailoring innovation to policies to leverage regional strengths, place-based leaders enable regions to showcase their unique knowledge, products, and services on an international stage (Foray, 2017, p. 47). The NCE Heidner Biocluster exemplifies this by supporting its members in securing regional, national and EU grants and facilitating connections with international research institutions and partners to promote knowledge exchange. By promoting the unique technologies of its members and harnessing its administrators' expertise, the cluster exemplifies how place-based leadership can internationalize regional strengths (personal communication with cluster management, 3 May 2024). This approach avoids the shortcomings of standardized innovation models of, for example, Silicon Valley, which may fail to recognize the "context-, sector-, and region-specific" advantages of peripheral regions (Foray, 2017, p. 47).

New Path Development

Radosevic (2017) describes Smart Specializations (RIS3) as an ambitious EU-wide industrial innovation policy aimed at fostering regional diversification at an unprecedented scale. These strategies drive growth based on more specialized and complex activities, enabling regions to identify their "place-based" advantages, leverage local assets to build effective research and innovation strategies, and establish the national priorities to implement them (Grillitsch & Asheim, 2018). Place-based leaders are crucial in enabling path development and regional transformation by understanding local resources, encouraging collaboration across different industries and knowledge bases, and driving new path development (Grillitsch & Asheim, 2018). In this context, the NCE Heidner biocluster administration exemplifies this role by supporting regional industrial diversification through funding support for hi-tech food-related startups and collaboration with local business incubators, supporting new path development in the Inland region (personal communication with cluster management, 3 May 2024).

2.4 Towards a Theoretical-Analytical Tool for Evaluating Cluster Policy

In addition to the need for underscoring context-specificity or "place" when analyzing a given cluster, to thoroughly examine the impact of cluster policies, there is a further need to distinguish clusters based on their distinct innovation processes across sectors, recognizing that cluster dynamics may differ across knowledge bases. Discussing the relationship between knowledge bases, clusters, and regional innovation systems, Asheim (2007) points to the increasing complexity of different innovation processes and the knowledge they are based on. To maintain global competitiveness, organizations must not only improve internally but maintain close relationships with other regional partners to improve the system's learning and competitiveness. Moreover, as the complexity of innovation processes increases, organizations must manage significantly more sources and inputs of knowledge and their associated processes of knowledge transfer (Asheim, 2007). In the following section, Asheim’s (2007) classification of knowledge bases are outlined and applied to the NCE Heidner Biocluster.

2.4.1 The Three Knowledge Bases of Clusters

To understand this increased complexity, Asheim (2007) proposes examining different kinds of knowledge and the way it dynamically interacts in the innovation processes of different types of organizations. Both codified (i.e., structured, documented and easily transferable across time and space) and tacit (i.e., context-specific knowledge that is difficult to share) forms of knowledge contribute to knowledge generation and are often combined, creating a sometimes complex and changing knowledge dynamic for organizations. Asheim (2007) suggests that these mixes of tacit and codified knowledge in innovation processes vary by sector, each constituting a specific knowledge base.

Asheim (2007) distinguishes three knowledge bases: analytical, synthetic, and symbolic. While organizations can make use of multiple knowledge bases, sectors tend to have specific innovation challenges that lend themselves to a particular knowledge base. The synthetic knowledge base relates to engineering and is often associated with industrial plants and the production of machinery. It uses existing knowledge to create products that may be specialized, and which may not be produced in large quantities. R&D is a less central focus and while university collaboration exists, organizations drawing on a synthetic knowledge base may be more focused on applied research. Knowledge is found in practical work, testing, and experimentation. Efficiency and reliability are important in the innovation process of synthetic knowledge bases. Symbolic knowledge bases are found in cultural, creative industries like media and fashion where the creation of ideas takes precedence over any actual physical production process. Knowledge generation is often based around projects and on-the-job-training thus having a strong tacit element. In industries with a symbolic knowledge base, knowledge is displayed through the production of various types of aesthetic mediums.

Biotechnology Firms: Analytical Knowledge Base

The analytical knowledge base, the third type, is predominantly found in industrial contexts where scientific knowledge is paramount. Per example, biotechnology organizations often represent the analytical knowledge base where knowledge is created through processes that require cognitive and rational thinking for the development of products and processes. Basic and applied research may be conducted internally, and university linkages are important.

This is reflected in the activities of the member organizations of the NCE Heidner Biocluster with many members like Norse Biotech AS seeking and maintaining collaborations with local and international HEIs. Research is conducted based on previous studies and creates formal codified knowledge, which is disseminated though research papers and reports. This knowledge base often has knowledge outputs such as patents and inventions leading to the creation of new organizations (Asheim, 2007; Chrisman & Calignano, 2024). Defining and understanding the kind of knowledge base that the NCE Heidner Biocluster draws on has implications for the types of collaborations its member firms would value and is important when trying to understand how and why knowledge transfer takes place – especially as it pertains to the relative importance of dimensions of proximity and its impact on knowledge sharing.

3

3. METHODOLOGY

This chapter discusses the methodological approach, tools, and standpoint used in this research project. First, it outlines relevant trends in RIS research before introducing the project's main case study approach and the case under investigation – the NCE Heidner Biocluster. It then presents how the project's scientific theoretical standpoint in Critical Realism informs its case study approach and the two methodological tools used to examine the case, namely Qualitative Comparative Analysis (QCA) and Qualitative Interviews as they were used in Papers 3 and 4 (see Appendices 3 & 4).

3.1 Relevant Trends in RIS Research and Methodologies

Research on RISs has gained popularity in the U.S. and Europe (Asheim et al., 2016, p. 49; Cooke, 2001, p. 949), particularly in business and management fields, due to its focus on technical change and innovation in different social, economic, and institutional contexts (Doloreux & Porto Gomez, 2017, p. 383). These studies often examine how organizations contribute to knowledge production, interact with one another, and foster R&D and technological innovation (Doloreux & Porto Gomez, 2017, p. 384). RIS research has historically been exploratory, with single case studies being common. Regions of interest are typically located in industrialized countries; however, research studies being conducted in less developed regions are increasing (Doloreux & Porto Gomez, 2017). Data collection in RIS research predominantly relies on observational studies and case studies. While modelling and other quantitative approaches have become more prevalent, qualitative approaches, such as interviews that provide in-depth insights into regional dynamics, remain a primary method (Doloreux & Porto Gomez, 2017, pp. 383-384).

3.2 Case Study Research and Application to Industrial Clusters

In keeping with the RIS research trends above, this project uses case study research as a method of inquiry to investigate a single case and understand the different relationships, mechanisms, and conditions that inform it (Lathlean & Denicolo, 2022). In general, case study research is useful as it defines a set time and place to investigate activities occurring locally, a characteristic that corresponds with the contextual and temporal nature of the cluster research conducted (Cleland et al., 2021). Following Dumez (2015), it engages the core questions researchers must consider when undertaking case study research and asks, "What is my case a case of? What is the stuff my case is made of?" (p. 43).

Case study research is useful in industrial cluster research for its flexibility in handling multiple data types across diverse contexts (Lathlean & Denicolo, 2022). Recent studies demonstrate this adaptability in focus areas that overlap with this project case, including studies highlighting the applicability of cluster models in smaller European countries (Palčič, 2022); and using data from a small number of companies to understand optimal strategies of collaboration (August & Walde, 2021). Additional case studies demonstrate the effect clustering can have on growth (Kwasny et al., 2019) while highlighting the role of government policy (He, 2019). Given this flexibility, case study research is applied in this research project as a powerful inquiry method for analyzing an industrial cluster (Lathlean & Denicolo, 2022).

3.2.1 Project Case: The NCE Heidner Biocluster

The NCE Heidner Biocluster, based in Hamar, Norway, is the country's only national cluster focused on sustainable food production and the green bioeconomy. Headquartered in the agricultural region of Inland, approximately 100 km (about 62.14 mi) north of Oslo, it includes over 50 members, ranging from micro-sized organizations to large corporations, as well as national university colleges and research institutions – collectively, employing more than 15,000 people and generating over NOK 66 billion in turnover (NCE Heidner Biocluster, 2020).

As discussed in chapter 2, the Norwegian Innovation Clusters (NIC) program implements its national policy strategy at four levels. Initially funded at the Arena level in 2012, the Heidner Biocluster was awarded Norwegian Centre of Excellence (NCE) status in 2018, marking its transition from regional to national significance in fostering innovation. With its NCE status, the Heidner Biocluster engaged in the broader work of targeting, improving, and accelerating ongoing development processes in Norwegian clusters. Its origins lie in informal collaborations among animal breeding organizations in Hamar in the 1960s, which gradually expanded to include plant breeding and aquaculture organizations (Cluster Management, personal communication, June 8th, 2023). Since then, the cluster has grown to include most of Norway's large food producers and local startups connected to the bioeconomy (NCE Heidner Biocluster, 2020).

The precursor cluster, BioInn, founded in the late 1990s, was the first attempt at formal clustering intended to promote networking among local bio-based organizations. BioInn was instrumental in the establishment of the Biohus in 2005, a Hamar-based center for R&D, that includes college laboratories, a business incubator called Klosser, and the Heidner offices (BioInn, 2016). Today, the Heidner Biocluster organizes its members into three core areas of the green bioeconomy:

- Genetics and biotechnology related to animal and plant breeding
- Sustainable feedstock ingredients like protein, fat
- Biorefinery utilization of production side-streams and recycling (NCE Heidner Biocluster, 2020).

The cluster's six-person team, with expertise in biosciences and business development, connects member firms through specialized programs and networking events designed to foster collaboration, competitiveness, and commercialization. As explained by the cluster management:

> the whole goal of the cluster program, the arena cluster program, was to develop regional clusters and stimulate them for more collaboration. So, it was a lot of focus on building trust and building relations, getting people to talk, get

> the university college to be more involved with the companies and vice versa (Cluster Management, personal communication, June 8th, 2023).

3.3 A Critical Realist Approach to Case Study Research

Critical Realism provides researchers with a distinct worldview from which to conduct their research. Blundel (2007, p. 4) uses Bhaskar's (1975) description of (ontological) reality to illustrate the critical realist view that there are three interrelated domains that make up reality: (1) the empirical domain that represents the world of human experience, which is different from (2) the actual domain in which events occur, regardless of whether (3) people have observed these events i.e., the domain of the real. Blundel suggests that one of the main concerns of science should then be:

> to probe beneath the 'empirical' and 'actual' domains in pursuit of generative mechanisms that occupy ontologically distinct strata (Blundel, 2007, p. 4).

In this research project, such a critical realist theoretical standpoint provides the foundation for conducting case study research, particularly for examining interorganizational relationships within clusters. Easton (2010) argues that critical realism is well-suited to case study research because it facilitates an understanding of complex systemic structures, particularly organizational relationships, in the inquiry. In a critical realist framework, entities like organizations or businesses are understood as real-world actors that can act and be acted upon by others. These organizations have internal structures (like departments) and external relationships (like collaborations) with other organizations, such as in clusters (p. 128), making critical realism a valuable lens for analyzing the intricate networks in which these organizations operate. This perspective is aligned with Systems Thinking (Chapter 2), by allowing for an examination of the interactions between organizations and their broader environments. Critical realism helps to conceptualize these interorganizational relationships within somewhat defined yet complex boundaries, capturing the so-called "nets" of connected organizations (Easton, 2010, p. 121).

QCA as a Methodological Tool

Critical Realism further provides an effective foundation for specifically QCA research through retroduction as a logic of inquiry (for more on how retroduction is applied as an inference tool in qualitative interviews, see paper 4, Appendix 4). Critical Realism employs retroduction as an inference tool which is about explaining events that happen in the social world by trying to determine the structures and mechanisms that can produce them (Blundel, 2007, p. 6). Put simply, in retroduction, data is used to come up with new concepts and ways to understand events. In case study research on clustered firms (like SMEs), the process of retroduction can be achieved as the researchers and research process constantly moves back and forth between the level of abstraction and theorization on the one hand, and the more concrete business of the case material on the other. It is in this interactive process that researchers can come to a type of scientific generalization by isolating the fundamental structures whose powers continue to exist (Blundel, 2007, pp. 6-7). Critical Realism thus gives researchers in regional development studies and cognate fields the concepts and tools to structure their research alongside the ability to modestly generalize their findings retroductively (for more on modest generalizability in QCA, see 4.3.1) (Zachariadis et al., 2013).

In addition to this project, several studies have explored the foundational connection between critical realist logics and QCA. Per illustration, Iannacci et al. (2022) investigated generative causality using QCA as a counterfactual lens combining Critical Realism and retroduction to explore how Critical Realism can be effective in case study research. Rutten (2021) explicated how QCA practice connects to the three domains of reality (the real, the actual, and the empirical) of Critical Realism, providing QCA researchers a better understanding of how to consistently practice the method’s interpretative approach. Finally, in their study of QCA and social complexity, Gerrits and Verweij (2013) described how Critical Realism can be used as a framework to illustrate that QCA is itself an effective method for doing complexity research.

The reasoning process of critical realist retroduction also aligns closely with the use of QCA in this project, specifically in exploring the underlying conditions (mechanisms and structures) within the NCE Heidner Biocluster that could explain observable outcomes like collaborative dynamics. This is because Critical Realism strives to find understanding in social reality that goes beyond deduction and induction. Instead, using the logic of retroduction, it "makes possible a research process that is characterized by the linking of evidence (induction) and social theory (deduction) in a continually evolving, dynamic process" (Sæther, 1998, p. 245) to understand the casual mechanisms behind the social reality (Vincent & O'Mahoney, 2016). QCA complements this approach by identifying conditions and combinations of conditions that lead to outcomes across the cases under investigation here, which, from a critical realist perspective, reflects an effort to uncover the underlying structures that could explain such patterns. Rather than simply describing correlations, QCA thus enables this project to explore how particular contextual and structural conditions interact to produce the specific outcomes observed.

Qualitative Interviews as Methodological Tool

From a critical realist perspective, qualitative interviews serve as a valuable method for uncovering the underlying structures and mechanisms within social systems, based on the belief that subjective accounts can reveal aspects of an objective reality within which social relations persist. Critical realism suggests that social actions occur within pre-existing social structures and relations that both enable and constrain behavior. Following from this understanding, interviews are used to capture participants' interpretations and experience, not as isolated narratives, but as insights into broader social contexts (Smith & Elger, 2014, p. 112).

In this research project, interviews with SME managers and owners offer accounts of their experiences of collaboration with HEIs. Analyzing these accounts enabled the identification of patterns and mechanisms that explain observable phenomena in a way that transcends these individual perspectives. As Pawson (1996) explains:

> People are always knowledgeable about the reasons for their conduct but in a way which can never carry total awareness of the entire set of structural conditions which prompt an action, nor the full set of consequences of that action […] In attempting to construct explanations for the patterning of social activity, the researcher is thus trying to develop an understanding which includes hypotheses about their subjects' reasons within a wider model of their causes and consequences (Pawson, 1996, p. 302 in Smith & Elger, 2014, p. 117).

Following this perspective, researchers may formulate these accounts as the mechanisms, contexts, and outcomes implemented in an effort to implement specific policies (Smith & Elger, 2014, p. 121).

While critical realism values qualitative interviews for gaining insight into subjective experience much in the same way as perspectivist approaches, it differs from more relative approaches such as constructivism which often make quite narrow claims about the status of the resulting accounts of experiences, emphasizing that interview data can only generate local narratives without broader reference to an external reality (Smith & Elger, 2014, p. 119). In contrast, the critical realist interviewing conducted here sought to interpret subjective accounts by going beyond valuing individual perspectives to uncover patterns that point to systemic dynamics. By interpreting subjective data within the context of an assumed objective reality, this approach supported the identification of mechanisms shaping observable phenomena in SME-HEI interactions, contributing to a more comprehensive understanding of these collaborations.

Towards Methodological Pluralism

Critical Realism would suggest that a business owners' account of their experience with collaborations only provides a starting point for further explanations (Blundel, 2007, p. 4). While the ability to give a distinct worldview is important to regional development research, it is generally understood that investigations that only consider this single level – the sole account of the business owners themselves – are likely to prove unsatisfactory in the pursuit of generative mechanisms. As such, any explanations or attempted generalizations based on single-level efforts to isolate the characteristics of successful firms will ultimately be inadequate (p. 5). For critical realists, it is the task of the researcher to go deeper and break through this superficial level. With this perspective in mind, this research project goes beyond single-level analysis to include empirical qualitative interviews (Paper 4) as a supplement to QCA (Paper 3) to, in the words of Blundel quoted above, identify the underlying generative mechanisms that exist within ontologically separate layers (Blundel, 2007, p. 4).

3.4 Methodological Tools: QCA and Qualitative Interviews

The two main methodological tools used to examine the present case were Qualitative Comparative Analysis (QCA) and qualitative interviews and are presented below.

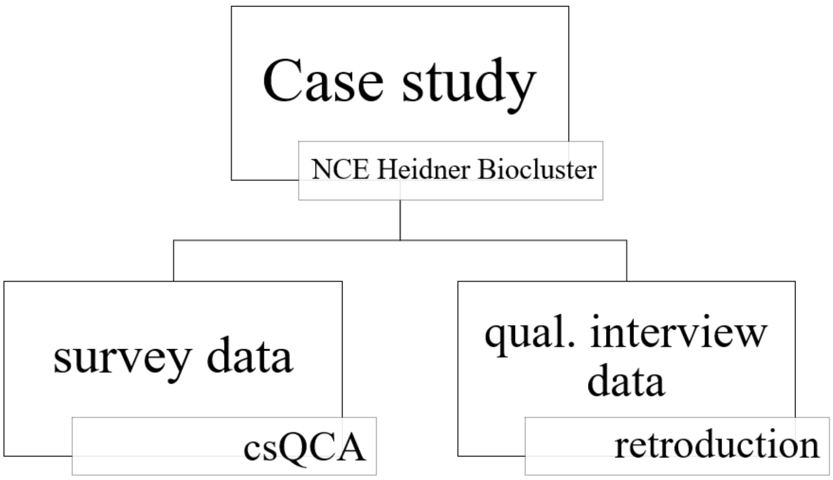

Figure 5: Methodological Approach and Tools

3.4.1 QCA

A demonstrated method for comparative case study research, Qualitative Comparative Analysis (QCA) was used to analyze survey responses from the NCE Heidner Biocluster members. QCA is a methodological tool for analyzing patterns in case-oriented qualitative data, allowing for the systematic comparison of cases to identify how different conditions interact to produce specific outcomes in complex, real-world situations (Rihoux & Marx, 2013; Schensul et al., 2010). QCA was the preferred methodological choice for this research project due to its suitability for analyzing small sample sizes, which is typical in case study research. Unlike quantitative methods that require large datasets to be statistically significant, QCA provides flexibility in case selection, making it possible to conduct meaningful comparative analysis with a limited number of cases (Ragin, 1987; Wagemann et al., 2016). Consequently, this adaptability allows for a deeper understanding of complex patterns within the smaller, targeted sample used in this case study research.

A key aspect of conducting such meaningful comparative analysis in this empirical project is to move beyond mere description and pursue an understanding through identifying explicit or specific connections in the data – ultimately aiming for what Berg-Schlosser et al. (2009) refer to as modest generalization. Berg-Schlosser et al. (2009) argue that identifying these connections provides a formal structure to observed patterns in the data and allows further investigation to develop an "explanation" that aims to describe the underlying mechanisms at play. Without this goal of generalization in the search for explanations, research findings would simply produce repetitive statements and descriptions. It is, however, important to mention that QCA does not seek the wide generalizability of statistical methods. Rather, modest generalizations support limited historical generalization where findings can, with appropriate caution, be extended to similar cases that share key characteristics and contexts. This form of generalization allows for more succinct explanations, avoiding individualized, case-by-case descriptions and contributing to a more structured understanding of the current case (Berg-Schlosser et al., 2009, p. 11-12).

In terms of type of QCA, I decided to use crisp-set QCA (csQCA). Although fuzzy-set QCA (fsQCA) is preferred for capturing greater data variance, careful consideration of my dataset and the calibration of its indicators led me to use csQCA over fsQCA as the former is better suited to the dichotomous and discrete variables that characterize my dataset (Yan et al., 2021). In this regard, I followed Rihoux and De Meur (2009) in calibrating my conditions, conscientiously providing a transparent rationale for thresholds based on substantive and theoretical considerations and using the median to distinguish between the presence and absence of the five target conditions. The risk one runs with using csQCA instead of fsQCA is that the cutoff chosen may lead to oversimplification, thus dividing similar cases arbitrarily. Neither of these events occurred with my results, as the data provided clear distinctions between high-scoring and low-scoring cases, either naturally through dichotomous variables or through critically determining the correct threshold for discrete and categorical variables. Table 3 in Paper 4 immediately illustrates that the use of fsQCA might even have been detrimental by complicating the clear structural differentiation between two groups of firms.

In addition to failing to capture variance, csQCA is, at times, considered potentially harmful as it could lead to contradictory configurations (Marx & Dusa, 2011). In my empirical analysis, this was avoided by rigorously dichotomizing the conditions "so that their presence [...] is theoretically expected to be associated with a positive outcome [...]" (Rihoux & De Meur, 2009, p.42). The rigor of my methodological strategy and, more specifically, calibration, is underscored by the successful publication of this QCA in *Regional Studies, Regional Science* following extensive participatory peer review.

A detailed description of this research project's application of QCA, particularly csQCA, can be found in section three, *Method, Data, and Analysis*, of Paper 3. In the following, QCA is discussed as it relates to the research project's larger impetus. First, the stages of the QCA approach are presented in the research design; and second, some limitations are discussed.

Research Design: QCA

The following outlines how QCA was applied based on the stages described by Setzke et al. (2020).

Stage 1 – Research Question

In the first stage, the researcher determines the theoretical framework and determines if the study will be exploratory or theory-testing, leading to the development of a research question. Grounded in theories of absorptive capacity, social ties, embeddedness, and trust (for more on absorptive capacity, see Paper 3 in the Appendix), this research project used an exploratory approach to examine whether the NCE Heidner Biocluster's implementation of an indirect policy measure positively impacted the number and strength of collaborations between cluster SMEs and HEIs (Chrisman, 2024). The research question was shaped by investigating the role of "softer" institutional elements (e.g., trust and embeddedness in the local context) and typical innovation indicators (human capital, degree of innovativeness, see paper 3) and how they impact collaborative networks.

Stage 2 - Research Model Design

In the second stage, the conditions and the outcomes of the research are determined and a hypothesis created, resulting in a research model. Unlike traditional methods, QCA allows flexibility in selecting multiple conditions that may lead to an outcome. The number of cases will determine how many conditions can be used. However, the cases used may not always lead to a clear outcome. In this research project, three hypotheses were formulated around the research model with 5 conditions selected from 11 cases to assess higher collaboration outcomes for the second period under investigation.

Stage 3 – Sampling of Cases

In the third stage, the cases are collected using approaches like meta-analysis of case studies (secondary data) or surveys (primary data), producing quantitative data. This research project adapted a survey method from Calignano et al. (2018) to analyze collaborations within the NCE Heidner Biocluster that was originally designed for analyzing firm collaborations in a regional aerospace network peripherally located in southern Italy. The two-part retrospective survey collected data from an earlier period and compared it to a more recent period, enabling before-and-after analysis of collaboration patterns. The first part of the survey collected information on the SME's background, economic performance, and intellectual property. Part two focused on collaborations with other organizations in the cluster; using a roster recall method (Calignano et al., 2018) – providing respondents with a list of names to aid memory recall – to help respondents identify specific collaborative partners and evaluate the strength and intensity of those connections, using specific knowledge channels such as research contracts, research projects and informal contracts.

Stage 4 – Data Collection

Data collection took place between September 2022 and August 2023. Cluster members were first informed of the upcoming survey via a short article in the NCE Heidner Biocluster newsletter, followed by individual email invitations informing members about the research and inviting them to complete the survey online. The survey respondents, mainly SME managers or owners, completed the comprehensive survey that averaged over 30 minutes.

Stage 5 – Data Analysis

At this stage, the collected survey data related to conditions and outcomes for the NCE Heidner Biocluster was calibrated and converted into binary values (0 or 1) using csQCA, using the calculated median as the threshold. This calibration enabled quantitative data from the survey to be systematically analyzed.

A truth table was created, where each case corresponded to a row, and frequency and consistency were used to reduce the table. Frequency indicated the number cases assigned to a row, and consistency measuring the degree to which the cases support that row empirically. Setting thresholds for both frequency and consistency metrics allowed for identifying the conditions consistently leading to certain outcomes (i.e., increased collaborations within the cluster). To evaluate the robustness of the table results, consistency and coverage metrics were applied following Setzke et al. (2020). For example, consistency, i.e., how consistently a combination of conditions leads to outcomes across all cases, was taken as a measure to test the strength of identified relationships. While consistency thresholds vary, the literature indicates that they should at least be above 0.75, ideally above 0.8 which is considered high in many applications of QCA (Mello, 2021; Setzke et al., 2020). This analysis achieved a consistency threshold of 1.0, indicating a strong alignment between the combination of conditions and the outcome of increased collaboration.

Stage 6 – Presentation of Results

In the final step, QCA results are reported and discussed in a narrative format. As can be seen in Paper 3 (see Appendix 3), after the coverage and consistency levels were verified, results were presented with a focus on two key tables: one demonstrated the combination of conditions most likely to lead to the outcome of higher collaborations (Table 1, Appendix 3) and another showed the conditions that may lead to the biggest difference in outcomes between the two periods (Table 2, Appendix 3). The tables were accompanied by a descriptive-interpretative narration explaining how specific configurations contributed to collaborative outcomes. One of the most important features of QCA, compared to other methods, is that QCA allows you to identify the single conditions that are necessary or the combinations of conditions (configurations) that are sufficient to achieve a certain outcome (Calignano & Winsents, 2023).

Limitations

As with other QCA research, this QCA approach had to exercise caution to reduce bias in case selection and data interpretation, particularly when converting qualitative survey responses into binary quantitative data using csQCA (Hanckel et al., 2021; Pagliarin et al., 2022). To mitigate potential bias in this process, the median was chosen as a threshold for binary coding because it is less sensitive to outliers (this is done by identifying the central tendency (median) in a dataset) and more reliable for small sample sizes, which was particularly relevant to the current study's dataset (see Calignano & Nordli, 2024 for more on the median approach).

With the small sample size in this research project, there were constraints on the number of conditions that could be analyzed, which could limit data diversity and could affect the complexity of patterns identified (Hanckel et al., 2021). However, it should be emphasized that this represents a minor problem, since QCA experts suggest that it is important to use as few conditions as possible even with many cases. In fact, an adequate but relatively low number of conditions greatly improves the interpretability of QCA (Glaesser, 2024).

3.4.2 Qualitative Interviews

This project used qualitative, semi-structured interviews with key representatives from SMEs in the NCE Heidner Biocluster. This approach allowed for an in-depth exploration of perspectives on collaboration, focusing on open-ended questions to uncover underlying outcomes of these partnerships. This flexible format enabled follow-up questions, allowing participants to elaborate on and add further clarity to specific points (Naz et al., 2022). In case study research, qualitative interviews are considered a key tool for understanding the underlying reasons behind observed outcomes as, according to Naz et al. (2022), qualitative interviews enable researchers "to explain, understand, and explore research subjects' opinions, behavior, and experiences" (p. 42). Like Warren and Bell's (2022) work on service innovation processes in small firms, this research project uses qualitative interviews to complement the results of the QCA, providing a detailed perspective on the mechanisms influencing cluster policy and knowledge exchange dynamics. Application of the research project's use of qualitative interviews can be found in section 3, *Methodology*, of Paper 4. In the subsequent section, an overview of the research design of the qualitative interviews is presented.

Research Design: Qualitative Interviews

The process of conducting qualitative interviews followed seven steps, adapted from Adeoye-Olatunde and Olenik (2021) to suit the specifics of this research project.

Step 1 - Assess Appropriateness

Qualitative interviews were deemed appropriate for addressing more complex research questions aimed at better understanding how a service is currently performing or can be improved from the perspective of different users. Given the research project's objective of understanding the performance drivers behind SME and HEI collaborations, in-depth semi-structured interviews were chosen to capture detailed insights that would have been more difficult to source through surveys or other methods.

Step 2 - Sampling and Recruitment

Purposive sampling was used and targeted SMEs within the NCE Heidner Biocluster based on specific criteria: appropriately SME-sized with less than 250 members, involvement in the bioeconomy sector, and a history of collaborations with local HEIs. Through size, age, and industry these SMEs represented an average cluster member.

Participants – managers or owners of the SMEs with the required knowledge of the subject area – were recruited through existing networks and the NCE Heidner Biocluster newsletter, with additional support from Norse Biotech AS, the Klosser business incubator, and Norse Biotech AS co-founder, Dr. Werner Christie, who was instrumental in using his local innovation network to help establish relationships, recruit participants, and conduct the interviews. Appropriate lines of communication with managers and owners were established by phone or email, introducing the topic and establishing a date and time to conduct interviews based on their availability.

Step 3 – Data Collection Design

To answer the research question, an interview guide was constructed based on Boschma's (2005) framework of proximity and innovation. In the first part, questions explored the SME's background and their relationship with the NCE Heidner Biocluster administration and members. The second part focused on both the barriers/enablers of different forms of proximity and the different innovation modes (STI vs DUI), to determine how these affect collaboration between SMEs and HEIs. The interview guide also included questions on local and international partnerships and collaborations.

Steps 4 – Conducting the Interviews, Transcription, and Data Storage

Data was collected in the summer and fall of 2023 through eight in-person interviews, each lasting approximately an hour. Interviews were conducted either at the SME's office or the Klosser business incubator in Hamar. Interviews were recorded and transcribed using the University of Oslo's Nettskjema-diktafon app and stored online on the secure Netskjema servers designed for sensitive data. Approval for the recording and storage of this data was obtained from both the Norwegian Agency for Shared

Services in Education and Research (https://sikt.no/en/home) and the interview participants.

Step 5 – Data Analysis

Interview transcripts were analyzed and coded using retroduction as an inference tool to explain events in the social world through determining the structures and mechanisms that can produce them (Blundel, 2007, p. 6). Trippl et al. (2015), Calignano and Quarta (2014), and Boschma's (2005) work on proximity and innovation was used to guide the coding process and focused on identifying patterns and configurations that differentiated two distinct categories. These cases were categorized using the Science, Technology, and Innovation (STI) and Doing, Using, and Interacting (DUI) modes.

Step 6 – Drawing Conclusions

Categorizations from the data analysis were synthesized into a table of two distinct categories (see Paper 4, table 1, in the Appendix). The interpretation of results was described and verified against existing literature, particularly Isaksen and Karlsen (2010), ensuring alignment with established research.

Step 7 – Reporting the Results

The results were written up as a journal paper (see Paper 4 in the Appendix) following general reporting guidelines used in the social sciences. Ethical considerations were included.

4

4. PUBLICATIONS

This chapter gives an overview of the four papers included in this research project. Starting, in order, with the first two conceptual papers focused on the challenges of transitioning to a circular bioeconomy and the potential benefits of integrating cluster technologies as a response. This is followed by two empirical papers, one on cluster administration policies and their impact on member collaboration and another on proximity and its implications on collaboration amongst cluster SMEs and HEIs. First, an overview of the four papers is presented in Table 1. This is followed by a descriptive summary of each paper that outlines their topic areas and main conclusions.

Title	Author(s)	Type	Context	Method	Topic	Publication
Transitioning to a Circular Bioeconomy: Key Drivers and the New Cluster Technologies to Accelerate Process Development in Biotechnology Sectors	John E. Chrisman Ray W. Chrisman	Conceptual	Circular bioeconomy challenges	Theoretical discussion	Discusses the implementation of organizational clusters to overcome the challenge of resource efficiency in bioeconomic development through geographical proximity and knowledge transfer.	Published in Chimica Oggi-Chemistry Today (2023)
New processing concepts and cluster technologies: Catalysts for a faster and more efficient transition to a circular bioeconomy and biobased carbon materials	John E. Chrisman Ray W. Chrisman Zekarias Fundusa	Conceptual	Challenge of industrial processing approaches in circular bioeconomic production	Theoretical discussion	Discusses cluster technologies and the inclusion of more stakeholders and comprehensive cluster governance to increase collaboration and knowledge exchange to facilitate the fast and effective transition to the circular bioeconomy	Published in Chimica Oggi-Chemistry Today (2023)
More frequent and stronger ties? Using QCA to assess the effects of policy in a Norwegian biotech cluster	John E. Chrisman	Empirical	Cluster policy analysis in the biotechnology sector	Qualitative comparative analysis based on survey data	Examines the impact of a cluster administration's indirect policy measures on enhancing collaborations between member SMEs	Published in Regional Studies, Regional Science (2024)
What drives collaboration between SMEs and academic institutions? Exploring barriers, enabling factors, and the role of proximities in the Norwegian biotechnology sector	John E. Chrisman Giuseppe Calignano	Empirical	Analysis of clusters and SME collaboration with HEIs in the biotechnology sector	Qualitative case study research based on semi-structured interviews	Examines how proximity drives collaboration between (SMEs) and higher education institutions (HEIs).	Submitted

Table 1: Outline of Research Papers

4.1 Paper 1 – Transitioning to a Circular Bioeconomy: Key Drivers and the New Cluster Technologies to Accelerate Process Development in Biotechnology Sectors

Authors – John E. Chrisman and Ray W. Chrisman

Publication Status – Published in Chimica Oggi-Chemistry Today

Description

This conceptual paper explores the interest of industry and governmental organizations in transitioning to a circular bioeconomy – an economy where materials stay in the system for a longer period, are reused, and waste is minimized (European Commission, 2015). The premise for this article, to delineate some key factors that have contributed to the push towards the transition to biobased materials to replace fossil carbon-based ones, was a presentation given by Norse Biotech AS at the annual Center for Process and Analytical Control (CPAC) conference in Rome, Italy in the spring of 2023.

The first half of the paper isolates five drivers pushing for a transition to a circular bioeconomy. The first driver entails the problem of finite resources and the growing demand for them. This growing demand for finite resources leads to the second specific driver of limited fossil carbon resources and the fact that, once it converts to carbon dioxide, it has a relatively slow rate to be recycled in the atmosphere. A third driver discussed is that carbon dioxide contributes to global warming as a greenhouse gas. The fourth is that in a traditional linear economy waste from producing products is not often reused. The final driver presented is the high cost of recycling materials which leads them to being disposed of instead of reused or recycled.

Main Conclusions

From these five drivers, two main conclusions are highlighted that relate to the implementation of a circular bioeconomy. First, new technologies and approaches will be needed to implement a shift to a circular bioeconomy. The paper discusses significant new technologies that will need to be developed to produce alternatives such as renewable carbon: the biotechnology vision and bioresource vision. The former suggests that organisms will need to be genetically modified to create new carbon-based products, and the latter suggests that existing biomass will need to be used to make products.

Second, to achieve a timely transition to the circular bioeconomy described, fast commercialization of these technologies is required. Here the paper introduces the importance of technologies like cluster technologies (the utilization of clusters as a key part of systemic solutions to technical challenges) to facilitate such a transition for their ability to improve resource efficiency through access to knowledge sharing and proximity. The potential benefits of cluster technologies in reducing both energy usage and access to starting materials left over from another process are demonstrated. By highlighting two characteristic elements, improved knowledge sharing and the benefits of geographical proximity, clusters emerge as accelerants that can address problem of slow commercialization of the new technologies needed in implementing the circular bioeconomy.

4.2 Paper 2 – New processing concepts and cluster technologies: Catalysts for a faster and more efficient transition to a circular bioeconomy and biobased carbon materials

Authors – John E. Chrisman, Ray W. Chrisman, Zekarias Y. Fundusa

Publication Status – Published in Chimica Oggi-Chemistry Today

Description

This paper outlines the transitional challenges of moving from products currently being produced with fossil fuels to developing biobased alternatives. It focuses specifically on the new processing concepts required to enable the transition to biobased products and its associated challenges. The key technological challenge posed by the molecular structural differences between fossil-based molecules and biobased molecules are presented, which leads to further barriers that hamper these innovations like that of long processing times.

Main Conclusions

New processing concepts and technologies to facilitate this transition in a faster and more effective way are discussed, such as the need for more real time data and the implementation of AI for speeding up catalyst development. However, purely technical solutions will not be sufficient to alleviate the problem of long processing times. Increases in productivity and efficiency should also be supported by the implementation of a systems-oriented cluster approach to facilitate better knowledge flows and co-learning in biotech industries to accelerate innovation. Particularly expanded models of planned innovation clusters that include more stakeholders beyond those accessible through geographic proximity are proposed. This can help facilitate increased collaboration and knowledge transfer among those in the bioeconomy trying to implement large, technical changes. Looking ahead, the addition of structural elements like cluster governance could, through its evaluation function, help to understand where cluster performance may be improved through targeted interventions.

4.3 Paper 3 - More frequent and stronger ties? Using QCA to assess the effects of policy in a Norwegian biotech cluster

Author – John E. Chrisman

Publication Status – Published in Regional Studies, Regional Science

Description

Paper three explores how the implementation of biotechnology clusters may allow peripheral regions to overcome their geographical marginality and 'lock-in' situation, by contributing to positive outcomes in terms of new industrial and development paths. The empirical study examines SMEs in a local biocluster in the Inland region of Norway and attempts to understand the role played by cluster administration in improving the collaboration between co-located SMEs and HEIs. Through a dynamic approach employing two distinct time periods, it explicates how indirect cluster management policies can be used as a tool for stimulating regional collaborative innovation.

Method and Data

Using QCA, the paper investigates the structural factors (year of foundation, size, etc.) that allow some SMEs to interact with HEIs. The paper collected data from 11 NCE Heidner bio-cluster member SMEs through a two-part survey. The first part focused on organization/institutional background, economic performance, intellectual property; part two on the organization's collaborations with other regional organizations. QCA was used to determine the patterns between the characteristics of the SMEs belonging to the cluster and their level of collaboration with HEIs in the second targeted period (2018-2021).

Main Conclusions

As cluster policy can be fragmented, there is a need for new and improved frameworks to help with its evaluation. This paper suggests that adopting QCA to examine relatively small clusters (<100 members) can contribute to a better understanding of the mechanisms of cluster policies and their evaluation such as the collaborations formed between SMEs and HEIs outlined in this paper. The paper demonstrates that elements such as age, size, and trust towards the cluster administration can overcome a lack of innovativeness and the elements of human capital and may lead to more frequent and intense ties. Using QCA to understand indirect policy measures and their impact on cluster collaboration thus constitutes a novel approach that contributes to the creation of toolkits for policymakers and researchers.

4.4 Paper 4 – What Drives Collaboration Between SMEs and Academic Institutions? Exploring Barriers, Enabling Factors, and the Role of Proximities in the Norwegian Biotechnology Sector

Author – John E. Chrisman and Giuseppe Calignano

Publication Status – Submitted

Description

This paper explores university-industry (U-I) linkages between SMEs and higher education institutions (HEIs) within the Inland bioeconomic region to understand what drives collaboration, i.e., knowledge exchange dynamics between these entities. It focuses on SMEs in the biotechnology sector in a peripheral region where the roles and types of universities can have greater potential impacts beyond knowledge transfer and business development.

Method and Data

Through qualitative interviews, this paper evaluates Boschma's (2005) concepts of proximity as it applies to HEIs and SMEs in peripheral regions with retroductive content analysis to test these concepts.

Eight qualitative interviews were conducted with CEOs and managers focusing on the barriers and enablers, intensity, and frequency of collaboration with HEIs during different product life stages and the role of the cluster administration in managing these linkages. The respondents were based in or near Hamar, Norway were chosen based on several factors including age and size and represented the average cluster member of the NCE Heidner Biocluster.

Main Conclusions

The main findings indicate that even though they operate in the same biotechnology industry, SMEs show differences in the intensity of their collaborations with HEIs. Geographic proximity is also not shown to be an important factor in university and industry linkages to certain members. Type of SME is, however, significant. Larger and older biotechnology-based SMEs may collaborate with HEIs more often and have a higher degree of satisfaction than the smaller, younger, and more internationally focused SMEs. The findings also indicate that firms in the same sector are different, and depending on the sub-sector, even biotechnology firms may employ both DUI and STI innovation modes. These findings suggest that over and above geographic proximity, other forms of proximity and the role of informal institutions may be relevant to U-I exchanges.

5

5. DISCUSSION, CONTRIBUTION, AND IMPLICATIONS

Across four research papers, this Industrial PhD project has endeavored to understand what tools and approaches are needed for SMEs based in the Inland region of Norway to succeed in the transition to a more innovative and greener bioeconomy, highlighting the role of cluster administration and governance in fostering the collaborative ecosystems needed for this transition. In the first two papers, the challenges faced by regional SMEs in the transition to this bioeconomy are outlined, and industrial perspectives on cluster research are explored as a potentially viable area for addressing them. In the final two papers, novel (QCA) and well established (semi-structured interviews) approaches to developing the knowledge to evaluate industrial clusters are explored, in an effort to optimize toolkits for researchers and policymakers to better facilitate these SME transitions. This chapter briefly synthesizes and discusses the knowledge about clusters developed across these four studies in response to the overarching questions posed in chapter 1. This is followed by a presentation of the contribution of this research project.

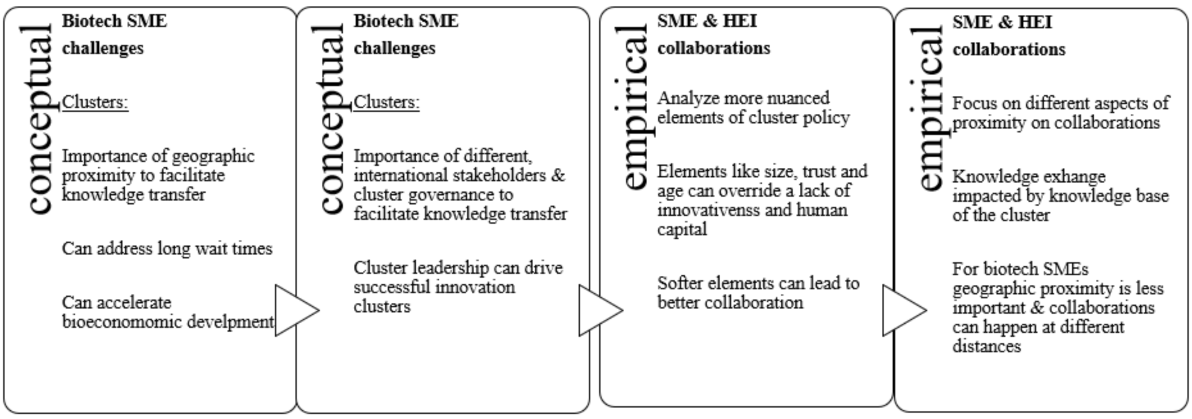

Figure 6: Leveraging Cluster Governance to Evaluate the Impact of Policy Measures

5.1 Cluster Technologies: Conceptual Development in the Biotechnology Sector

To address the first research question on understanding how cluster technologies and policies facilitate process development and commercialization in the biotechnology sector towards achieving the transition to a circular bioeconomy, the presentation of clusters in the first paper introduces and defines the concept with a focus on two of its central features: the proximity of firms (in the traditional geographical sense) and the knowledge spillovers that clustered firms often benefit from. Looking at the problem of resource efficiency, it highlights how cluster technologies may be useful in addressing long wait times for process development and commercialization that may hinder bioeconomic development. The paper reflects on the role that clusters can play in alleviating difficulties like those faced by biotechnology SMEs, given the way that nearby firms promote knowledge transfer and resource sharing among their members to help them more quickly develop systems – acting as potential accelerants to bioeconomic development by increasing resource productivity (Chrisman & Chrisman, 2023).

This is followed by Paper 2, that further develops the cluster literature focusing on the inclusion of more stakeholders and comprehensive cluster governance to expand traditional understandings of collaboration and knowledge transfer addressing the second research question of how enhanced knowledge flows and effective governance can accelerate a key innovation process in biotechnology clusters shifting towards biobased alternatives (Chrisman et al., 2023). It brings clusters into conversation with systems thinking to move beyond the traditional understanding of clusters as only operating through geographic proximity at the local level (as discussed in Paper 1) to considering the establishment of knowledge networks and exchanges as an asset of the global economy. Given this expanded scale, Paper 2 concludes by considering the role of cluster leadership i.e., the planning, management, and governance of clusters and its potential role in driving regional transitions. It highlights the level of cluster governance as a potential model from which to investigate effective cluster planning and management by evaluating the relationships between stakeholders related to different values, for example, the outcomes of cluster management strategies (Chrisman et al., 2023).

The conceptual examination of industrial clusters' potential role in addressing challenges faced in the biotechnology sector, as explored in the critical reflections on clusters presented in Papers 1 and 2, progress from a narrower, geographic understanding of cluster policy to a more expansive view of its role in bioeconomic path development. This examination concludes that the model of cluster governance can be leveraged to evaluate the impact of policy measures implemented by regional bioclusters and to understand how they encourage collaboration between clusters and various stakeholders. These conceptual discussions provide the premise for examining cluster policy as an evaluation tool of cluster management in the empirical part of this research project (Papers 3 & 4) that is discussed next.

5.2 Analysis of Clusters: Empirical Examination of an Industrial Case

Papers 3 and 4 empirically examine the role of clusters and their policies within the NCE Heidner Biocluster to understand how cluster management facilitates enhanced collaborations between SMEs and HEIs from different analytical perspectives.

Paper 3 examines the third research question to understand how the implementation of an indirect policy measure by the NCE Heidner Biocluster affected collaboration between member SMEs and HEIs. It takes up the analysis of clusters to address the tension between the demonstrated importance of cluster management to promote knowledge exchange, and the fact that cluster evaluation has proven to be challenging and fragmented due to factors including the variety of sectors, cultures, traditions, and the challenge in quantifying "softer" elements such as trust and knowledge spillovers. Through a novel use of csQCA, the paper presents new ways to analyze the more nuanced elements of cluster policy. With this approach, the analysis reveals that "softer" elements like size, trust, and age can work to override a lack of innovativeness and human capital and lead to potential higher collaboration.

Following from this empirical understanding of the possible conditions that can facilitate collaborations for knowledge exchange, Paper 4 set out to explore how factors of proximity may affect those collaborations with regards to university-industry linkages. In answering the fourth research question, it specifically interrogated how knowledge exchange occurs through different channels and how the geography of these interactions is influenced by the knowledge base of the industry. For biotechnology firms relying on an analytical knowledge base (see chapter 2, section 2.4.1 for more on the different knowledge bases), the fact that proximity was less critical for these organizations was a key concept of Paper 4, allowing an exploration of SME and HEI collaborations at different distances – regional, national, and international. This was important because biotechnology firms, even if their core business is locally based, often collaborate with academic institutions abroad. In this research project this was demonstrated by SMEs in breeding, acquiring their specialized knowledge from HEIs in the U.K. and the United States, knowledge that could not be sourced locally. This approach to the analysis of clusters showed SMEs and HEIs collaborating at different distances and through alternative dimensions of proximity not solely connected to geography. The findings also indicated that even SMEs in the same sector are different, as biotechnology firms, depending on the subsector, may employ both STI and DUI innovation modes. Even if cluster members operate in the same sector, their age and size may impact the ways in which they collaborate and with whom. It demonstrates that the type of firms (older, larger) consider participation in cluster events as one important part of higher social and institutional engagement, which may lead to more and stronger collaborations with HEIs. The paper also suggests that other types of firms (younger, smaller) may benefit from different approaches from cluster administration to encourage HEI collaboration, such as creating more focused networking opportunities.

5.3 Clusters as Mechanisms of Knowledge Diffusion: The Critical Role of Place-based Leaders in a Peripheral RIS

This project has aimed to understand how the innovation system (the developing Inland RIS) and its individual actors (e.g., SMEs and HEIs) are coordinated (through cluster administration, governance, and policy) during the process of regional bioeconomic path development (regional diversification towards a green circular economy). This coordination takes places through knowledge diffusion in the RIS (see section 2.3), with cluster policy understood as the knowledge management mechanism that organizes and facilitates the flow of knowledge within and beyond clusters in the

RIS (see section 2.3.1). Within the NCE Heidner Biocluster, the multi-scaler mechanisms of knowledge diffusion utilized by the administration to facilitate better knowledge flows and co-learning in biotech industries exemplifies Giest's (2021) understanding of the role of clusters in organizing and managing knowledge flows through structured management and absorptive capacity-building (see section 2.3.1).

Through structured cluster management, the NCE Heidner Biocluster administration facilitates knowledge exchange through several collaborative capacity-building activities. First, the administration has been instrumental in defining a shared vision, working as a coordinator to connect members from different sectors and aligning them with regional, national and international policies for green transitions (*Innlandsporteføljen*, 2023). This has fostered a collective focus on addressing common challenges in a sector like biotechnology, where technical problems often have high costs and long development times. Second, the cluster administration developed formal structures for regular communication and collaboration through workshops, events, and webinars. These platforms have not only allowed stakeholders to present challenges and propose solutions (i.e., gain access to each other's expertise), but also to build trust for future collaborations. Third, the cluster administration has created multi-scalar collaborations by actively working to provide funding support, connecting members to international HEIs and other partners to join or create new project proposals.

Moreover, through absorptive capacity-building activities, the NCE Heidner Biocluster administration facilitates the continuous development of cross-sector knowledge systems to increase knowledge spillovers (Giest, 2021). For example, long-standing collaborations between cluster SMEs and HEIs (INN) are reported by members, particularly during the knowledge building and testing stages of product development. Members also note significant improvements in the quality of work provided by the HEI over the last decade, highlighting the cluster administration's role in fostering enduring collaborations that promote knowledge exchange from diverse industries.

Linked to performance, the cluster administration's success in fostering new collaborations is thus reflected in its measurable outcomes, such as recorded new projects and partnerships, which are reported to Innovation Norway and the Norwegian Research Council. These demonstrated increases in collaborations have earned the cluster numerous national and international leadership awards, reinforcing its role as a knowledge management mechanism and the importance of cluster policy to support such organizational drivers of innovation.

The success of the NCE Heidenr Biocluster administration as a mechanism for knowledge diffusion can be attributed to its role as an effective place-based leader within a peripheral RIS. Located in a region where access to centralized resources is scarce, the cluster administration addresses developmental challenges by leveraging their in-depth understanding of Inland's "place-specific" conditions and opportunities (Grillitsch & Asheim, 2018). By promoting the region's strengths in sustainable food production, forestry, and agriculture, the administration fosters knowledge-sharing collaboration networks that drive localized industrial diversification.

As effective place-based leaders, the cluster administration implements national cluster policy informed by a deep understanding of the local and regional history, issues, concerns and communication styles, as well as the embeddedness of its members in the RIS. Cluster administration members are involved in regional debates, bringing their knowledge as farm owners and scientists themselves to engage in local issues, further solidifying their role as a bridge between regional strengths and broader innovation goals, all the while enabling the region to promote its unique knowledge, products, and services on an international stage (personal communication with cluster management, 3 May 2024).

5.4 Contributions and Policy Implications

The primary contribution of this research project is a better understanding of how clusters in a peripheral RIS participate in knowledge exchange through their members – particularly with higher education institutions – and the effects that both indirect policy implementation by cluster administration and proximity have on that exchange.

A Unique Empirical Perspective

Through the synthesis of its four papers, this research project contributes knowledge from the unique perspective of a peripheral region. Placing a peripherally located biotechnology SME (Norse Biotech AS) center stage, this research provides a distinct perspective on the challenges that organizations in the biotechnology sector face that are attempting to participate in the transition to a circular bioeconomy through the production of biobased products. Understanding how cluster administration acts as a place-based leader to help overcome marginality contributes to research on peripheral regions (Calignano & Nilsen, 2024; Grillitsch & Sotarauta, 2020; Hauge et al., 2023).

The Centrality of "Softer" Elements

Examining the impact of indirect policy measures on the collaborations between SMEs and HEIs over two time periods, this research highlights what combinations of conditions may lead peripheral SMEs to benefit from these policy measures. It contributes several novel findings showing how "softer" structural elements such as age, size, and trust can make up for the lack of human capital present at SMEs when it comes to increasing the number and intensity of collaborations. This is a potentially valuable contribution for firms in peripheral biotechnology sectors in their understanding of how to improve collaborations, especially in contrast to harder structural elements such as innovativeness and human capital (Calignano & Jørgensen Nordli, 2024).

A New Methodological Approach

The use of csQCA for evaluating the collaboration between HEIs and SMEs signals a new methodological approach for smaller case studies. Using csQCA to examine indirect policy measures in small clusters in peripheral regions is a novel approach in the field of regional studies with potential implications for studying cluster evaluation in the future (Bennat, 2022; Duodu et al., 2023; Rauf & Weber, 2021).

A Better Understanding of Proximity in Cluster Theory

Through findings from interviews with SMEs in the NCE Heidner Biocluster, the research project contributes novel findings regarding the nature and role of proximity in university-industry (U-I) linkages. Demonstrating that larger, older SMEs collaborate more frequently and with higher satisfaction with local HEIs than the smaller, newer SMEs that are more internationally focused, the project contributes new knowledge on the importance of other forms of proximity (e.g., cognitive, organizational) in addition to or as an alternative to traditional conceptions of geographic proximity. Applying new forms of proximity, the research extends the current literature on proximity in cluster theory with the insight that firms may differ even if they belong to the same industry (Alpaydin & Fitjar, 2021; Boschma, 2005; Lauvås & Steinmo, 2021).

Policy Implications

Haus-Reve & Asheim (2023) highlight the ability of regional clusters, supported by state-level policies, to provide cluster policy directionality. Clusters can thus play a key role in addressing transformative changes in regions by aligning policies of growth, competitiveness, and strategic reshoring with targeted innovation policies. Industrial clusters and their members can thus be key change agents in regions by promoting resilient and sustainable industries that hold implications when considering the generative potential of peripheral clusters. The cluster administration exemplifies this role by acting as an effective place-based leader, orchestrating activities, motivating members, and engaging local stakeholders.

Building on this potential, this research addresses the role of industrial clusters in process and product development during the transition to a circular bioeconomy. By empirically analyzing the indirect policy measures implemented by the cluster administration and investigating barriers, enablers, and the role of proximity in SME and HEI collaborations, this project contributes to a deeper understanding of the role of cluster policies. These insights could inform the development of more effective regional cluster administration strategies and policies that could benefit cluster organizations, policymakers, and evaluators alike.

6

6. LIMITATIONS AND FUTURE RESEARCH

6.1 Limitations

The key limitations to this research project are related to its overall focus on a single regional industrial area as well as the perspective from which the research has been conducted. Two further limitations in Papers 3 and 4 point to the potential of increasing the number of participating SMEs and looking beyond the current case to include a comparative study that includes other clusters also operating in the region. In the following, these four limitations and the future directions they could inspire are presented. This is followed by an extended discussion of research possibilities connected to an increased response rate: the integration of Social Network Analysis (SNA) as a tool for the analysis of clusters.

Regarding the first limitation, the impetus of this industrial research project was to conduct research benefiting the project owner, Norse Biotech AS, an SME participating in the transition to the circular bioeconomy. This meant that the project would largely be concentrated on the Inland region. This is in line with common practice in RIS research to focus on a specific industry located in a particular region (Doloreux & Porto Gomez, 2017). However, as we have seen with recent case-study based research on industrial clusters, there is much potential to look further across industries and regions (Asplund & Walde, 2021; Palčič, 2022).

The second limitation of the research project is that it does not consider the point of view of the academic sphere in answering the research question. Expanding the interviews (used in Paper 4) to include research institutes and universities would add another dimension to the project, allowing researchers to better understand the role of HEIs in initiating and managing collaboration projects. This may provide important perspectives on the differences in organizational cultures between SMEs and HEIs in the region and point to new avenues where connection can be fostered for optimal and increased collaborations.

In Paper 3, adding a control group to further strengthen the validity of the results and, while the response rate of SMEs is sufficient at 31%, increasing the number of cases so that even more conditions can be added for exploratory analysis is pertinent. These conditions could incorporate alternatives such as R&D spending, as many SMEs did not publish patents, and would allow researchers to explore other possible combinations and factors that influence the outcomes. In addition, adding more conditions to the csQCA could avoid risks of neglecting possible relevant conditions leading to a given outcome. Given these limitations, future studies should seek a clearer causality between cluster policy and outcomes, gaining better insight into what other factors may influence the outcomes – an aspect that the present research project cannot completely verify.

Finally, in Paper 4, using the current project as a base, further studies could continue to refine and evaluate the barriers and enablers and re-interview the SMEs to confirm and validate the findings in addition to expanding on the number of interviewed firms.

6.2 Proposed Research Direction – Integrating Social Network Analysis

As mentioned above, while the response rates obtained during this research project were sufficient for QCA, higher response rates from those surveyed at Heidner Biocluster would open more analytical possibilities. Specifically, higher response rates would allow for the novel combination of Social Network Analysis (SNA) and QCA signaling an exciting new approach for future regional studies research.

Beyond QCA, the application of SNA could be used to extend the study conducted in Paper 3 to demonstrate if the targeted policy actions implemented by the biocluster also materialize in the subsequent targeted period 2018-2021. This could be accomplished by comparing network structures through Quadratic Assignment Procedures (QAP), examining node positioning, and the phases in which collaborations primarily take place.

6.2.1 Understanding the Role of SNA in Future Studies

Originating in social science research, Social Network Analysis (SNA) refers to "a set of analytical tools that can be used to map networks of relationships and provides an important means of assessing and promoting collaboration in strategically important groups," (Chan & Liebowitz, 2006, p. 20).

Per definition, SNA is the study of the relationship between an individual element's behavior at the micro level and the pattern of interactions at the macro level (Stokman, 2001). As such, SNA can help identify and examine the knowledge linkages within a system. The maps and graphs created through SNA can illustrate the "sources, sinks, and constraints" of knowledge linkages and allow decision-makers to analyze these flows and implement changes to improve the network accordingly (Chan & Liebowitz, 2006, p. 20). Given these strengths, SNA has become an essential tool in regional innovation studies to trace and quantify the evolution of knowledge flows and inter- and intra-organizational interactions (Ter Wal & Boschma, 2009, p. 740).

Ter Wal and Boschma (2009) discuss two important trends in SNA relevant to RIS dynamics. First, SNA research on clusters has transitioned from a static perspective, examining only a single point in time, to one interested in exploring a more dynamic network theory. This is important because, to develop robust research on knowledge flows, an analytical approach is required that can account for how changes take place over time. Secondly, an SNA perspective, particularly as it pertains to working with regional economics, can contribute to cluster literature, RIS literature as well as literature on knowledge spillovers (Ter Wal & Boschma, 2009, p. 740). SNA thus provides an appropriate analytic toolbox for understanding which knowledge linkages are most valuable for economic growth and addressing challenges faced by more peripheral RISs (Ter Wal & Boschma, 2009, p. 754).

This potential of SNA has been demonstrated in previous research conducted by Fritsch and Kauffeld-Monz (2010) who explored the application of SNA to 300 German firms within 16 regional innovation networks. Their research was focused on the knowledge flows and absorption capacity of the firms in the networks. Survey data was collected, and SNA procedures applied to produce a networked graph illustrating the relationships among the public research institutes and private firms, the direction of the knowledge flows, and the extent of knowledge absorption between them. These results showed elevated levels of knowledge exchange and the causes in the differences in the absorptive capacity of the two groups. It demonstrated the essential role universities played throughout the network. The study emphasized how SNA could be used to determine salient actors in the knowledge exchange process and contribute to improving existing policy measures (Fritsch & Kauffeld-Monz, 2010).

More recently, Calignano et al. (2018) used SNA to explore the impact of indirect policy support on high-tech clusters in knowledge exchange networks of peripheral regions in southern Italy. The study, using interviews to collect data, describes the challenge of choosing a constructive policy measurement tool that can effectively examine changes in network structures over time, especially one that can account for the impact of complex indirect policy measures. They conclude SNA can produce an analysis of knowledge exchange that is sufficiently robust as a policy evaluation tool and makes it a practical choice as a quantitative method to explore inter-organizational interactions (Calignano et al., 2018).

Demonstrating the utility of SNA in explicating knowledge flows and absorptive capacity within clusters, such studies lay the groundwork to further develop understandings of clusters as useful policy development tools.

6.2.2 Future Research Design and Research Case

Future case studies could employ an exploratory, qualitative-dominant sequential research design, beginning with survey-based data collection, network visualization and analysis utilizing SNA methods and techniques. This can be followed by semi-structured qualitative interviews with stakeholders of the NCE Heidner Biocluster or other regional clusters such as the Hamar Game Collective or the Wood Cluster in a mixed method case study.

Looking into one or more of these regional clusters as a social network would involve examining both the external structures of the entire observable network and the internal social relations of the actors in the network, thus considering the different viewpoints of structures and relationships (Coviello, 2005; Edwards, 2010). One key research outcome would be to show the strengths of the connections between cluster member organizations.

These connections and the patterns demonstrated by them have a foundation in mathematics and graph theory from which computational models are created. These models are then visualized as the researcher determines where the focus of multiple parts of the network structure should be (Marin & Wellman, 2011). The visualized network is analyzed to elucidate its complexity by asking and answering questions concerning the graph (Wasserman & Faust, 1994). Formulated from a socio-centric view and informed by the theoretical approach and research questions, these questions are posed in relation to the resultant networked structure's overall shape, density, where the actors are located, and the centrality of the strongest actors. Once the strongest actors are determined, questions about their role in the network follow, such as: How do they facilitate communication? Who else is in the most similar position? What characteristics determine their success in this position in the network? (Yousefi Nooraie et al., 2018). As this research would be cluster-focused, questions could also explore why certain actors are more connected, and who is in a similar position in the cluster. Questions regarding what organizational qualities determine these connections are also pertinent, and could include, among others, organizational age, industry, size, and structure (Yousefi Nooraie et al., 2018). Labelling the actors based on their association with others in the group and their different attributes helps researchers delineate patterns within the networks.

Qualitative techniques researchers often use to conduct their analysis include holistic profiling which entails labelling the entirety of the network based on a common characteristic or label based on several diverse sources of information (Teddlie & Tashakkori, 2009). This technique can also be used in the qualitative interview stage where researchers gather data based on the generated labels to better understand the connections and relationship possibilities. The data can then be analyzed qualitatively based on the content (Marsden, 1990). Mixed analysis of the graphs is another technique involving the use of graphs developed from quantitative data, then using those graphs in semi-structured interviews. The data collected from respondents can then be used to revise the graphs' structure in this novel SNA-inspired mixed method case study (Ryan & D'Angelo, 2018).

References

Adams, R., Tranfield, D., & Denyer, D. (2006). Innovation Types: Configurations of Attributes as a Basis for Innovation Classification. *Advanced Institute of Management Research Paper*, No. 046. http://dx.doi.org/10.2139/ssrn.1309554

Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi-structured interviews. *Journal of the American College of Clinical Pharmacy,* 4(10), 1358-1367. https://doi.org/10.1002/jac5.1441

Alpaydın, U. A. R. & Fitjar, R. D. (2021). Proximity across the distant worlds of university–industry collaborations. *Papers in Regional Science*, *100*(3), 689-712. https://doi.org/10.1111/pirs.12586

Archibugi, D., & Michie, J. (Eds.). (1997). Technological globalization and national systems of innovation: An introduction. In D. Archibugi & J. Michie (Eds.), *Technology, Globalization, and Economic Performance* (pp. 1-23). Cambridge University Press.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy, 34*(8), 1173–1190. https://doi.org/10.1016/j.respol.2005.03.013

Asheim, B. (2007). Differentiated Knowledge Bases and Varieties of Regional Innovation Systems. *Innovation: The European Journal of Social Science Research, 20*(3), 223-241. https://doi.org/10.1080/13511610701722846

Asheim, B. T., Grillitsch, M., & Trippl, M. (2016). Regional innovation systems: past – present – future. In R. Sheamur, C. Carrincazeaux & D. Doloreux (Eds.) *Handbook on the Geographies of Innovation* (pp. 45–62). Edward Elgar Publishing.

Asheim, B. T., Grillitsch, M., & Trippl, M. (2017). Smart specialization as an innovation-driven strategy for economic diversification: Examples from Scandinavian regions. In S. Radosevic, A. Curaj, R. Gheorghiu, L. Andreescu, & I. Wade (Eds.*), Advances in the theory and practice of smart specialization* (pp. 74–99). London: Elsevier. https://doi.org/10.1016/B978-0-12-804137-6.00004-8

Asheim, B. T., Isaksen, A., & Trippl, M. (2019). *Advanced Introduction to Regional Innovation Systems*. Edward Elgar Publishing.

Asplund, A., & Walde, O. (2021). Interacting with Foreign Industrial Clusters – A Case Study of Swedish Companies in Japanese Clusters. https://lup.lub.lu.se/student-papers/search/publication/9055922

Austin, D., May, J., Andrade, J., & Jones, R. (2020). Delivering digital health: The barriers and facilitators to university-industry collaboration. *Health Policy and Technology, 10*(1), 104-110. https://doi.org/10.1016/J.HLPT.2020.10.003

Bathelt, H., & Glückler, J. (2003). Toward a relational economic geography. *Journal of Economic Geography*, *3*(2), 117-144. https://doi.org/10.1093/jeg/3.2.117

Bathelt, H., & Glückler, J. (2011). *The relational economy: geographies of knowing and learning*. Oxford University Press. https://doi.org/10.1093/acprof:osobl/9780199587384.001.0001

Bathelt, H., & Glückler, J. (2018). Relational research design in economic geography. In G. L. Clark & others (Eds.), *The New Oxford Handbook of Economic Geography* (pp. 179-195). Oxford University Press. (Original work published 2018). https://doi.org/10.1093/oxfordhb/9780198755609.013.46

Bennat, T. (2022). High innovativeness of SMEs and the configuration of learning-by-doing, learning-by-using, learning-by-interacting, and learning-by-science: A regional comparison applying fuzzy qualitative comparative analysis. *Journal of the Knowledge Economy*, *13*(2), 1666-1691. https://doi.org/10.1007/s13132-021-00774-1

Berg-Schlosser, D., Meur, G., Rihoux, B., & Ragin, C. (2009). Qualitative comparative analysis (QCA) as an approach. *In Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques* (Vol. 51, pp. 1–18). SAGE Publications, Inc. https://doi.org/10.4135/9781452226569

Bertello, A., Ferraris, A., Bernardi, P., & Bertoldi, B. (2021). Challenges to open innovation in traditional SMEs: An analysis of pre-competitive projects in university-industry-government collaboration. *International Entrepreneurship and Management Journal*, 18. https://doi.org/10.1007/s11365-020-00727-1

Bhaskar, R. (1975). *A realist theory of science* (2nd ed.). Leeds Books.

Bioinn. Vikinglauget. (2016, August 26). Retrieved from https://vikinglauget.no/bioinn/

Blundel, R. (2007). Critical realism: A suitable vehicle for entrepreneurship research? In H. Neergaard & J. P. Ulhoi (Eds.). *Handbook of Qualitative Research Methods in Entrepreneurship* (pp. 49–74). Edward Elgar Publishing. https://doi.org/10.4337/9781847204387

Boggs, J. S., & Rantisi, N. M. (2003). The 'relational turn' in economic geography. *Journal of Economic Geography*, *3*(2), 109-116. https://doi.org/10.1093/jeg/3.2.109

Boschma, R. (2005). Proximity and Innovation: A Critical Assessment. *Regional Studies, 39*(1), 61-74. https://doi.org/10.1080/0034340052000320887

Boschma, R. A., & Martin, R. (2010). The aims and scope of evolutionary economic geography. In R. Boschma & R. Martin (Eds.), The Handbook of Evolutionary Economic Geography (pp. 3-39). Edward Elgar Publishing.

Bråtå, H. O., Estensen, L., & Ekambaram, A. (2015). Competence Brokering: An Efficient Tool to Provide R&D to SMEs in Rural Areas. In *Proceedings of the 16th European Conference on Knowledge Management ECKM 2015*. The University of Udine, Italy, September 3-4, 2015.

Broadhurst, K., Ferreira, J., & Berkeley, N. (2020). Place leadership: Developing a model to guide regional partnerships. *Regional Studies*, *55*(3), 556-567. https://doi.org/10.1080/00343404.2020.1836343

Bunnell, T. & Coe, N. (2001). Spaces and scales of innovation. *Progress in Human Geography, 25*(4), 569-589. https://doi.org/10.1191/030913201682688940

Calignano, G. & Quarta, C. A. (2014). University of Salento's transactional relations: Assessing the knowledge transfer of a public university in Italy. *Erdkunde, 68*(2), 109-123. https://doi.org/10.3112/erdkunde.2014.02.03

Calignano, G. & Fitjar, R. D. (2017). Strengthening relationships in clusters: How effective is an indirect policy measure carried out in a peripheral technology district? *The Annals of Regional Science*, 59, 139-169. https://doi.org/10.1007/s00168-017-0821-x

Calignano, G., Fitjar, R. D., & Kogler, D.F. (2018). The core in the periphery? The cluster organization as the central node in the Apulian aerospace district. *Regional Studies, 52*(11), 1490-1501. https://doi.org/10.1080/00343404.2017.1420155

Calignano, G. & Nilsen, T. (2024). *Political leaders as agents in regional development* (Papers in Innovation Studies No. 2024/4). Lund University, CIRCLE-Centre for Innovation Research. https://wp.circle.lu.se/upload/CIRCLE/workingpapers/202404_calignano.pdf

Calignano, G. & Jørgensen Nordli, A. (2024). Less-advanced regions in EU innovation networks: Could nanotechnology represent a possible trigger for path upgrading? *Plos one*, *19*(1), 1-23. https://doi.org/10.1371/journal.pone.0288669

Calignano, G., & Winsents, E. (2024). Relations between academic reputation and innovation networks. *Scientometrics*, 129, 889–908. https://doi.org/10.1007/s11192-023-04869-1

Chan, K. & Liebowitz, J. (2006). The synergy of social network analysis and knowledge mapping: A case study. *International Journal of Management and Decision Making, 7*(1), 19–35. https://doi.org/10.1504/IJMDM.2006.008169

Chrisman, J. & Chrisman, R. (2023). Transitioning to a circular bioeconomy: Key drivers and the new cluster technologies to accelerate process development in biotechnology sectors. *Chimica Oggi - Chemistry Today, 41*(2), 14–18.

Chrisman, J., Chrisman, R., & Fundusa, Z. (2023). New processing concepts and cluster technologies: Catalysts for a faster and more efficient transition to a circular bioeconomy and biobased carbon materials. *Chimica Oggi - Chemistry Today*, *41*(5), 51–55.

Chrisman, J. E. (2024). More frequent and stronger ties? Using QCA to assess the effects of policy in a Norwegian biotech cluster. *Regional Studies, Regional Science*, *11*(1), 645–659. https://doi.org/10.1080/21681376.2024.2402934

Chrisman, J. & Calignano, G. (2024). What drives collaboration between SMEs and academic institutions? Exploring barriers, enabling factors, and the role of proximities in the Norwegian biotechnology sector. Manuscript submitted for review at the *European Spatial Research and Policy*.

Chrisman, R.W. (2023, March 20-22). New processing concepts will help enable the transition to a circular bio-economy. CPAC Summer Institute, Rome, Italy.

Cleland, J., MacLeod, A. & Ellaway, R. (2021). The curious case of case study research. *Medical Education*, *55*(10), 1131-1141. https://doi.org/10.1111/MEDU.14544

Collier, A., Gray, B. & Ahn, M. (2011). Enablers and barriers to university and high technology SME partnerships. *Small Enterprise Research*, 18, 18-2. https://doi.org/10.5172/ser.18.1.2

Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change, 10*(4), 945–974. https://doi.org/10.1093/icc/10.4.945

Cooke, P. (2004). Integrating global knowledge flows for generative growth in Scotland: Life sciences as a knowledge economy exemplar. In J. Potter (Ed.), *Global Knowledge Flows and Economic Development* (pp. 73–96). Paris: OECD. https://doi.org/10.1787/9789264107687-5-en

County Governor of Inland. (2015). The Bioeconomy Strategy for the Inland Region 2017-2024. https://www.regjeringen.no/contentassets/afc36304247d48f0a3546f992e0e0305/biookonomistrategi-for-innlandet_feb18.pdf

Coviello, N. (2005). Integrating qualitative and quantitative techniques in network analysis. *Qualitative Market Research, 8*(1), 39-60. https://doi.org/10.1108/13522750510575435

Delgado, M., Porter, M. E. & Stern, S. (2016). Defining clusters of related industries. *Journal of Economic Geography*, *16*(1), 1-38. https://doi.org/10.1093/jeg/lbv017

Doloreux, D., & Parto, S. (2005). Regional innovation systems: Current discourse and unresolved issues. *Technology in Society*, *27*(2), 133–153. https://doi.org/10.1016/j.techsoc.2005.01.002

Doloreux, D. & Porto Gomez, I. (2017). A review of (almost) 20 years of regional innovation systems research. *European Planning Studies, 25*(3), 371–387. https://doi.org/10.1080/09654313.2016.1244516

Dumez, H. (2015). What Is a Case, and What Is a Case Study? *Bulletin of Sociological Methodology/Bulletin de Méthodologie Sociologique*, *127*(1), 43-57. https://doi.org/10.1177/0759106315582200

Duodu, I., Schösser, F., Reuther, K., Dahle, Y. & Posselt, T. (2023, June). Accessibility of Entrepreneurial Ecosystem Elements: A Qualitative Comparative Analysis of Developed and Emerging Economies. In *2023 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)* (pp. 1-10). IEEE.

Easton, G. (2010). Critical realism in case study research. *Industrial Marketing Management, 39*(1), 118–128. https://doi.org/10.1016/j.indmarman.2008.06.004

Ebbekink, M., & Lagendijk, A. (2013). What's next in researching cluster policy: Place-based governance for effective cluster policy. *European Planning Studies, 21*(5), 735-753. https://doi.org/10.1080/09654313.2013.734460

Edwards, G. (2010). Mixed methods approaches to social networks analysis (Rev. Pap. NCRM/015). *ESRC National Centre for Research Methods*. 1-30. https://eprints.ncrm.ac.uk/id/eprint/842

European Commission. (n.d.). *A European Green Deal*. European Commission. Retrieved November 15, 2024, from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

European Commission. (2007). *Improving knowledge transfer between research institutions and industry across Europe: Embracing open innovation* (EUR 22836). http://ec.europa.eu/invest-in-research/pdf/download_en/knowledge_transfe_07.pdf

European Commission. (2015). *Closing the loop–an EU action plan for the circular economy.* COM/2015/0614. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614

European Commission Directorate-General for Research and Innovation. (2018). *A sustainable bioeconomy for Europe: Strengthening the connection between economy, society, and the environment: Updated bioeconomy strategy*. Publications Office. https://data.europa.eu/doi/10.2777/792130

Foray, D. (2017). The economic fundamentals of smart specialization strategies. In S. Radosevic, A. Curaj, R. Gheorghiu, L. Andreescu, & I. Wade (Eds.), *Advances in the theory and practice of smart specialization* (pp. 37–50). London: Academic Press. https://doi.org/10.1016/B978-0-12-804137-6.00003-6

Fritsch, M. & Kauffeld-Monz, M. (2010). The impact of network structure on knowledge transfer: An application of social network analysis in the context of regional innovation networks. *Annals of Regional Science, 44*(21), 1-26. https://doi.org/10.1007/s00168-008-0245-8

Gabrielle, B., Barbottin, A. & Wohlfahrt, J. (2018). The Environmental Impacts of Non-food Biomass Production Through Land-Use Changes: Scope, Foci and Methodology of Current Research. In O. Réchauchère, A. Bispo, B. Gabrielle & D. Makowski (Eds.). *Sustainable Agriculture Reviews 30*. (pp. 39-77) https://doi-org.ezproxy.inn.no/10.1007/978-3-319-96289-4_3

Galanakis, K., Passey, S. & Yazdani, B. (2000). A Management Tool for Innovation using Systems Thinking Approach. *Proceedings of the 2000 IEEE International Conference on Management of Innovation and Technology. ICMIT 2000. 'Management in the 21st Century,'* 1, 378–383. https://doi.org/10.1109/ICMIT.2000.917367

Ganske, P., & Carbon, C.-C. (2023). Successful clusters through successful communication: Why clusters should be managed by place leaders. *Frontiers in Communication*, 8, 1-13. https://doi.org/10.3389/fcomm.2023.1194103

Giest, S. (2021). *The capacity to innovate: Cluster policy and management in the biotechnology sector*. University of Toronto Press.

Glaesser, J. (2024). Case-to-condition ratios in qualitative comparative analysis: Adding cases instead of removing conditions. *Field Methods, 0*(0). https://doi.org/10.1177/1525822X241231479

Grashof, N. (2021). Putting the watering can away: Towards a targeted (problem-oriented) cluster policy framework. *Research Policy*, *50*(9), 1-23. https://doi.org/10.1016/j.respol.2021.104335

Grillitsch, M., & Asheim, B. T. (2018). Place-based innovation policy for industrial diversification in regions. *European Planning Studies*, *26*(8), 1638-1662. https://doi.org/10.1080/09654313.2018.1484892

Grillitsch, M. & Sotarauta, M. (2020). Trinity of change agency, regional development paths and opportunity spaces. *Progress in human geography*, *44*(4), 704-723. https://doi.org/10.1177/0309132519853870

Hallén, A. (2016). In S. Mekjan (2016). *New national strategy on the bioeconomy launched*. The Research Council of Norway. https://www.forskningsradet.no/en/Newsarticle/New_national_strategy_on_the_bioeconomy_launched/1254022868420

Hamar historielag. (2024). *Hamar historielag årbok 2024*. Printex Trykkeri. Retrieved from https://www.hamarhistorielag.no

Hanckel, B., Petticrew, M., Thomas, J. & Green, J. (2021). The use of Qualitative Comparative Analysis (QCA) to address causality in complex systems: A systematic review of research on public health interventions. *BMC Public Health*, *21*(1), 1-22. https://doi.org/10.1186/s12889-021-10926-2

Haraldsson, H. V. (2004). *Introduction to system thinking and causal loop diagrams*. Reports in Ecology and Environmental Engineering (Report nr. 1, 5th ed.). Lund University.

Hauge, A., Johnstad, T., & Ørbeck, M. (2009). Innlandets innovasjonssystem og forskningsstrategi. In T. Johnstad & A. Hauge (Eds.), *Samhandling og innovasjon: Aktører, systemer og initiativ i Innlandet.* (pp. 125–144). Oplandske Bokforlag.

Hauge, A., Calignano, G., Bern, A. & Lønningdal, K. H. (2023). Small cities: Regional motors or sponges? The case of Inland County, Norway. *GeoJournal, 88*(6), 6393-6406. https://doi.org/10.1007/s10708-023-10975-7

Haus-Reve, S. & Asheim, B. (2023). The role of clusters in addressing societal challenges in European regions. *European Planning Studies*, 1-16. https://doi.org/10.1080/09654313.2023.2273317

He, B. (2019). Case study on enterprise behavior considering cluster brand. *American Journal of Industrial and Business Management,* 9, 1908-1914. https://doi.org/10.4236/ajibm.2019.910124

Healy, A. & Morgan, K. (2012). Spaces of innovation: Learning, proximity, and the ecological turn. *Regional Studies, 46*(8), 1041-1053. https://doi.org/10.1080/00343404.2012.672725

Iannacci, F., Fearon, C., Kawalek, P. & Simeonova, B. (2022). Aligning the qualitative comparative analysis (QCA) counterfactual approach with the practice of retroduction: Some preliminary insights. *Information Systems Journal, 33*(3), 467-485. https://doi.org/10.1111/isj.12409

Innlandsporteføljen. (2023). *Innlandsporteføljen 2023* [PowerPoint presentation]. Retrieved from https://innlandsportefoljen.no/wp-content/uploads/2023/12/Innlandsporteføljen-2023.pdf

Innovation Norway. (2019). *Norwegian Innovation Clusters*. Retrieved February 5, 2022, from https://www.innovasjonnorge.no/no/subsites/forside/Om_NIC/

Innovation Norway. (2020, February 3). *Our Mission*. Retrieved January 5, 2022, from https://www.innovasjonnorge.no/en/start-page/about/our-mission/

Isaksen, A. & Karlsen, J. (2010). Different Modes of Innovation and the Challenge of Connecting Universities and Industry: Case Studies of Two Regional Industries in Norway. *European Planning Studies, 18*(12), 1993-2008. https://doi.org/10.1080/09654313.2010.516523

Isaksen, A. & Trippl, M. (2016). Path development in different regional innovations systems: A conceptual analysis. In M.D. Parrilli, R.D. Fitjar & A. Rodriguez-Pose (Eds.), *Innovation Drivers and Regional Innovation Strategies* (pp. 66-84). Routledge.

Isaksen, A., & Jakobsen, S.-E. (2017). New Path Development Between Innovation Systems and Individual Actors. *European Planning Studies, 25*(3), 355-370. https://doi.org/10.1080/09654313.2016.1268570

Jakobsen, E. W., & Røtnes, R. (2012). *Cluster programs in Norway: Final report*. Menon Economics. Retrieved November 17, 2024, from https://www.menon.no/wp-content/uploads/19clusters-programs-in-draft-final-report-jan-12-2.pdf

Jasimuddin, S. M., Li, J. & Perdikis, N. (2015). Linkage between geographic space and knowledge transfer by multinational enterprises: a structural equation approach. *The Annals of Regional Science*, 54, 769-795. https://doi.org/10.1007/s00168-015-0684-y

Jofre, S. (2011). Exploring the role of knowledge and technology transfer in innovation systems. In *Proceedings of Triple Helix IX International Conference: "Silicon Valley: Global Model or Unique Anomaly?"* (Vol. IX). Stanford University Press.

Kong, X. & Li, X. (2007). A Systems Thinking Model for Innovation Management: The Knowledge Management Perspective. In *2007 International Conference on Management Science & Engineering* (14th) (August 20-22), Harbin, P.R. China (pp. 1499-1504). https://doi.org/10.1109/ICMSE.2007.4422055

Krugman, P. R. (1991). *Geography and trade*. MIT Press.

Kwaśny, J., Mroczek, A. & Ulbrych, M. (2019). Industrial clustering and economic performance: In search for evidence from Poland. *Ekonomicko-manazerske Spektrum, 13(*1), 109-119. https://doi.org/10.26552/ems.2019.1.109-119

Lathlean, J., & Denicolo, P., (2022). Research Skills: Collecting, Analyzing, and Interpreting Qualitative Data. In *SAGE Skills: Student Success*. SAGE Publications, Inc. https://doi.org/10.4135/9781071885628

Lauvås, T. & Steinmo, M. (2021). The role of proximity dimensions and mutual commitment in shaping the performance of university-industry research centres. *Innovation, 23*(2), 182-208. https://doi.org/10.1080/14479338.2019.1662725

Lucena-Piquero, D., & Vicente, J. (2019). The visible hand of cluster policy makers: An analysis of aerospace valley (2006-2015) using a place-based network methodology. *Research Policy*, *48*(3), 830-842. https://doi.org/10.1016/j.respol.2019.01.001

Lundvall, B. A. (1992). National systems of innovation: Towards a theory of innovation and interactive learning. London: *Francis Printer*. https://doi.org/10.1080/08109029308629360

Maffioli, A., Pietrobelli, C., & Stucchi, R. (2016). Evaluation of cluster development programs. In A. Maffioli, C. Pietrobelli, & R. Stucchi (Eds.), *The Impact Evaluation of Cluster Development* (pp. 1-18). Inter-American Development Bank.

Malmberg, A. & Power, D. (2005). (How) do (firms in) clusters create knowledge? *Industry and innovation*, *12*(4), 409-431. https://doi.org/10.1080/13662710500381583

Marin, A. & Wellman, B. (2011). Social network analysis: An introduction. In J. Scott & P. Carrington (Eds.). *The SAGE Handbook of Social Network Analysis* (pp. 11-25). Sage publications.

Marsden, P. V. (1990). Network data and measurement. *Annual Review of Sociology,* 16, 435-463. https://www.jstor.org/stable/2083277

Marx, A., & Duşa, A. (2011). Crisp-set qualitative comparative analysis (csQCA), contradictions and consistency benchmarks for model specification. *Methodological Innovations Online, 6(*2), 103–148. https://doi.org/10.4256/mio.2010.0037

Mekjan, S. (2016). *New national strategy on the bioeconomy launched*. The Research Council of Norway.

Mello, P. A. (2021). Measures of Fit (Chapter 6). In P.A. Mello (Ed.). *Qualitative Comparative Analysis: An Introduction to Research Design and Application*. Georgetown University Press.

Molloy, P. (2021). Australian biotechnology: Promissory expectations and ecosystem performance far from the global superclusters. *Journal of Commercial Biotechnology, 26*(1). https://doi.org/10.5912/jcb970

Naz, N., Gulab, F. & Aslam, M. (2022). Development of qualitative semi-structured interview guide for case study research. *Competitive Social Science Research Journal, 3*(2), 42-52. https://cssrjournal.com/index.php/cssrjournal/article/view/170

NCE Heidner Biocluster. (2020). Value Chain. NCE Heidner Biocluster. https://heidner.no/

Nilsen, T., Calignano, G., Lien, S. & Nordli, A. J. (2024). Norwegian wood, isn't it good? Narratives of the lumber industry and development paths in the Nordic periphery. *Journal of Rural Studies, 105*, 103182. https://doi.org/10.1016/j.jrurstud.2023.103182

Norwegian Ministry of Climate and Environment. (2019). *National expectations regarding regional and municipal planning 2023–2027*. Retrieved November 17, 2024, from https://www.regjeringen.no/contentassets/f6c799ac7c474e5b8f561d1e72d474da/t-1573n.pdf

Norwegian Ministry of Climate and Environment. (2021). *Norway's strategy for developing a green circular economy. Government of Norway*. Retrieved from https://www.regjeringen.no/en/historical-archive/solbergs-government/Ministries/kld/news/2021/norways-strategy-for-developing-a-green-circular-economy/id2861246

O'Connor, G. C. (2008). Major Innovation as a Dynamic Capability: A Systems Approach. *The Journal of Product Innovation Management*, 25, 313–330. https://doi.org/10.1111/j.1540-5885.2008.00304.x

Obadic, A. (2013). Specificities of EU cluster policies. *Journal of Enterprising Communities: People and Places in the Global Economy, 7*(1), 23 – 35. https://doi.org/10.1108/17506201311315581

OECD. (2009). *The bioeconomy to 2030: Designing a policy agenda*. OECD Publishing. http://www.oecd.org/futures/long-termtechnologicalsocietalchallenges/thebioeconomyto2030designingapolicyagenda.htm

Pagliarin, S., Mendola, S. & Vis, B. (2022). The "qualitative" in qualitative comparative analysis (QCA): Research moves, case-intimacy, and face-to-face interviews. *Quality & Quantity, 57*(1), 489-507. https://doi.org/10.1007/s11135-022-01358-0

Palčič, I. (2022). Model of development and organization of industrial clusters. *Annals of PAZU, 3*(1), 26-33. https://doi.org/10.18690/analipazu.3.1.26-33.2013

Pawson, R. (1996). Critical realism and interviewing subjects. In C. Smith & T. Elger, *Studying organizations using critical realism: A practical guide*. In P. K. Edwards, J. O'Mahoney, & S. Vincent (Eds.), Oxford Academic. https://doi.org/10.1093/acprof:oso/9780199665525.003.0006

Porter, M. E. (1990). *The Competitive Advantage of Nations*. Macmillan Press.

Porter, M. E. (1998). Clusters and the new economics of competition. *Harvard Business Review, 76*(6), 77-90. https://biblioteca.fundacionicbc.edu.ar/images/d/de/Clusters_1.pdf

Radosevic, S. (2017). Assessing EU smart specialisation policy in a comparative perspective. In S. Radosevic, A. Curaj, R. Gheorghiu, L. Andreescu, & I. Wade (Eds.), *Advances in the theory and practice of smart specialization* (pp. 2–36). London: Academic Press. https://doi.org/10.1016/B978-0-12-804137-6.00001-2

Ragin, C. (1987). *The comparative method: Moving beyond qualitative and quantitative strategies*. University of California Press.

Rauf, M. A. & Weber, O. (2021). Regional studies and conceptual fuzziness: A critical review. *Resources and Environmental Economics, 3*(1), 251-262. https://doi.org/10.25082/REE.2021.01.005

REDINN & Innlandsstatistikk. (2022*). Regionale nøkkeltall* [PowerPoint slides]. Retrieved from https://redinn.no/wp-content/uploads/2022/03/regionale-nokkeltall-redinn-i-samarbeid-med-innlandsstatistikk100322.pdf

Reve, T. & Jakobsen, E. W. (2001). *Et verdiskapende Norge*. Universitetsforlaget.

Rihoux, B., & De Meur, G. (2009). Crisp-set qualitative comparative analysis (csQCA). In B. Rihoux & C. C. Ragin (Eds.), *Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques.* (pp. 33–68). SAGE Publications. https://doi.org/10.4135/9781452226569.n3

Rihoux, B. & Marx, A. (2013). QCA 25 years after "The Comparative Method." *Political Research Quarterly, 66*(1), 167-235. https://doi.org/10.1177/1065912912468269

Robledo-Abad, C., Althaus, H.-J., Berndes, G., Bolwig, S., Corbera, E., Creutzig, F., Garcia-Ulloa, J., Geddes, A., Gregg, J.S., Haberl, H., Hanger, S., Harper, R.J., Hunsberger, C., Larsen, R.K., Lauk, C., Leitner, S., Lilliestam, J., Lotze-Campen, H., Muys, B., Nordborg, M., Ölund, M., Orlowsky, B., Popp, A., Portugal-Pereira, J., Reinhard, J., Scheiffle, L. & Smith, P. (2017), Bioenergy production and sustainable development: science base for policymaking remains limited. *GCB Bioenergy,* 9(3), 541-556. https://doi.org/10.1111/gcbb.12338

Roelandt, T. & Den Hartog, P. (1999). Cluster analysis and cluster-based policy making in OECD countries: an introduction to the theme. OECD Proceedings: *Boosting innovation: The cluster approach, (*pp. 9-23) OECD Publications.

Ross, D. A. & Wade, J. P. (2015). A Definition of Systems Thinking: A Systems Approach. *Procedia Computer Science*, 44, 669-678. https://doi.org/10.1016/j.procs.2015.03.050

Rutten, R. (2021). Uncertainty, possibility, and causal power in QCA. *Sociological Methods & Research*, *52*(4), 1707-1736. https://doi.org/10.1177/00491241211031268

Ryan, L. & D'Angelo, A. (2018). Changing times: Migrants' social network analysis and the challenges of longitudinal research. *Social Networks*, 53, 148-158. https://doi.org/10.1016/j.socnet.2017.03.003

Sæther, B. (1998). Retroduction: An alternative research strategy? *Business Strategy and the Environment*, *7*(4), 245-249. https://doi.org/10.1002/(SICI)1099-0836(199809)7:43.0.CO;2-C

Schensul, J., Chandran, D., Berg, M., Singh, S. & Gupta, K. (2010). The use of qualitative comparative analysis for critical event research in alcohol and HIV in Mumbai, India. *AIDS and Behavior*, *14*(S1), 113-125. https://doi.org/10.1007/s10461-010-9736-6

Schmiedeberg, C. (2010). Evaluation of cluster policy: A methodological overview. *Evaluation*, *16*(4), 389–412. https://doi.org/10.1177/1356389010381184

Setzke, D. S., Böhm, M. & Krcmar, H. (2020, August). *Combining the Case Survey Method and Qualitative Comparative Analysis for Information Systems Research*. 26th Americas Conference on Information Systems. Salt Lake City, USA https://www.researchgate.net/publication/341217031_Combining_the_Case_Survey_Method_and_Qualitative_Comparative_Analysis_for_Information_Systems_Research

Shen, H., Wang, L., Xu, Q., Li, Y. & Liu, X. (2009). Toward a Framework of Innovation Management in Logistics Firms: A Systems Perspective. *Systems Research and Behavioral Science*, 26, 297-309. https://doi.org/10.1002/sres.963

Silva, D., Lucas, L. & Vonortas, N. (2019). Internal barriers to innovation and university-industry cooperation among technology-based SMEs in Brazil. *Industry and Innovation*, 27, 235-263. https://doi.org/10.1080/13662716.2019.1576507

Siva, S.F. (2020, March 27). Home: English information. Siva. Retrieved January 20, 2022, from https://siva.no/english/

Smith, C., & Elger, T. (2014). Critical realism and interviewing subjects. In P. K. Edwards, J. O'Mahoney, & S. Vincent (Eds.), *Studying organizations using critical realism: A practical guide.* Oxford Academic. https://doi.org/10.1093/acprof:oso/9780199665525.003.0006

Sotarauta, M. (2014). Territorial knowledge leadership in policy networks: A peripheral region of South Ostrobothnia, Finland, as a case in point. In R. Rutten, P. Benneworth, D. Irawati, & F. Boekema (Eds.), *The social dynamics of innovation networks* (pp. 42–59). Abingdon: Routledge

Sotarauta, M., & Beer, A. (2017). Governance, agency and place leadership: Lessons from a cross-national analysis. *Regional Studies*, *51*(2), 210-223. https://doi.org/10.1080/00343404.2015.1119265

Sotarauta, M., Suvinen, N., Jolly, S., & Hansen, T. (2020). The many roles of change agency in the game of green path development in the North. *European Urban and Regional Studies*, *28*(2), 92–110. https://doi.org/10.1177/0969776420944995

Sotarauta, M. (2021). Combinatorial power and place leadership. In M. Sotarauta & A. Beer (Eds.), *Handbook on City and Regional Leadership* (pp. 152–166). Cheltenham: Edward Elgar Publishing. https://doi.org/10.4337/9781788979689.00018

Stokman, F. N. (2001). Networks: Social. *International Encyclopedia of the Social & Behavioral Sciences*, 10509–10514. https://doi.org/10.1016/B0-08-043076-7/01934-3

Sverdrup, H. U., Haraldsson, H. V., Nordby, A., Vibeto, H., Olafsdottir, A. H., Belyazid, S., & Svensson, M. (2022). *System Thinking, Systems Analysis and System Dynamics* (7th ed.). Oplandske Bokforlag.

Teddlie, C. & Tashakkori, A. (Eds.). (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage publications.

Ter Wal, A. L. J. & Boschma, R. A. (2009). Applying social network analysis in economic geography: Framing some key analytic issues. *Annals of Regional Science,* 43, 739–756. https://doi.org/10.1007/s00168-008-0258-3

Teräs, J., Lindberg, G., Johnsen, I. H. G., Perjo, L. & Giacometti, A. (2014). Bioeconomy in the Nordic region: Regional case studies. *Nordregio Working Paper* 2014:4, 1-70. Stockholm, Sweden.

The Assessment Company. (n.d.). *Strategy and organizational development*. Retrieved November 17, 2024, from https://theac.no/en/services/strategy-and-organizational-development

The Research Council of Norway. (n.d.). *What does the research council do*? Retrieved January 20, 2022, from https://www.forskningsradet.no/en/about-the-research-council/what-we-do/what-does-the-research-council-do/

Tödtling, F. & Trippl, M. (2011). Regional innovation systems. In P. Cooke, B. Asheim, R. Boschma, R. Martin, D. Schwartz & F. Tödtling (Eds.). *Handbook of regional innovation and growth*. Edward Elgar Publishing. https://doi.org/10.4337/9780857931504.00053

Tödtling, F., & Trippl, M. (2018). Regional innovation policies for new path development – beyond neo-liberal and traditional systemic views. *European Planning Studies, 26*(9), 1779-1795. https://doi.org/10.1080/09654313.2018.1457140

Tödtling, F., Trippl, M., & Desch, V. (2022). New directions for RIS studies and policies in the face of grand societal challenges. *European Planning Studies*, *30*(11), 2139–2156. https://doi.org/10.1080/09654313.2021.1951177

Trippl, M., Sinozic, T. & Lawton Smith, H. (2015). The role of universities in regional development: Conceptual models and policy institutions in the UK, Sweden, and Austria. *European Planning Studies, 23*(9), 1722-1740 https://doi.org/10.1080/09654313.2015.1052782

Trippl, M., Grillitsch, M., Isaksen, A. & Sinozic, T. (2017). Understanding cluster evolution. In F. Belussi & J.L. Hervas-Oliver (Eds.), *Unfolding Cluster Evolution* (pp. 267-281). Routledge.

Vale, M., Peponi, A., Carvalho, L., Veloso, A. P., Queirós, M., & Morgado, P. (2023). Are peripheral regions in troubled waters for sustainability transitions? A systematic analysis of the literature. *European Urban and Regional Studies, 0*(0), 1-16. https://doi.org/10.1177/09697764231194316

Verweij, S. & Trell, E.-M. (2019). Qualitative Comparative Analysis (QCA) in Spatial Planning Research and Related Disciplines: A Systematic Literature Review of Applications. *Journal of Planning Literature, 34*(3), 300-317. https://doi.org/10.1177/0885412219841490

Vincent, S. & O'Mahoney, J. (2016). Critical realism and qualitative research: An introductory overview. In C. Cassell, A. L. Cunliffe & G. Grandy (Eds.). The SAGE Handbook of Qualitative Business and Management Research Methods: History and Traditions. (pp. 201-216). SAGE publications https://doi.org/10.4135/9781526430212

Warren, V. & Bell, R. (2022). The Role of Context in Qualitative Case Study Research: Understanding Service Innovation. In *Sage Research Methods Cases Part 1*. SAGE Publications. https://doi.org/10.4135/9781529604467

Wasserman, S. & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815478

Weber, K.M. & Truffer, B. (2017). Moving innovation systems research to the next level: towards an integrative agenda. *Oxford Review of Economic Policy*, 33, 101-121. https://doi.org/10.1093/oxrep/grx002

Wohlfahrt, J., Ferchaud, F., Gabrielle, B., Godard, C., Kurek, B., Loyce, C. & Therond, O. (2019). Characteristics of bioeconomy systems and sustainability issues at the territorial scale: A review. *Journal of Cleaner Production,* 232, 898-909. https://doi.org/10.1016/j.jclepro.2019.05.385

Yan, H., Hu, X., Wu, D., & Zhang, J. (2021). Exploring the green development path of the Yangtze River Economic Belt using the entropy weight method and fuzzy-set qualitative comparative analysis. *PLOS ONE*, *16*(12): e0260985. https://doi.org/10.1371/journal.pone.0260985

Yousefi Nooraie, R., Sale, E. M., Marin, A. & Ross, L. E. (2018). Social network analysis: An example of fusion between quantitative and qualitative methods. *Journal of Mixed Methods Research, 14*(1), 110-12.4 https://doi.org/10.1177/1558689818804060

Zachariadis, M., Scott, S. & Barrett, M. (2013). Methodological implications of critical realism for mixed-methods research. *MIS Quarterly*, *37*(3), 855–879. http://www.jstor.org/stable/43826004

APPENDICES

Appendix 1: Paper 1

Appendix 2: Paper 2

Appendix 3: Paper 3

Appendix 3: Paper 4

1

Transitioning to a Circular Bioeconomy: Key Drivers and the New Cluster Technologies to Accelerate Process Development in Biotechnology Sectors

Key words: circular economy; biotechnology; bioeconomy; organizational clusters; biomass

ABSTRACT:
There is growing interest from governmental organizations and firms in the biotechnology sector in transitioning to a circular bioeconomy to meet their climate and economic goals. We use data from a recent presentation given at the CPAC Rome Workshop 2023 (30) to present five key factors driving the transition away from carbon-based materials to biobased ones and the technologies that are being implemented to achieve this. We address some of the new challenges that have arisen such as long wait times at the process development and commercialization stages. Finally, we offer solutions through the implementation of organizational clusters to overcome the challenge of resource efficiency through geographical proximity, and knowledge transfer.

INTRODUCTION

This paper presents some of the arguments from a presentation given at the recent CPAC Rome Workshop 2023 (30) at the University of Washington Rome Center. The presentation "To Facilitate a Rapid Transition to a Circular bioeconomy will Require the Development of New Tools to Speed Process Development" focused on some of the key drivers for a circular bioeconomy, which included a description of the new technologies that will be required to enable a smooth and rapid transition. The presentation started with a review of the problems that led to the development of the circular economy concept that was an overarching topic at this year's workshop titled, "Utilization of New Processing Concepts to Support the Demand for Sustainable Materials in a Circular Economy, often enabled by Exploring New Reaction Routes for Continuous Flow Processing Aided by Real-Time Monitoring Technology" (1). Designed to be "restorative and generative" the circular economy approach speaks to an economic system where the resources in the economy are maintained for as long as possible and the generation of waste is minimized (2) – an approach that demands a great deal of innovations and technologies to address the resource management needs of today.

A PUSH TOWARDS THE CIRCULAR BIOECONOMY

The increasing need for bioeconomy strategies to center around sustainability and circularity resulted therein that all the European bioeconomy-related strategies have increasingly been linked to the circular economy concept. Given this large conceptual overlap, the two concepts have been merged into the term 'circular bioeconomy' to encapsulate the circular nature of bioeconomy action plans and agendas (3).

Both internationally and regionally, research into the implementation of a bioeconomy to move from fossil-based economies to greener, more sustainable economies has become increasingly pressing. Governing bodies all over the world, particularly in the United States and Europe, are investing a growing number of resources into facilitating this transition through policy strategies and agendas. To encapsulate the areas of focus within bioeconomy, the OECD defines the bioeconomy in their policy agenda, *the Bioeconomy to 2030*, as follows:

"The emerging bioeconomy is likely to involve three elements: the use of advanced knowledge of genes and complex cell processes to develop new processes and products, the use of renewable biomass and efficient bioprocesses to support sustainable production, and the integration of biotechnology knowledge and applications across sectors” (4, p. 11).

For the development of this circular bioeconomy, the OECD stresses the importance of successful innovation across sectors requiring a focus on the application of new knowledge and business models across sectors (4). Implementing the circular bioeconomy thus necessitates a cross-sectional approach that will involve a broad range of system-level changes and innovations to succeed (5). To this end, an increasing amount of funding has been allocated to promote the creation and dissemination of new knowledge on biotechnology and bioeconomy research, among them the European Commission's Bioeconomy Strategy, that aims to promote innovations in research to accelerate “progress towards a circular and low-carbon economy” (6).

Given this global push towards the circular bioeconomy, this paper presents and expands on the key problems driving the adoption of the circular bioeconomy. It then presents a few of the technologies required in this process and describes how to achieve faster commercialization thereof. For new technology, process development through to production often takes 2-15 years (7), and commercialization can add several more years. Finally, this paper proposes emerging cluster technologies as one effort to accelerate the introduction of new biotechnology which will be needed for a smooth transition to a circular bioeconomy in the regional innovation systems they are intended for.

KEY DRIVERS OF THE CIRCULAR BIOECONOMY: GLOBAL ISSUES, THEIR MEASUREMENT AND AVENUES OF RESOLUTION

Five Key Drivers

The presentation pointed to at least five problems driving the need for a circular bioeconomy. The first is that earth resources are finite and that we are running out of easily available materials. Tables have been developed which include the information that there is a factor of 10 growth in demand every 50 years for most metals and which when coupled with data on proven deposits predict when key metals will be short of demand. The problem is even worse since the quality of ores is dropping which means that more energy is required to process the ores. A comment is often made that the concentration of certain elements is higher in trash dumps around the world than in the ores that are being processed. However, it should be mentioned that except for helium all the elements are still present on earth. The problem is that they are often being dispersed into the broader environment such as with phosphorus being leeched into the oceans or the elements are being transformed into forms that are less usable such as fossil carbon to carbon dioxide.

The second point is simply that fossil carbon is also a finite resource, and it is running out. There are various projections for how long supplies will last given various usage rates, but cheap fossil carbon is clearly going away. Currently, much of it is burned and converted to carbon dioxide with a half-life of over 100 years in the atmosphere meaning that it is not being recycled at any rate that can match current usage. The related third point is that carbon dioxide is the largest greenhouse gas contributor to global warming. The buildup of various greenhouse gases has increased global warming as exemplified by the rapid increase in average temperature of northern areas, such as Svalbard where the average temperature has increased 4 degrees Celsius in the last 50 years (8). This has led to unstable glaciers resulting in avalanches in some housing areas and the need to abandon certain residential areas of this northern most island group. In addition, the global seed repository is located on the islands and has had to deal with the flooding issues that are in part due to local warming (9).

The fourth area is waste caused by the linear economy in which products are made and production waste is discarded into the environment. Unfortunately, pollution and toxic waste, among other waste products, are a result of various production practices in the linear economy where it is cheaper to discard waste materials than it is to deal with them. One example was the Cuyahoga River in the Cleveland Ohio area of the US where the released waste caused such disastrous pollution that the river caught fire 14 times (10). Another frequent problem occurred in many rivers flowing past production plants whose released waste polluted the rivers making downstream water unfit to drink. While bulk pollution such as that is now less likely, waste in production is still a major problem. As an example, the pharmaceutical industry is noted for producing over 100 Kg of waste for every Kg of product produced partly due to the discarding of solvents rather than recycling them (11).

The fifth area is also a function of the lack of recycling in the linear economy where it is lower cost to discard materials after their useful product life than it is to recover and reuse them. One of the most obvious is plastic waste which often is discarded into the oceans where it can cause problems for fish mistaking it for food as well as making many previously pristine beaches unusable. This fifth area also mentions the problem with discarded fabrics which globally amounts to a dump truck load of waste every second. Fabric waste also highlights the problem that 8- 10% of global green-house gases are related to fabric processing and that fabric processing contributes to 20% of global wastewater (12, 13).

The presentation mentioned several measurement tools, some satellite based, that were being employed to help understand and control some of these problems. The oldest, which has been continuously operating since the late 1950's, measures the concentration of CO2 in the atmosphere. The data now available online demonstrates the constantly increasing level of CO2 which can be correlated with fossil carbon usage and global temperatures. It also shows a saw tooth pattern, the seasonal variation in concentrations related to the CO2 consumption by plants in the northern hemisphere (14). Satellite data using solar induced fluorescence can track photosynthesis to better understand the impact of weather and crop selection on CO2 uptake (15). Satellite data is also being used to map methane concentrations to help locate leaks from wells, processing plants, and from piping to enable fixes (16).

Such measurements made it clear to those looking at the data that the problems were getting worse and that, without a major change in how the world operates, the problems would lead to even more severe issues. The need for such operational changes to address these problems on a large, system-wide scale has been addressed through the development of the concept of a circular bioeconomy. The circular bioeconomy is focused on waste and how to reduce it by recycling wherever possible. This requires a shift in thinking from the linear processes to a close loop system, from the extraction, use and disposal of materials to a system of reuse for certain materials (17). While the approach is not focused solely on energy, significant energy is saved by recycling as it only takes 5% of the energy to reprocess aluminum metal as opposed to the amount of energy to produce it from ore. It has become clear that the concepts involved in implementing a circular bioeconomy will help minimize many of the above problems including reducing greenhouse gas emissions.

Significant Amount of New Technologies Needed

Unfortunately, to lower carbon dioxide emissions and avoid the depletion of fossil carbon resources in its entirety requires a more concerted focus on carbon and its use. This has led to the circular bioeconomy which uses similar concepts as the circular economy to reduce waste and implement various recycling efforts (18). The recycling of carbon has led to the idea that we need to move away from burning carbon for fuel since converting it to carbon dioxide makes it much less available for recycling and it has negative impacts on the environment due to global warming. Thus, the circular bioeconomy is focused on using renewable carbon to replace fossil carbon and to recycle products after its useful lifetime is over. This strategy also means moving from fossil carbon to sustainable approaches for electricity production.

However, the use of renewable carbon is not a drop-in replacement for fossil carbon as fossil carbon is mostly reduced carbon meaning reactions to use it are quite different from using biomass carbon which is more oxygenated. This means that many new reaction pathways and production plants will need to be developed if renewable carbon is to replace fossil carbon (19). In addition to new reaction routes needing to be developed, an entire range of new harvesting, handling/transportation, storage, and separation processes need to be developed since a corn stalk or tree is quite different from oil. Also, a key goal in biomass handling will be to mirror the waste minimization in the refinery area where only 0.1 Kg of waste is produced per Kg of useful products (20). This really means that the current widespread practice of removing a product of interest such as essential oils or wheat grains and discarding the rest of the biomass is not ideal.

Other changes will be needed as well since if carbon materials are not being burned for chemical reaction energy, then standard thermal reactions such as cracking molecules like ethane for ethylene or calcining calcium carbonate for making lime for cement will need to be replaced. This is significant since these two products are near the top of the list in terms of CO_2 release during production. One approach will be to use electrochemical routes for these reactions but that will mean the development of new optimized reaction routes and the building of new processing plants.

Key Visions of the Biotech-based Circular Bioeconomy

As the concept of a circular bioeconomy has evolved several visions have developed. The two key ones relative to the replacement of fossil carbon are the biotechnology vision and the bioresource vision (21). The first one focuses on recent advances in biotechnology with the idea that organisms will be genetically modified to make desired carbon-based products either in field crops or by fermentation. The second one is focused on the modification of existing biomass to make the desired products. Clearly the two concepts need to be used together, taking advantage of the most efficient aspects of each to complement each other in the replacement of the broad range of fossil carbon products. In both cases new technology will be needed to bring products to market. For example, if corn is modified to produce a key starting material, the compound will still need to be efficiently extracted from the corn plant and the bioresource concept will need to be used to efficiently utilize the rest of the plant biomass unless the product is extruded like natural rubber.

Taken together, the biotechnology and bioresource visions describe a particular type of path development in economic geography models towards the establishment of a circular bioeconomy in a designated regional innovation system. New path development often follows a planned model that adapts the specific innovation system to the needs of organizations, industries, technologies, etc. in the implementation of a desired innovation agenda (22). With such planned innovation evolution, regions can then define how development will take place. However, some challenges remain in planned path development – particularly as they pertain to the high-tech biobased sectors under discussion here.

The step to commercialization – a key to the transition to circular processes in the bioeconomy – is also slow and that innovative approaches need to be developed in that area to enable the introduction and use of these technologies and to understand the spatial impacts of organizations trying to implement circular bioeconomic policies. This is particularly important in the biotechnology area as very few groups have the broad range of technologies to do the whole commercialization. This was just noted in a paper describing the efforts in the US to develop second generation bioethanol. Major plants were built and then shut down partly due to the complexity of collecting and processing corn stover (23). Thus, an understanding of technical and spatial factors must be taken into consideration.

For circular bioeconomies to have the immediate impact that is needed, solutions are required to achieve much faster commercialization of the described technologies. Here organizational clusters have emerged as potentially instrumental technologies accelerating the introduction of a bioeconomy within and across biotechnology-focused regions by addressing the related issues of problems of resource efficiency, geographical proximity, and access to knowledge resources.

ORGANIZATIONAL CLUSTERS AS EMERGENT TECHNOLOGIES IN IMPLEMENTING CIRCULAR BIOECONOMIES

Cluster Technologies

The proximity of organizations leads to the organic formation of clusters, and these clusters support regional development through their research, innovations, and the formation of new organizations (24). Clusters can be defined as “geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions […] in particular fields that compete but also co-operate" (25). Also defined as “a concentration of ‘inter-dependent’ firms within the same or adjacent industrial sectors in a small geographic area" (26) clusters are viewed as technologies that can be implemented in a planned and systematic manner. Research on cluster-based firms has shown that members are more likely to innovate than those outside of the agglomeration. This is due, in part, to knowledge spillovers, which is especially prevalent among biotechnology firms with close geographical proximity. The challenges preventing firms from participating in the circular bioeconomy from a shortage of capital, resources, or technical expertise can be alleviated by cluster participation (27). Cluster formation thus leads to better proximity, knowledge spillovers and increased innovations and allows organizations to leverage circular bioeconomy concepts more easily across their existing network and participate in the new bioeconomy (24).

Cluster Technologies as Accelerants in Implementing the Circular Bioeconomy
As resource efficiency is a key challenge for industrial production, developing systems that integrate and reuse waste into the starting material of another process is a key solution. This reduction in material consumption and energy usage can have a significant impact on environmental damage and have economic benefits. It is now that cluster technologies can step into the breach: the agglomeration of firms or, the phenomenon that businesses tend to cluster, has been shown to promote both knowledge transfer and subsequent resources sharing between them, helping them more quickly develop systems that reuse each other's waste materials. Resource productivity can thus work as a measure to help evaluate a firm's ability to implement circular bioeconomy practices (24). As companies work towards greater resource productivity, clusters can act as the bridge between companies allowing them to reach their efficiency goals and work together based on the re-use of resources and recycling (24).

The aspect of knowledge transfer is an important part of setting up the groundwork for implementing these practices as "a properly functioning knowledge transfer system is a crucial part of the surrounding support system of a circular economy" (28, p. 13). Prior literature suggests that the adoption of new innovative practices in manufacturing or service contexts, such as the circular bioeconomy, necessitates a firm's capability to acquire, disseminate and utilize internal and external knowledge (29). For example, (29) indicated that knowledge transfer positively influenced organizational innovation and performance in knowledge-intensive industries in Taiwan.

Cluster leadership of green focused clusters often implement circular economic principles as their core focus. These principles can help organizations, particularly small to medium firms, understand the regionally- based best practices for implementing circular economic solutions thereby making the administration of clusters and their agreed upon core principles the key agents toward circular bioeconomy transitions. Effective cluster leaderships can demonstrate the efficiency, innovation and economic benefits or adopt these principles to their member organizations. They also help organizations understand their role in the value chain and develop networking opportunities for their partners to create resource symbiosis (24).

CONCLUSION

Drawing on a presentation from the 2023 CPAC conference in Rome (30), this paper discussed transitions to a circular bioeconomy in terms of some of its key drivers and technologies to accelerate development and implementation in biotechnology sectors. The new technologies needed in transitions to a circular bioeconomy, especially ones focused on the transition from fossil carbon to biomass-based carbon materials, were found to produce new challenges related to long wait times for process development and commercialization – a challenge that significantly hinders the rapid transition to circular bioeconomies in planned regional innovation systems. Here, organizational clusters were proposed as emerging technologies addressing issues of resource efficiency through geographical proximity and increased knowledge transfers that would facilitate the accelerated transition to the circular bioeconomy.

REFERENCES AND NOTES

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1. What is CPAC? [Internet]. CPAC. [cited 2023Mar26]. Available from: https://apl.uw.edu/project/project.php?id=cpac
2. European Commission, 2015. *Closing the loop–an EU action plan for the circular economy*. Commun. from Comm. to Eur. Parliam. Counc. Eur. Econ. Soc. Comm. Comm. Reg. 21. COM/2015/0614
3. Stegmann P, Londo M, Junginger M. The circular bioeconomy: Its elements and role in European bioeconomy clusters. *Resources, Conservation & Recycling: X*. 2020 May 1;6:100029.
4. OECD (2009). *The bioeconomy to 2030. Designing a policy Agenda*. OECD Publishing. 1-326. Available at: http://www.oecd.org/futures/long-termtechnologicalsocietalchallenges/thebioeconomyto2030designingapolicyagenda.htm. Accessed: 19 February 2018.
5. Teräs, J., Lindberg, G., Johnsen, I.H.G., Perjo, L. & Giacometti, A. (2014). Bioeconomy in the Nordic region: Regional case studies. Nordregio Working Paper 2014:4, 1-70. Stockholm, Sweden.
6. European Commission, Directorate-General for Research and Innovation, *A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment: updated bioeconomy strategy*, Publications Office, 2018, https://data.europa.eu/doi/10.2777/792130
7. Miremadi M, Musso C, Oxgaard J. *Chemical innovation: An investment for the ages*. New York, NY: McKinsey & Company; 2013 p. 1–9.
8. Beake N, Vandy K. Svalbard: *The Race to save the fastest-warming place on Earth* [Internet]. BBC News. BBC; 2022 [cited 2023Mar26]. Available from: https://www.bbc.com/news/world-europe-63387233
9. WeForum. *How rising temperatures might impact Arctic 'Doomsday vault' in Norway* [Internet]. World Economic Forum. 2020 [cited 2023Mar26]. Available from: https://www.weforum.org/agenda/2020/07/svalbard-seed-doomsday-vault-arctic-climate-change/
10. Jefferson A. *The Cuyahoga River burned today for the first time in 51 years. Here's what we can learn from it.* Highly Allochthonous [Internet]. 2020Aug25 [cited 2020Mar26]; Available from: https://all-geo.org/highlyallochthonous/2020/08/the-cuyahoga-river-burned-today-for-the-first-time-in-51-years-heres-what-we-can-learn-from-it/
11. Hughes A. [Internet]. Life Sciences & Process Automation. COPADATA; 2022 [cited 2023Mar26]. Available from: https://blog.copadata.com/optimised-production-for-pharmaceutical-waste-reduction
12. Leal Filho W, Perry P, Heim H, Dinis MA, Moda H, Ebhuoma E, et al. An overview of the contribution of the textiles sector to climate change. *Frontiers in Environmental Science*. 2022;10.
13. Fane B, Wastl J. *When economy meets environment: Sustainable development and the case of wastewater pollution in textile manufacturing* [Internet]. Digital Science. Digital Science & Research Solutions Ltd.; 2022 [cited 2023Mar26]. Available from: https://www.digital-science.com/blog/2022/04/sdgs-wastewater-pollution-in-textile-manufacturing/#:~:text=Textile%20dyeing%20is%20the%20second,wastewater%20produces%20highly%20polluted%20discharge
14. Lindsey R. *Climate change: Atmospheric carbon dioxide* [Internet]. Dlugokencky ED, editor. NOAA Climate.gov. NOAA; 2022 [cited 2023Mar26]. Available from: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide
15. He L, Magney T, Dutta D, Yin Y, Köhler P, Grossmann K, et al. From the ground to space: Using solar-induced chlorophyll fluorescence to estimate crop productivity. *Geophysical Research Letters*. 2020;47(7).
16. Reuland F, Bylsma S. *Clean energy 101: Methane-detecting satellites* [Internet]. RMI. RMI; 2023 [cited 2023Mar26]. Available from: https://rmi.org/clean-energy-101-methane-detecting-satellites/
17. Zeng X, Ogunseitan OA, Nakamura S, Suh S, Kral U, Li J, et al. Reshaping global policies for circular economy. *Circular Economy*. 2022 Sep 1;1(1):100003
18. Tan EC, Lamers P. Circular bioeconomy concepts—a perspective. *Frontiers in Sustainability*. 2021;2.
19. Deuss PJ, Barta K, de Vries JG. Homogeneous catalysis for the conversion of biomass and biomass-derived platform chemicals. *Catal Sci Technol*. 2014Jan23;4(5):1174–96
20. Sheldon RA, Arends I, Hanefeld U. *Green Chemistry and Catalysis*. Weinheim: Wiley-VCH; 2008.

21. Frisvold GB, Moss SM, Hodgson A, Maxon ME. Understanding the U.S. bioeconomy: A new definition and landscape. *Sustainability*. 2021;13(4):1627.
22. Asheim, B. T., Isaksen, A. & Trippl, M. (2019). Advanced introduction to regional innovation systems. Edward Elgar publishing limited.
23. Bettenhausen C. [Internet]. Vol. 101, *Chemical & Engineering News*. 2023 [cited 2023Mar26]. Available from: https://cen.acs.org/magazine/101/10106.html
24. Razminienė, Kristina & Tvaronavičiene, M. (2018). Detecting The Linkages Between Clusters and Circular Economy*. Terra Economicus*. 2018. 50-65. 10.23683/2073-6606-2018-16-4-50-65.
25. Porter, M. (1998), *On Competition*. Harvard Business School Press: Cambridge, MA.
26. Isaksen, A., & Hauge, E. (2002). Regional clusters in Europe. Observatory of European SMEs, 3, 5-55.
27. Koudelková, P., Strielkowski, W., and Hejlová, D. (2015). Corruption and system change in the Czech Republic: Firm-level evidence // *DANUBE: Law and Economics Review*, 6(1), 25–46. https://doi.org/10.1515/danb-2015-0002
28. Dieleman H, Martínez-Rodríguez MC. Potentials and Challenges for a Circular Economy in Mexico. In: Greening of Industry Networks Studies. *Springer Nature*; 2019. p. 9–24.
29. Tseng, Chun-Yao & Pai, Da & Hung, Chi-Hsia. (2011). Knowledge Absorptive Capacity and Innovation Performance in KIBS. J. *Knowledge Management*. 15. 10.1108/13673271111179316.
30. Chrisman R. *To Facilitate a Rapid Transition to a Circular bioeconomy will Require the Development of New Tools to Speed Process Development* [Internet]. 2023 Mar 20. Available from: https://apl.uw.edu/project/projects/cpac/pdfs/cpac_rome_2023_agenda.pdf

2

New processing concepts and cluster technologies: catalysts for a faster and more efficient transition to a circular bioeconomy and biobased carbon materials

KEY WORDS: Circular bioeconomy; process development; biobased carbon solutions; systems thinking; cluster governance

ABSTRACT:
Addressing some of the challenges in a transition to the circular bioeconomy, this paper first explores the use of next generation processing approaches to help move pharmaceutical, chemical, and biomaterial products from fossil carbon to its biobased alternative. It posits the use of system-oriented cluster technologies through the application of cluster governance to increase both collaboration and knowledge exchange and to help facilitate the transition to a circular bioeconomy in a fast and effective manner.

INTRODUCTION
The transition to a circular bioeconomy is an important and complex task facing many governments and organizations. (1) Our previous study, *Transitioning to a Circular Bioeconomy: Key Drivers and the New Cluster Technologies to Accelerate Process Development in Biotechnology Sectors*, (2) provided a broad overview of the problems that the global community needs to address; among them the rapidly developing concern over the supply of raw materials and related environmental issues. After describing general challenges such as the loss of finite resources including metals and fossil carbon, (3) pollution caused by manufacturing waste, single use plastic and fabric waste, (4) and the increasing production of global warming gases, it went on to outline how a transition to the circular economy would help. It described the subset of issues related to circular bioeconomy and the many technology issues that will need to be solved to transition away from the use of fossil carbon for materials production. Of the two general methods discussed to provide the needed materials in the circular bioeconomy, the biotech vision (organisms genetically modified to produce needed materials) and the bioresource vision (carbon-based products would be produced from existing biomass sources), (5) the presentation focused on the bioresource vision as a promising avenue for the transition to the circular bioeconomy. It further introduced cluster technologies (interconnected companies, specialized suppliers, service providers, and firms in related industries and institutions that compete but also cooperate) (6) as one application for realizing the bioresource vision by addressing issues of resource efficiency through geographical proximity and increased knowledge transfers. (2, p. 17)

This paper continues with this discussion to expand on the new challenges produced by the technologies needed to rapidly transition to the bioeconomy with special focus on the phases of processes pertinent to the shift from fossil carbon to biomass-based carbon materials. (2, p. 17) It presents some of the findings from the presentation, *New Processing Concepts Will Help Enable the Transition to a Circular Bio-Economy* (3), given at the recent symposium hosted by the Center for Process Analysis and Control (1) held at the University of Washington, Seattle. The presentation focused on addressing symposium questions related to:

1. Next generation processing approaches to enable maximum efficiency in the production of sustainable pharmaceutics, chemicals, and biomaterials, and

2. Expanding process understanding based on the use of sensors and data handling – Enabling more efficient process optimization of complex bio-based processes, petrochemical operations, and personalized medicine (3)

Utilizing this presentation as its point of departure, this paper outlines the specific transition barriers and possibilities in moving from fossil carbons to bio-based carbons and introduces new processing concepts and technologies to facilitate this transition faster and more effectively. It looks particularly at the case of catalyst development to produce biobased carbons as well as the associated time imperative facing a new processing innovation. In addressing this issue, this paper proposes the implementation of system-oriented cluster technologies through the application of comprehensive cluster governance and the inclusion of more stakeholders to expand traditional understandings of collaboration and knowledge transfer at the global levels required to facilitate high-tech process development groups.

BARRIES TO RAPID TRANSITION TO THE CIRCULAR BIOECONOMY: TARGETING NEW PHASE PROCESSING AND ITS IMPLEMENTATION

From Fossil Carbon to Biobased Carbon: Key Technology Challenges

The key technology problem is that biomass carbon-based molecules are quite different from fossil carbon molecules both in physical state, oil liquids versus biomass solids, and in oxidation state, reduced versus oxidized. (7) These facts mean that standard gas phase processing for oil will not work for raw biomass. In addition, the catalysts used to functionalize reduced carbon will be different from catalysts needed to defunctionalize (hydrotreat) biomass carbon. (7) Thus, a whole new range of catalysts will need to be developed and optimized. This is even more difficult since more sustainable energy sources will need to be used, which suggests a transition away from thermal energy to the use of electrical energy (not simple resistance heating) for electrochemistry to drive reactions.

Also, the circular bioeconomy concept is focused on waste reduction which means developing uses for the broad range of molecules present in the 13 billion tons per year of waste ligno-cellulosic biomass (8). To productively use all of it means the biomass should be deconstructed, small molecules extracted, biopolymers components separated, and all components used whenever possible instead of burning (8). This suggests new biomass deconstruction methods such as cavitation (9) followed by steam extraction for the non-polars. The biopolymer solids may then be treated with hydrothermal liquefaction, HTL. Cavitation and HTL may be further facilitated by catalysts to aid the molecular breakup of the biomass structure. New separation methods will be needed to handle the broad range of valuable components that are released by these methods which will include non-polars, polars, and many high boilers. Also, the separated biopolymers, lignin, hemicellulose, and cellulose will for most uses need to be hydrolyzed and hydrotreated (heteroatoms removed). In general, these will be liquid phase reactions compared to the current gas phase reactions for fossil carbon processing.

THE NEED FOR NEW PROCESSING CONCEPTS

Unfortunately, one of the growing problems which initially precipitated thinking about the circular economy is the declining availability of metals which necessitates the need for more efficient catalyst use to control costs. This immediately suggests greater use of nanoparticles and single atom metal catalysts to improve efficiency. In addition, new catalyst structures are also expected to be needed as electrodes to enable better use of sustainable energy for the electrodes used in electrochemistry. In addition, modern technology will be required to produce, optimize, use, and recycle these new catalysts.

Another often overlooked problem with biomass is the composition variability, low density, and seasonable availability. This suggests the use of distributed preprocessing to optimize conditions for local variability and to reduce shipping costs which then will require more use of process analyzers coupled with advanced data processing tools to understand and insure both product composition and quality. Also, the wide range of specialty molecule extractables offers the potential for small preprocessing businesses able to extract, process, and market the diverse range of low-level molecular components while shipping the denser bulk products to larger processing operations. The distributed preprocessing will facilitate the use of local renewable power such as wind and solar for remote power generation for the mechanical equipment needed for biomass deconstruction and would also be compatible with microwave and electrochemical processing.

ADDRESSING THE TIME IMPERATIVE IN PHASE PROCESSING INNOVATION

However, all this modern technology for materials production will need to be rapidly developed if the 12% of the current oil usage (100 million barrels per day) (10) that is used to produce petrochemicals falls with the dropping demand for fossil fuel. It will be a major problem since a new chemical process often takes 5-15 years to develop (11). In addition, since new catalysts will be needed for the various liquid phase steps a significant amount of time will be needed for catalyst development. It does appear that some of the new artificial intelligence (AI) methods will be able to help speed catalyst development, but this will require a concerted effort both to further develop the optimization methods and the transfer of those techniques to process development groups. Also, for those methods to work, significantly more real time data will be required which means process development groups will need to increase their use of online analyzers. It seems that the most efficient way to speed the transition to the circular bioeconomy would be to have the various groups involved in harvesting, preprocessing, separation, conversion, and commercialization of biomass-based products work together to move forward.

AN INTEGRATIVE SYSTEMS APPROACH TO ACCELERATING INNOVATION

The insight that accelerating the transition to the circular bioeconomy through the interconnection of disparate elements and processes which involves creating new and dynamic systems in the form of much more interactive process development groups, is reflective of the integrated approaches suggested by systems thinking. Systems thinking signals the move away from interested parties merely looking into selected elements and processes taking a "one product and/or one resource" approach. (12, p. 41) This is because such an approach fails to consider the inherent nature of any given system as it consists of dynamic interconnected elements and processes, thereby overlooking the system and its complexity. (13, p. 14) As a "science of wholeness" (14, p. 5), systems theoretical thinking creates a more integrated approach (14, pp. 58-59) that, since the latter half of the 20th century, has been reconceptualized into a science based on understanding connections and relations between isolated things. (14) Systems thinking becomes increasingly relevant given the urgency of the current proposed transition to the circular bioeconomy. Considering that it can provide a holistic understanding of the intricate interactions needing to take place between entities within larger networked systems, systems thinking provides a useful framework for understanding how such process development groups can secure the quality of interactions that are needed between entities that determine performance. Given that systems thinking is particularly useful in confronting complex problems or behaviors and can be used to better predict such behaviors and adjust their outcomes for the better, (16) such an approach is pertinent in the execution of networked innovations in and through the different sectors as proposed here. (17)

APPLYING CLUSTER TECHNOLOGIES

Within specifically circular bioeconomic models, organizational clusters have emerged as an application to innovate through systems thinking. Organizational clusters are kinds of systems that allow the different actors therein (industry organizations, research institutions, and governmental institutions) to generate more efficient solutions to individual challenges. This, in turn, allows them to innovate more effectively, increasing their competitive advantage through collaborative practices (18). Clusters are formed following either research-based evidence suggesting clustering, or through bottom-up approaches that result in the more native agglomeration of firms and institutes in similar industries. As Porter (19, 6) describes, co-learning, access to qualified talent and suppliers, the sharing of specialized information, and easier experimentation and rapid prototyping are all potential benefits of cluster formation. Clusters also contribute gains in knowledge flows at multiple organizational levels with their ability to increase collaboration and the absorptive capacity of knowledge. (20) Given these benefits, clustering typically leads to increases in sustainable development through associated higher innovation and productivity outcomes. (21) Early research on the favorable outcomes demonstrated by clustering saw national governments gradually begin to introduce cluster programs throughout the 1990s and early 2000s to support innovation for sustainable development. (21) In the decades since, clusters have grown in prominence as a tool for innovation, particularly in high tech and biotech industries, where they have demonstrated their utility in helping national economies grow and increase the efficiency and productivity of organizations regionally. (20)

Special interest groups, especially the SMEs that make up these clusters, thus need access to the latest national and international networks for knowledge exchange and to develop effective collaboration with the correct stakeholders to move forward with the commercialization of biomass products. However, the formation of such clusters varies, and the policies that drive them are often difficult to define. Moreover, while loosely clustered groups may reap some of the benefits offered by basic cross-sectional collaborations and partnerships, an initiator or facilitator may still be needed to jumpstart these interactions – a role that can be taken up by effective cluster leadership. (20)

Research has explored the question of whether these collaborations and partnerships are happening spontaneously or if they are more carefully planned or "purpose built." Current findings suggest that, at least in Norway, these local and international partnerships were carefully planned, not established through casual encounters of proximity alone, (22) suggesting that a push for new process development groups would also require such initiating drivers.

ACCESS TO KNOWLEDGE NETWORKS

Moreover, effecting a timely transition to the circular bioeconomy will require the application of cluster technologies predicated upon knowledge exchanges at both local and, increasingly, international level. (23) As knowledge has become important in our globalized economy, the transition from a closed to an open model of innovation happened rapidly, with knowledge exchange becoming an important driver. (24) Research has shown that developing collaborative partnerships with both local and international organizations is essential for innovation and for the desired network effects of clustering to occur. (25) One benefit of cluster membership is the geographical proximity which gives its members access to local knowledge leading to competitive advantages. However, gaining access to international knowledge and international innovation networks has been shown to be increasingly pertinent for innovation outcomes and the ability to access the latest technology, markets, and skills. (25) Purpose built innovation clusters with access to international innovation networks are thus crucial to not only develop the optimization methods required, but to facilitate the transfer of those techniques and mitigate development time to speed the transition to the circular bioeconomy.

LOOKING AHEAD: CLUSTER GOVERNANCE AND EXPANDED MODELS FOR TARGETED INTERVENTION

While cluster leadership has a significant role in facilitating the aforementioned collaborative interactions, additional structural elements must be included to ensure the cluster can work as a catalyst to meet its desired outcomes "to advance the cluster and develop a sustainable competitive advantage." (26 p. 20) Called cluster governance, this supposes a more integrated approach to the functional running of the cluster than cluster management alone. While cluster management may be focused on the daily tasks of managing the cluster members and trying to establish common goals of the member organizations, one goal of effective cluster governance is to evaluate how well the cluster itself is being managed. Cluster governance thus represents the interests of the cluster stakeholders which can include universities and research institutes, large and small companies, governmental institutions, and several other supporting structures. (26 p. 20) Cluster governance may be tasked with hiring the cluster management and be involved in evaluating the outcomes of short-term planning and long-term strategies.

Effective cluster governance can be evaluated on how well certain values of cluster governance are implemented. This can, for example, include an evaluation of the effectiveness of the cluster which relates to how aligned the cluster (through its management) is to its stakeholders' vision and goals. This is achieved through communication with stakeholders on what the vision should be and effective dialogue to understand concerns. A second value, accountability, relates to the members fulfilling their collaborative responsibilities. These responsibilities are those of the actors in the triple helix cluster formation (governmental institutions – industry organizations– research institutions) and can include how well industry clusters facilitate collaborations between themselves and their partner research institutions to develop new products. Additionally, values like efficiency and commitment relate to evaluating the outcomes based on set targets, commitment in the long term and contributing support to members. (26) Through such targeted steering practices, effective cluster governance can equal more accountability and responsiveness for the cluster (26)

Traditional cluster governance and management is based on the triple helix model and its evaluation is, in part, based on the outcomes of such three-pronged relationships. To achieve the large transitions towards the circular bioeconomy as proposed here, including more stakeholders than those found in the traditional triple helix model may be needed. Research over the last two decades argues that entrepreneurship and venture capital should be added as important and equal pillars to the cluster model. (27) Range (28) explains the entrepreneur-pillar to encompass everything from business incubators and accelerators to small meetups and large events, while venture capital and startup companies is an important pillar in helping to fund a system and to then help it scale up. These two additions would then create a "supercluster" that see a shift from the triple helix model of cluster compositions to a five-point Pentagon model that actively recruits cluster members from corporate, capital, government, academia, and entrepreneurship from which "a system-level innovation engine for national and international impact" (28, p. 1) can be built. Such expansions in cluster models and their evaluation may be critical targeted interventions to facilitate and speed the transition to the circular bioeconomy.

CONCLUSION

Drawing on the presentation from Center for Process Analysis and Control (3) held at the University of Washington, Seattle, this paper addressed the importance of a transition to the circular bioeconomy. It charted specific transition barriers and outlined processing technologies that can help move pharmaceutical, chemical, and biomaterial products from fossil carbon to its biobased alternative. It looked particularly at the case of catalyst development to produce biobased carbons as well as the associated time imperative facing a new processing innovation. In helping to facilitate this transition faster and more effectively, this paper proposed the implementation of system-oriented cluster technologies through the application of comprehensive cluster governance and the inclusion of more stakeholders to expand traditional understandings of collaboration and knowledge transfer at the global levels required to facilitate high-tech process development groups. Building on this research, future studies could evaluate outcomes-based cluster governance on purpose-built bioclusters that have adopted a multi-stakeholder or pentagon approach to understand how such practices can be replicated for future cluster formations.

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REFERENCES AND NOTES

Koch M. CPAC *Summer Institute. In: Center for process analysis and control* [Internet]. Seattle; 2023 [cited 2023 Aug 21]. Available from: https://apl.uw.edu/project/project.php?id=cpac

Chrisman JE, Chrisman RW. Transitioning to a circular bioeconomy: key drivers and the new cluster technologies to accelerate process development in biotechnology sectors. *Chimica Oggi - Chemistry Today*. 2023;41(2):14–8.

Chrisman RW. *New Processing Concepts Will Help Enable the Transition to a Circular Bio-Economy* [Internet]. CPAC Summer Institute. CPAC; 2023 [cited 2023 Aug 5]. Available from: https://drive.google.com/drive/folders/1mH4gl7cEkWhtsDXOl3yPDhXB5zeUatHi

Why consider a circular economy? J.P. Morgan; [cited 2023 Aug 21]. Available from: https://privatebank.jpmorgan.com/gl/en/insights/investing/why-consider-a-circular-economy

Frisvold GB, Moss SM, Hodgson A, Maxon ME. Understanding the U.S. bioeconomy: A new definition and landscape. *Sustainability*. 2021;13(4):1627.

Porter ME. *Clusters and the new economics of competition*. Harvard Business Review; 1998. p. 77–90.

Deuss PJ, Barta K, de Vries JG. Homogeneous catalysis for the conversion of biomass and biomass-derived platform chemicals. *Catal Sci Technol*. 2014;4(5):1174–96.

Bimestre TA, Júnior JA, Canettieri EV, Tuna CE. Hydrodynamic cavitation for Lignocellulosic Biomass Pretreatment: A review of recent developments and future perspectives. *Bioresources and Bioprocessing*. 2022;9(1).

Calcio Gaudino E, Cravotto G, Manzoli M, Tabasso S. Sono- and mechanochemical technologies in the catalytic conversion of biomass. *Chemical Society Reviews*. 2021;50(3):1785–812.

Fossil fuels [Internet]. EESI. *Environmental and Energy Study Institute*; 2021 [cited 2023 Aug 5]. Available from: https://www.eesi.org/topics/fossil-fuels/description

Miremadi M, Musso C, Oxgaard J. *Chemical innovation: An investment for the ages*. New York, NY: McKinsey; 2013. p. 1–9.

Gabrielle B, Barbottin A, Wohlfahrt J. The Environmental Impacts of Non-food Biomass Production Through Land-Use Changes: Scope, Foci and Methodology of Current Research. *Sustainable Agriculture Reviews*. 2018;30:39–77. https://doi.org/10.1007/978-3-319-96289-4_3

Robledo-Abad C, Althaus H-J, Berndes G, Bolwig S, Corbera E, Creutzig F, et al. Bioenergy production and sustainable development: science base for policymaking remains limited. *GCB Bioenergy*. 2016;9(3):541–556. https://doi.org/10.1111/gcbb.12338

Haraldsson HV. *Introduction to system thinking and causal loop diagrams. Reports in ecology and environmental engineering* 1. 5th edn. Lund University, Lund, Sweden; 2004.

Checkland P. Systems Thinking. In: Currie WL, Galliers B, editors. *Rethinking Management Information Systems: An Interdisciplinary Perspective*. Oxford University Press; 1999. p. 45–56. https://doi.org/10.1604/9780198775331

Ross DA, Wade JP. *A Definition of Systems Thinking: A Systems Approach. Procedia Computer Science*. 2015;44:669-678. https://doi.org/10.1016/j.procs.2015.03.050.

Jofre S. *Exploring the role of knowledge and technology transfer in innovation systems*. In Proceedings of Triple Helix IX International Conference: “Silicon Valley: Global Model or Unique Anomaly?” Vol. IX. Stanford University Press; 2011. http://www.leydesdorff.net/th9/Paper%20O-109%20JOFRE.pdf

Wilson J, Wise E, Smith M. Evidencing the benefits of cluster policies: towards a generalised framework of effects. Policy Sci [Internet]. 2022;55(2):369–91. Available from: https://doi.org/10.1007/s11077-022-09460-8

Porter ME. The competitive advantage of nations. Free Press; 1990.

Giest S. *The Capacity to Innovate - cluster policy and management in the biotechnology sector*. 2021. p. 1–188.

Mar M, Massard N. Animate the cluster or subsidize collaborative R&D? A multiple overlapping treatments approach to assess the impacts of the French cluster policy. *Industrial and Corporate Change*. 2021 Aug 1;30(4):845–67.

Fitjar RD, Rodríguez-Pose A. Nothing is in the Air. *Growth Change*. 2017 Mar 1;48(1):22–39.

Calignano G, Quarta CA. The persistence of regional disparities in Italy through the lens of the European Union nanotechnology network. *Regional Studies, Regional Science*. 2015;2:469-478. 10.1080/21681376.2015.1075898.

Chesbrough H. *The era of open innovation*. MIT Sloan Management Review. 2003;44:35–41.

Calignano G, Hassink R. Increasing innovativeness of SMEs in peripheral areas through international networks? The case of Southern Italy. *Region*. 2016 Mar 14;3(1):25–42.

Schretlen JH, Dervojeda K, Jansen W, Schafmeister B. *Uncovering excellence in cluster management*. PwC, the Netherlands; 2011. https://www.pwc.com/gx/en/psrc/pdf/cluster_management.pdf. Accessed 15 August 2023.

Boye J. *Exploring business models in Global Innovation Clusters* [Internet]. Boye & Company. Boye & Company; 2021 [cited 2023 Aug 22]. Available from: https://www.boye-co.com/blog/2021/5/31/exploring-business-models-in-global-innovation-clusters

Rangen C. *Five Pillars of Innovation Superclusters - Strategy tools* [Internet]. Strategy Tools - The Modern Strategist's Platform. 2021 [cited 2023 Aug 22]. Available from: https://www.strategytools.io/superclusters/

3

More frequent and stronger ties? Using QCA to assess the effects of policy in a Norwegian biotech cluster

Abstract
The purpose of this article is to evaluate the possible impact of an indirect policy measure implemented in a Norwegian biotech cluster aiming to enhance collaborations between small and medium-sized enterprises (SMEs) and higher education institutions (HEIs). Through the adoption of a dynamic approach (i.e., two distinct periods; 2014-2017 and 2018-2021) and qualitative comparative analysis (QCA), this study demonstrates an increase in the frequency and intensity of collaboration between the two periods. It also highlights the combinations of conditions possibly enabling SMEs to benefit from the targeted indirect policy measure. The study shows how structural, 'softer' elements such as age, size, and trust towards the cluster administration can overcome deficiencies in innovativeness and human capital and similarly lead to more frequent and intense ties.

Key Words
cluster administration, policy evaluation, regional innovation systems, regional development, qualitative comparative analysis

1. Introduction

To contribute to overarching national goals of improved sustainable development, policymakers of the Inland region of Norway are pushing for the expedited implementation of the bioeconomy among its industries. The second largest county located in the east of the country bordering Sweden, with a total land area slightly larger than Denmark, Inland is a peripheral region built on agricultural activities and the extraction of natural forest-based resources due to its favorable geography. Numerous small to medium-sized enterprises (SMEs) and higher education institutions (HEIs), which are geographically and economically separate from the oil producing west of the country, remain closely linked to food production and forestry industries. Among the Inland regional governments' recent targeted developmental goals, was to facilitate cooperation by encouraging more cluster projects and strengthening interaction between stakeholders within the innovation sector (HEIs, business, and government). This strategy has resulted in the establishment of a bioeconomy-focused regional innovation system (RIS) organized around individual companies, networks, and clusters focused on high-tech sectors, including food technology, genetics and breeding, biotechnology, agriculture, and forestry (Cavicchi, 2018; The Inland region, 2017).

These goals are also supported at the national level, with the Norwegian bioeconomy strategy aiming to provide the knowledge exchange platform needed "to encourage sustainable, bioeconomy-oriented industrial development" (Hallén, 2016). At the regional level, this development is implemented through individual biotechnology clusters which may allow peripheral regions like Inland to overcome their geographical marginality and 'lock-in' situation, by contributing to positive outcomes in terms of new industrial and developmental paths (Isaksen & Jakobsen, 2017; Nilsen et al., 2023; Tödtling & Trippl, 2018). This exploratory study focuses on the Hamar-based NCE Heidner Biocluster. The cluster focuses on sustainable food production and the green bioeconomy, which are the key industries in the Inland region of Norway and consists of 45 members of which 38 are SMEs. Recognized in 2018 as a National Cluster of Excellence (NCE) by the Norwegian government and recipient of a Gold Label from The European Secretariat for Cluster Analysis (ESCA), the Heidner Biocluster members combined have over 15,000 employees and a NOK 66 billion turnover (NCE Heidner Biocluster, 2021).

Several gaps in the literature are examined. This includes the research gap that aims to understand the collaboration that occurs between SMEs and HEIs in clusters and how SMEs can overcome their lack of absorptive capacity (Makedos, 2014); the policy gap of how effective cluster management is in implementing its policies (Wilson et al., 2022); and the method gap that few studies feature a dynamic approach, and few say much on the characteristics that organizations should possess to benefit from the policy measures implemented by cluster management. QCA allows us to find these characteristics and focus on how the policies affect individual SMEs (Calignano et al., 2018). The research was carried out to understand, *what are the possible effects of indirect policy measures carried out by the cluster administration? and what are the characteristics of the* *targeted SMEs that primarily benefit from these policies*? To address the research gaps and the questions above, this article compares the policies implemented in 2014-2017 to their outcomes in 2018-2021 based on different knowledge channels to understand whether the policy measures implemented by the cluster administration led to more and stronger connections. Understanding these connections may help policymakers create better tools to implement improved cluster policies (Doloreux & Porto Gomez, 2017).

In response to these questions, a crisp-set qualitative comparative analysis (csQCA) was conducted based on two data sets. One set is the number and frequency of ties and the second set is on the characteristics of firms in which these ties mainly materialize the effects of the policy measures. The analysis shows that more than half of the surveyed SMEs saw an increase in collaboration with HEIs from the first to the second period. This increase reflects the policy measures implemented by the cluster administration in the first period which aimed to increase collaboration not only amongst its members, but between SMEs and HEIs (personal communication, cluster management, August 25, 2023). This article shows the combinations of conditions that led to this increase in collaboration over the two time periods. The latter is a critical point since it shows which characteristics (conditions) a given SME should possess to benefit from policy measures to enhance networking and related knowledge exchange in a technology cluster.

2. Background and Previous Research

2.1 Understanding Cluster Dynamics and their Evaluation

Porter (1998) defines clusters as "geographic concentrations of interconnected companies and institutions in a particular field" (p.78) that is "widely acknowledged as a type of activity-specific system, situated within broader regional innovations systems" (Wilson et al., 2022, p. 2). As a mechanism for effective knowledge exchange, Norway implemented cluster policies through its national cluster program in 2002. To date, it has supported the development of 33 clusters with financial and other services in fields from cancer to maritime research with funding provided through The Norwegian Ministry of Trade and Labor and The Ministry of Local Government and Innovation (Norwegian Innovation Clusters, n.d.). Support for cluster development derives, as Giest (2021) explains, from the national and regional economic benefits cluster activities demonstrate through, for example, improvements in employment and productivity. Such benefits result from increases in collaboration between SMEs, created by the innovative ways clusters organize and manage knowledge flows. On the one hand, structured cluster management facilitates knowledge exchange through collaborative capacity-building activities. This includes defining a shared vision and allocating joint resources to this end; developing formal structures of regular communication, support, and collaboration amongst members and partners; and establishing financing powers for shared projects. On the other hand, absorptive capacity-building activities facilitate the establishment and continuous development of both intra- and extra-cluster knowledge systems to increase competitive advantage (Giest, 2021, pp. 138-139). Far from being the simple product of knowledge spillovers due to geographic proximity, cluster dynamics itself – particularly its function as a knowledge management mechanism – is understood as linked to performance, and merits further attention (Schretlen et al., 2011).

For several reasons, the literature on cluster policy evaluation is still largely fragmented, among them complex policy effects, methodological challenges, and difficulty comparing cluster policy programs (Wilson et al., 2022). There are multiple factors that make evaluating cluster policy challenging – from the variety of industries represented in a cluster to the challenge of evaluating and quantifying the effects of knowledge spillovers and the degree of trust amongst members (O'Dwyer et al., 2023; Ter Wal & Boschma, 2009). Moreover, it is problematic to determine a direct relationship between a given indirect policy and the outcomes observed (Calignano et al., 2018). Such challenges are further compounded when considering variation in contexts – the different histories, industries, organizations, socioeconomic settings, cultures, traditions, etc. – that clusters are characterized by (Giest, 2021). As such, the differing outcomes of similar policy measures in different clusters across regions may impact how they can be measured. The literature reveals that a flexible and adaptable approach, one that relates to the specific region and the current context with a "smart and flexible combination of indicators and evaluation approaches" (Wilson et al., 2022. p. 14), may be the most effective. Studying the effects of indirect policy measures in peripheral regions, Calignano and Fitjar (2017) found that partnerships amongst organizations in Italy can form through indirect policy measures when compared against direct R&D support. Moreover, Nishimura and Okamuro (2011) describe indirect networking having a greater impact on innovation outcomes in Japanese clusters when compared with direct R&D support. Given both the complexity and nuance of cluster policy evaluation, research would benefit from more empirical analyses on the nature, impact, and evaluation of indirect policy measures in different types of clusters across different geographical scales (Wilson, 2022).

2.2 The Targeted Policy Measure and Theoretical Framework

This study presents a snapshot of two policy periods to examine if the NCE Heidner Biocluster cluster's indirect initiatives from 2014-2017 impacted on the 2018-2021 period. In the 2014-2017 period, the Biocluster management implemented a policy to increase collaboration between SMEs and HEIs, responding to the Norwegian Innovation Cluster program's imperative to implement policy instruments that specifically targets cluster mechanisms that "promote knowledge transfers, increased interaction, collaboration, networking and learning" (Røtnes, 2017, p. 15) i.e., building stronger connections. The desire for stronger connections was driven by the understanding that knowledge sharing could benefit all SMEs, especially knowledge exchange from HEIs to SMEs. Stronger connections between members could also lead to more collaborations outside the cluster – both nationally and internationally – at a subsequent stage of the cluster's development. The specific actions carried out by the cluster administration to increase ties included hosting webinars, sending out email newsletters, consulting on research grants, hosting themed workshops, and conducting individual update meetings by phone (personal communication with cluster management, January 4th, 2022).

In its capacity as a knowledge management mechanism, the NCE Heidner Biocluster thus implemented an indirect policy measure aimed at enhancing the innovativeness of SMEs through intra-cluster collaborations with HEIs – a management strategy prevalent in the cluster literature (Gulbrandsen & Solesvik, 2018). As demonstrated by Calignano et al. (2018), such collaborations can be based on a variety of knowledge channels (e.g., partnerships, business contacts, co-publications, informal contacts) through which SMEs may exploit knowledge that they acquire from HEIs. However, for this knowledge to be truly beneficial to a region, the knowledge flows must exist in an ecosystem designed to absorb and disseminate new knowledge. This is what scholars define as 'absorptive capacity' (i.e., the ability of an SME/groups of SMEs to recognize, assimilate and exploit relevant external knowledge) (Cohen & Levinthal, 1990) and is a critical theoretical concept through which to study and interpret the potential number and strength of intra-cluster collaborations (Giuliani, 2007). These concepts, together with trust (Liao, 2010), seem to play a key role in embeddedness and networking dynamics at the cluster level. If, in the case of larger SMEs, their resources make it more likely to have the capacity to form linkages with HEIs even at further distances (Calignano, 2019), smaller SMEs may still benefit from these knowledge flows through their position in a regional ecosystem such as a cluster (Calignano & Jøsendal, 2018). Based on these considerations, this study tests the assumption that the indirect policy measure implemented by the NCE Heidner Biocluster management, to a certain degree, positively impacted the number and strength of collaborations between the cluster's SMEs and HEIs. To this end, csQCA is used to test three hypotheses: (1) large SMEs with more human capital collaborate more; (2) large, more innovative SMEs benefit more from cluster policy; and (3) older firms with higher trust towards cluster administration benefit more from cluster policy.

3. **Method, Data, and Analysis**

3.1 Qualitative Comparative Analysis

To test the three hypotheses presented above, I utilized Qualitative Comparative Analysis (QCA). QCA is an effective but still largely unexplored approach in regional science and refers to a group of techniques designed for small, case-based comparative research and evaluation (Ragin, 1987; Wagemann et al., 2016). Through the adoption of crisp set QCA (csQCA - dichotomous outcome and conditions), this study can identify the combinations of structural factors (year of foundation, size, human capital, innovativeness, trust) of cluster members that allow some SMEs to interact more frequently and intensely with HEIs, both in general and in comparison, with the first targeted period. csQCA is used to better understand the connections between structural factors (also called conditions) and their outcomes. Used in fields like political science, sociology, and business studies, with cases ranging from five to several thousand, csQCA combines the benefits of both qualitative and quantitative research to reach conclusions even when only a limited number of cases are available (Jordan et al., 2011; Verweij et al., 2019; Wagemann et al., 2015). Within csQCA, once cases are determined, outcomes and conditions are decided, and the data is calibrated and used to build a matrix. Thereafter, the necessary conditions are analyzed, and a truth table is built which corresponds to the analysis of sufficient conditions. This is followed by interpretation and the presentation of results (Astbury, 2022).

Following these assumptions of csQCA, the median was used to differentiate between the presence and absence of the outcome and the various conditions (i.e., year, size, innovativeness, and trust, with the only exception of human capital (i.e., presence or absence of employees with a Ph.D. degree)). This analysis can reveal not only what makes SMEs more prone to collaborate with HEIs (i.e., higher number of collaborations in the 2018-2021 period), but also the possible differentiated impact of the cluster policy on SMEs based on the characteristics of the latter i.e., difference in terms of number of ties and ties' intensity in the 2018-2021 compared to 2014-2017 periods, the higher the positive difference the more relevant the possible impact. The impact of the policy measure is materialized in a positive difference related to ties' strength relating to the transition from the first to the second period.

3.2 Data and Analysis

Member SMEs were contacted between fall 2022 and summer 2023. The surveyed members were an accurate representation of the cluster, by size (SMEs), industry (bioeconomy), and location (based near Hamar). The survey focused on basic information, including year of establishment and the sectors they operated in. It covered changes in leadership, educational backgrounds, and economic data between the two periods. Main product areas and product development stages and the main areas of collaboration were investigated. The survey covered patents granted and then focused on the SME's level of trust in and outside the cluster. It concluded with questions on the performance of the cluster leadership and their involvement in encouraging collaborations and meeting expectations on the activities carried out in the cluster.

The survey thus focused on collecting data on the numbers and strength of ties based on different relational indicators. These indicators were selected based on the knowledge channels used to calculate the frequency and intensity of ties inspired by the framework from Calignano and Fitjar (2017). The following relational indicators from their study were used:

- 'partnerships' refer to participation in joint research projects at the EU and domestic level. The knowledge transferred through this type of collaboration is considered critical by many authors (Autant-Bernard et al. 2007; Calignano 2014; Muscio & Ciffolilli, 2018).
- 'business contracts' refer to agreements with clients and suppliers, while 'research contracts' designates an agreement related to research activities (Calignano & Fitjar 2017).
- 'co-publications' are published research involving industrial and academic scholars belonging to the NCE Heidner Biocluster (on how co-publications are used as indicators in research and innovation networks, see Schaeffer et al., 2020).
- 'Informal contacts' are relationships based on acquaintance, kinship, previous common work experiences, etc. This is considered a key indicator for capturing a trustful atmosphere in a cluster or innovation ecosystem (Schaeffer et al., 2020).

Table 1. *Operationalization of knowledge channels and ties' strength between 2014-2017 and 2018-2021*

Two Periods (2014-2017 and 2018-2021)				
		Strength of Ties		
Relational Indicators/knowledge channels	**Description of ties**	**Weak**	**Moderate**	**Strong**
Business Contracts	Overall number of contracts	1 to 5	6 to 10	>10
Research Contracts	Overall amount of research contracts	Up to 1mil. NOK	1-6mil. NOK	>6mil. NOK
Co-publications	Overall number of co-publications	1	2 to 5	>5
Partnerships	Overall number partnerships	1	2 to 5	>5
Informal contact	Intensity of informal contact	Weak	Moderate	Strong

Table based on Calignano and Fitjar (2017) and Calignano et al. (2018). NOK=Norwegian kroner.

From the survey data, ties established through different knowledge channels (partnerships, business contacts, research contracts, and informal contact) were weighted based on their intensity (weak, moderate, strong) as illustrated in Table 1 (see Table 2 for how ties and their weight were operationalized). The value of 1 was attributed to each weak tie, 1.5 to moderate ties, and 2 to strong ties. All weighted ties in each targeted period were added and both the overall weighted ties in 2018-2021, and the difference between weighted ties in 2014-2017 and 2018-2021 were calculated. This is in line with the approach used by Calignano et al. (2018) and

Calignano (2019). This approach considers the intensity of ties (weighted ties) in addition to their frequency (number of ties) – a more accurate way to measure the potential outcome of a certain collaboration. That is, based on the objectives of the analysis, it is assumed that having fewer, stronger ties could be more relevant in terms of knowledge acquisition than having more, weaker ties (i.e., the stronger the tie, the higher the possible impact of collaborations). From a relational viewpoint the assumption is that bigger research projects and related contractual agreements normally involve more face-to-face meetings, phone calls, email exchanges, joint tests etc. This leads to more intense knowledge exchange. Alternatively, the number of recurring contracts allows determination of the frequency of knowledge exchange. This is particularly relevant with respect to contact without research content due to more cyclical and standardized operations.

4. Results and Discussion

The survey response rate (n=11) represents 31% of the total cluster SMEs. For a small case study with few observations such as this, csQCA remains an effective choice since it can extrapolate reliable and meaningful findings even when very few cases are available (e.g., from <10 to a few hundred; see Jordan et al., 2011). As shown in Table 4, csQCA was used to examine what the single conditions (year, size, human capital, innovation, trust), if any, would be necessary for the hypothesized outcomes to take place (i.e., overall weighted ties in 2018-2021 and difference between the two periods) and which combinations of conditions would be considered sufficient for qualifying an organization as high scoring in terms of collaborations in 2018-2021 (Table 4). The same sufficiency analysis was carried out regarding the difference in terms of weighted ties from the second to the first period to capture the type of SMEs in which the impact of the policy measure implemented by the Heidner cluster materialized (Table 5).

4.1 SME Collaborations of the NCE Heidner Biocluster

This section presents selected statistics related to the surveyed SMEs and their frequency and intensity of collaborations expressed through the evolution of their ties. The different knowledge channels, (i.e., the partnerships, research contracts, business contracts, co-publications, and informal contacts) reported between each SME and HEI were calculated and weighted.

Based on the raw data from Table 2, Figure 1 illustrates the 11 cluster members' weighted ties in the two surveyed periods. A total of 39 ties in 2014-2017 and 42 ties in 2018-2021 were observed, with an increase of 7.7% between the periods. Moreover, the overall values for weighted ties in both periods, and their difference from the second to the first, were calculated. The number of overall weighted ties increased from 51.5 in 2014-2017 to 61 in 2018-2021. This corresponds to an 18.4% increase. This positive result would have been even more significant if not for a key SME (firm 6), which experienced the most significant decrease in ties from the first to the second period of 14 to 9 (-36%) and a weighted decrease of ties from 22 to 15 (-32%) despite being the SME with the greatest number of ties.

Figure 1. *Weighted Ties of SMEs for the periods 2014-2017 and 2018-2021.*

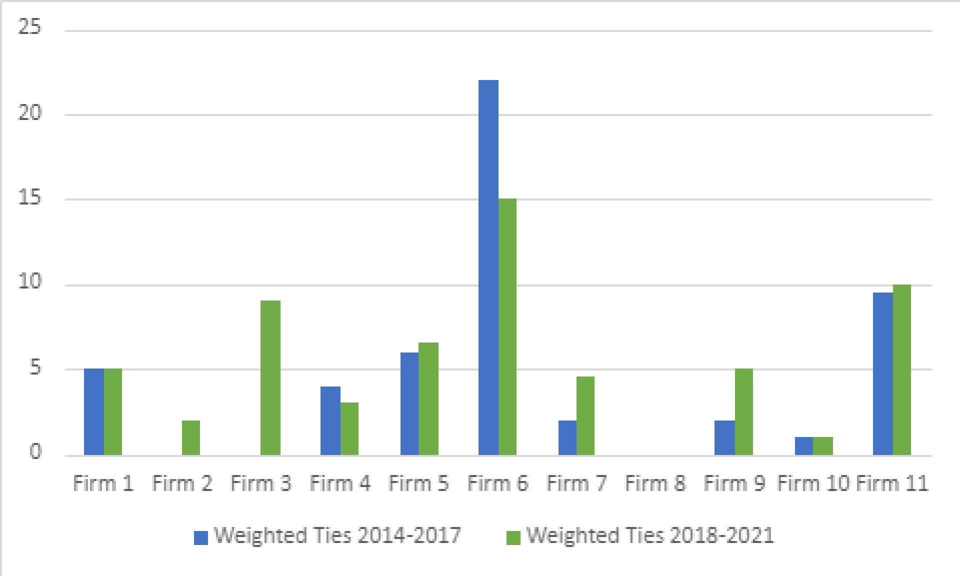

Table 2. *Raw data of ties, weighted ties, and differences for the periods 2014-2017 and 2018-2021.*

SMEs	Ties 1st Period	Ties 2nd Period	Difference	Weighted Ties 1st Period	Weighted Ties 2nd Period	Difference
Firm 1	5	5	0	5,00	5	0,00
Firm 2	0	2	2	0,00	2	2,00
Firm 3	0	5	5	0,00	9	9,00
Firm 4	3	2	-1	4,00	3	-1,00
Firm 5	5	4	-1	6,00	6,5	0,50
Firm 6	14	9	-5	22,00	15	-7,00
Firm 7	2	4	2	2,00	4,5	2,50
Firm 8	0	0	0	0,00	0	0,00
Firm 9	2	4	2	2,00	5	3,00
Firm 10	1	1	0	1,00	1	0,00
Firm 11	7	6	-1	9,50	10	0,50
TOTAL	39	42	**3**	51,50	61	**9,50**

4.2 SME characteristics of the NCE Heidner Biocluster

Table 3 illustrates the raw data of the surveyed SME firms' characteristics during the first period. On average, SMEs were founded in 1979. The oldest SME in absolute terms was founded in 1895, while the youngest in 2019. Older SMES represent more traditional agricultural SMEs in sectors such as animal breeding and food production and were instrumental in forming the cluster. Older SMEs also demonstrated stronger and more varied views of the performance of cluster management and stronger embeddedness in its function, demonstrated in Table 4 as trust (personal communication, July 14th, 2023). For workers with PhDs, since all the companies who have at least one PhD worker reported less than 25% of the total, I decided to use binary variable to describe them. The median (i.e., the statistical method used to calibrate Outcomes 1 (Table 4) and 2 (Table 5) as well as the conditions in csQCA) year of foundation of the SMEs under analysis is 2002. The median size of the cluster SMEs is nine employees, and of a total 351 employees of the eleven SMEs, 89% work for SMEs established before 2002. The median opinion score on the cluster administration from the SME firms was an 8 out of 10.

Table 3. *Raw data of firms' characteristics from first period 2014-2017.*

Firm	Foundation Year	Size	Workers with PhD	Patents	Opinions about the cluster
Firm 1	**2005**	6	1	0	8
Firm 2	**2016**	1	0	0	8
Firm 3	**2019**	0	0	0	8
Firm 4	**2015**	1	0	1	8
Firm 5	**1895**	15	1	0	5
Firm 6	**2002**	28	1	8	9
Firm 7	**1935**	200	1	0	9
Firm 8	**1935**	40	1	1	7
Firm 9	**1958**	50	1	0	6
Firm 10	**2015**	1	0	0	9
Firm 11	**1975**	9	0	0	10

4.3 Conditions for SME Collaborations of the NCE Heidner Biocluster

The previous two sections reported the key statistics related to the surveyed SMEs, their frequency and intensity of collaborations in both periods under analysis and in the transition between them, as well as their key characteristics. Building on these findings, this section presents the combinations of conditions leading to increased collaborations in the second period.

As a first step, an analysis of necessity was conducted to understand if each of the conditions (year, size, human capital, innovation, and trust) alone could represent a necessary condition to achieve one of the outcomes of higher collaborations in period two. In both cases, no conditions are necessary since the consistency is <0.90 (on the interpretation of this result, see Ide & Mello, 2022). More interestingly, Table 4 shows the combination of conditions sufficient to achieve higher collaborations with HEIs in the 2018-2021 period, achieved through an analysis of sufficiency. It also shows the SMEs meeting these conditions. Table 4 indicates that SMEs with Ph.D.-level staff and higher levels of trust in cluster administration are more likely to collaborate with HEIs. The SMEs that are older and larger and have more trust in the cluster leadership do not need human capital (Ph.Ds.) or innovativeness (patents) to have increased collaboration. However, those that have a low level of trust can still collaborate if they have year (older), size (larger) and human capital. This may indicate that larger, more established, and embedded SMEs that have in-house technical expertise do not need to rely on the cluster administration to increase the number of collaborations with HEIs, but if the SMEs do not have the technical expertise themselves, trust in cluster leadership can lead to more collaborations.

***Table 4**. Outcome 1: Combinations of Conditions for the period 2018-2021*

Outcome: COLLABORATIONS WITH HEIs (2018-2021)	**YEAR**	**SIZE**	**HUMAN CAPITAL**	**INNOVATION**	**TRUST**	**Raw coverage**	**Unique coverage**	**Consistency**	**Cases**
Solution 1	○	○	●	○	●	0.17	0.17	1	SME 1
Solution 2	●	●	●	○	○	0.33	0.33	1	SME 5, 9
Solution 3	●	●	○	○	●	0.17	0.17	1	SME 11
Solution 4	●	●	●	●	●	0.17	0.17	1	SME 6
Solution consistency: 1									
Solution coverage: 0.83									

Legend: Black circles (‘●’) indicate the high level of a condition; Empty circles (‘○’) indicate the low level of a condition; Blank cells indicate an irrelevant condition where the condition can be at a high or low level.

Table 5 shows the move from collaborations in 2018-2021 to the changes observed in this second period compared to the previous one (i.e., the possible outcome of the policy measure implemented by the NCE Heidner Biocluster and the second outcome in csQCA terms). The combination of SME age (year), size and human capital (percentage of Ph.Ds.) was more likely to impact the difference in the number of collaborations from the second to the first period. The combination of age (year) and size and trust was another combination that had a high level of impact on the difference in collaborations. Innovation (patents) had a low impact. It may indicate that the SMEs who were older, larger, and already had a highly educated workforce, did not need patents or high levels of trust in the cluster administration to collaborate. However, if trust was present, SMEs could benefit from needing less in-house expertise to show the biggest difference in collaborations from the second to the first period.

***Table 5**. Outcome 2: Combinations of Conditions and Difference from the 2nd to the 1st period*

Outcome: DIFFERENCE (from the 2nd to the 1st period)	YEAR	SIZE	HUMAN CAPITAL	INNOVATION	TRUST	Raw coverage	Unique coverage	Consistency	Cases
Solution 1	●	●	●	○		0.50	0.33	1	SME 5, 7, 9
Solution 2	●	●		○	●	0.33	0.17	1	SME 7, 11
Solution consistency: 1									
Solution coverage: 0.67									

Legend: Black circles (‘●’) indicate the high level of a condition; Empty circles (‘○’) indicate the low level of a condition; Blank cells indicate an irrelevant condition where the condition can be at a high or low level.

The unique combination of conditions that lead to the outcomes from the findings are used to inform the three stated hypotheses: first, that larger SMEs with more human capital collaborate more; second, that large, more innovative SMEs benefit more from cluster policy and; third, that older firms with higher trust towards cluster administration benefit more from cluster policy.

When examining the first hypothesis, the results confirm that larger firms with more human capital are more likely to collaborate with HEIs. This may be due to their higher absorptive capacity, taking advantage of their in-house expertise and existing organizational frameworks and policies for collaborating with HEIs. Similarly, the second hypothesis, that larger, more innovative firms are more likely to benefit from cluster policy, is confirmed, which may also relate to the SMEs' higher absorptive capacity. These firms have historically focused on developing their intellectual property and may be more likely to collaborate with HEIs to further their development. When examining the third hypothesis, high levels of trust, this softer element played a key role in overriding the need for human capital (as proposed in hypothesis one). This may be explained by the higher likelihood of older and larger SMEs having more embeddedness in the cluster network and relying less on cluster management for increased collaborations. However, despite the overall increase in terms of ties' frequency and intensity, I cannot exclude that the effects of the cluster policy are skewed towards certain older, better equipped and more integrated members. In terms of increased collaboration, the cluster administration also took an active role in fostering and evaluating them. This was accomplished through surveys, annual reports, which counted the number of projects and grants received, one on one interviews, and focus groups by theme (personal communication, cluster management, December 15, 2023).

5. Concluding Remarks

Globally, effective cluster policies are an important part of regional innovation and development. However, work remains to develop more cohesive frameworks for cluster policy and its evaluation (Wilson et al., 2022). Clusters are essential in operationalizing regional policies and their progression towards a common framework for cluster policy evaluation. Following recent studies, this paper demonstrates the efficacy of csQCA as a tool in identifying and evaluating enablers of collaborations between SMEs and HEIs to make more effective policy decisions for the development of a region. In line with previous research, this paper suggests that adopting csQCA to examine relatively small clusters (<100 members) can contribute to a better understanding of the mechanisms of cluster policies and their evaluation (Calignano et al., 2019; Ter Wal & Boschma, 2009; Wilson, 2022) such as that of enhanced relationships between SMEs and HEIs in the present case study. This paper represents one of the first attempts known to the author using a promising yet unexplored methodological tool such as csQCA in examining policy initiatives in relatively small clusters in peripheral regions. This paper could help create a toolkit to help cluster organizations, policymakers, and evaluators understand the real impact of the implemented policy and possibly improve their strategies in this regard.

Future studies should consider adding a control group to further strengthen the validity of the results and, while the response rate of SMEs is sufficient at 31%, the number of cases could be increased so that even more conditions could be added for exploratory analysis. Adding more conditions to the csQCA could avoid risks of neglecting possible relevant conditions leading to a given outcome. Finally, as many SMEs did not publish patents, further studies could incorporate alternative conditions such as R&D spending. Given these limitations, future studies should seek a clearer causality between cluster policy and outcomes, an aspect that the present paper cannot completely verify.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Research Data

Written informed consent was obtained by all study participants following the Norwegian Center for Research Data enshrined in the General Data Protection Regulation (GDPR) and pertains to the storage, anonymization, and use of the research data.

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References

Astbury, B. (2022). Everything you ever wanted to know about qualitative comparative analysis (QCA) but were too afraid to ask, ARTD. Available at: https://www.artd.com.au/news/everything-you-ever-wanted-to-know-about-qualitative-comparative-analysis-qca-but-were-too-afraid-to-ask/ (Accessed: 25 August 2023).

Autant-Bernard, C., Billand, P., Frachisse, D., & Massard, N. (2007). Social distance versus spatial distance in R&D cooperation: Empirical evidence from European collaboration choices in micro and nanotechnologies. Papers in Regional Science, 86, 495-519. https://doi.org/10.1111/j.1435-5957.2007.00132.x

Calignano, G. (2014). Italian organisations within the European nanotechnology network: presence, dynamics and effects. DIE ERDE – Journal of the Geographical Society of Berlin, 145(4), 241–259. https://doi.org/10.12854/erde-145-21

Calignano, G., & Fitjar, R. D. (2017). Strengthening relationships in clusters: How effective is an indirect policy measure carried out in a peripheral technology district? Annals of Regional Science, 59(1), 139–169. https://doi.org/10.1007/s00168-017-0821-x

Calignano, G., & Jøsendal, K. (2018). Does the Nature of Interactions with Higher Education Institutions Influence the Innovative Capabilities of Creative Firms? the Case of a South Western Norwegian County. Quaestiones Geographicae, 37(4), 67–79. https://doi.org/10.2478/quageo-2018-0040

Calignano, G., Fitjar, R. D., & Hjertvikrem, N. (2019). Innovation networks and green restructuring: Which path development can EU Framework Programmes stimulate in Norway? Norsk Geografisk Tidsskrift - Norwegian Journal of Geography, 73(1), 65-78. https://doi.org/10.1080/00291951.2018.1561512

Calignano, G. (2019). Long-distance connections, long-term ties, and novel knowledge networks in technology districts. Scienze Regionali.

Cavicchi, B. (2018). The burden of sustainability: Limits to sustainable bioenergy development in Norway. Energy Policy, 119, 585–599. https://doi.org/10.1016/J.ENPOL.2018.05.015

Ciffolilli, A., & Muscio, A. (2018). Industry 4.0: National and regional comparative advantages in key enabling technologies. European Planning Studies, 26(12), 2323-2343. https://doi.org/10.1080/09654313.2018.1529145

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly, 35(1), 128–152. https://doi.org/10.2307/2393553

Doloreux, D., & Porto Gomez, I. (2017). A review of (almost) 20 years of regional innovation systems research. European Planning Studies, 25(3), 371–387. https://doi.org/10.1080/09654313.2016.1244516

Giest, S. (2021). The Capacity to Innovate - Cluster Policy and Management in the Biotechnology Sector. University of Toronto Press.

Giuliani, E. (2007). The selective nature of knowledge networks in clusters: Evidence from the wine industry. Journal of Economic Geography, 7, 139–168. doi:10.1093/jeg/lbl014

Gulbrandsen, M., & Solesvik, M. (2018). University-Industry Linkages in Two Industrial Clusters in Norway. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2707272

Hallén, A. (2016). In: Mekjan, S. (2016). New national strategy on the bioeconomy launched. The Research Council of Norway. Available at: https://www.forskningsradet.no/en/Newsarticle/New_national_strategy_on_the_bioeconomy_launched/1254022868420

Ide, T., & Mello, P. A. (2022). QCA in International Relations: A Review of Strengths, Pitfalls, and Empirical Applications. International Studies Review, 24(1). https://doi.org/10.1093/isr/viac008

Isaksen, A. & Jakobsen, S-E. (2017). New Path Development Between Innovation Systems and Individual Actors. European Planning Studies, 25 (3), 355-370. DOI: 10.1080/09654313.2016.1268570

Jordan, E., Gross, M. E., Javernick-Will, A. N., & Garvin, M. J. (2011). Use and misuse of qualitative comparative analysis. Construction Management and Economics, 29(11), 1159–1173. https://doi.org/10.1080/01446193.2011.640339

Liao, T. J. (2010). Cluster and performance in foreign firms: The role of resources, knowledge, and trust. Industrial Marketing Management, 39(1), 161–169. https://doi.org/10.1016/J.INDMARMAN.2008.08.003

Makedos, I. (2014). The Collaboration of SMEs through Clusters as Defense against Economic Crisis. Economics Research International, 2014, Article ID 407375. https://doi.org/10.1155/2014/407375

NCE Heidner Biocluster. (2021, February 24). https://heidner.no/nce-heidner-biocluster/

Nilsen, T., Grillitsch, M., & Hauge, A. (2023). Varieties of periphery and local agency in regional development. Regional Studies, 57(4), 749–762. https://doi.org/10.1080/00343404.2022.2106364

Nishimura N, Okamuro H (2011). Subsidy and networking: the effects of direct and indirect support programs of the cluster policy. Res Policy 40:714–727. doi:10.1016/j.respol.2011.01.011

Norwegian Innovation Clusters. (n.d.). https://nic.innovasjonnorge.no/

O'Dwyer, M., Filieri, R., & O'Malley, L. (2023). Establishing successful university–industry collaborations: barriers and enablers deconstructed. Journal of Technology Transfer, 48(3), 900–931. https://doi.org/10.1007/s10961-022-09932-2

Porter, M. E. (1998). Clusters and the new economics of competition (pp. 77–90). Harvard Business Review.

Ragin, C. (1987). The comparative method: Moving beyond qualitative and quantitative strategies. University of California Press, Berkeley.

Røtnes, R., Norberg-Schulz, M., Rybalka, M., Myhre Walbækken, M., Ibenholt, K., Håkansson, A., & Izsak, K. (2017). Evaluation of Norwegian Innovation Clusters (Report No. 76-2017). Samfunnsøkonomisk analyse AS. https://www.regjeringen.no/contentassets/377067362c2d4f5e87cd87063bce7a62/evaluation-of-norwegian-innovation-clusters_.pdf

Schaeffer, V., Öcalan-Özel, S., & Pénin, J. (2020). The complementarities between formal and informal channels of university–industry knowledge transfer: a longitudinal approach. Journal of Technology Transfer, 45(1), 31–55. https://doi.org/10.1007/s10961-018-9674-4

Schretlen JH, Dervojeda K, Jansen W, Schafmeister B (2011). Uncovering excellence in cluster management. PwC, the Netherlands. https://www.pwc.com/gx/en/psrc/pdf/cluster_management.pdf. Accessed 15 August 2023

Ter Wal, A. L. J., & Boschma, R. A. (2009). Applying social network analysis in economic geography: Framing some key analytic issues. Annals of Regional Science, 43(3 SPEC. ISS.), 739–756. https://doi.org/10.1007/s00168-008-0258-3

The Inland region. (2017). The Bioeconomy Strategy for the Inland Region 2017-2024 A business strategy and action plan.

Tödtling, F. & Trippl, M. (2018). Regional innovation policies for new path development – beyond neo-liberal and traditional systemic views, European Planning Studies, 26:9, 1779-1795, DOI: 10.1080/09654313.2018.1457140

Verweij, S., & Trell, E.-M. (2019). Qualitative Comparative Analysis (QCA) in Spatial Planning Research and Related Disciplines: A Systematic Literature Review of Applications. Journal of Planning Literature, 34(3), 300-317. https://doi.org/10.1177/0885412219841490

Wagemann, C., Buche, J., & Siewert, M. (2015). QCA and business research: Work in progress or a consolidated agenda?. Journal of Business Research. https://doi.org/10.1016/j.jbusres.2015.10.010

Wilson, J., Wise, E., & Smith, M. (2022). Evidencing the benefits of cluster policies: towards a generalised framework of effects. Policy Sciences, 55(2), 369–391. https://doi.org/10.1007/s11077-022-09460-8

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What if the DUI mode is important in university-industry interactions? Exploring barriers, enabling factors, and the role of proximities in the Norwegian biotechnology sector

ABSTRACT. The objective of this article is to reveal what drives collaboration between biotechnology-based small and medium-sized enterprises (SMEs) and local and non-local higher education institutions (HEIs), as well as to determine how different dimensions of proximity (e.g., geographic, cognitive, social, organizational, and institutional) influence collaboration choices and patterns. Based on in-depth interviews with key informants, a case study of companies belonging to the Norwegian Heidner Biocluster is presented. Our results primarily reveal how the importance of geographic proximity in university-industry (U-I) collaboration varies depending on the type of company considered. Larger and older biotechnology-based SMEs appear to collaborate more frequently and with a greater degree of satisfaction with local HEIs than smaller, newer, and more internationally oriented SMEs. These findings have some thought-provoking implications for both research and policy, including that firms are different and employ different innovation modes (Doing-Using-Interacting [DUI] in addition to Science-Technology-Innovation [STI]) even when they belong to the same industry and in the peculiar case of U-I interactions, the role that informal institutions and firms' embeddedness play in generating local knowledge exchange between the industrial and academic sphere, and the importance of other forms of proximity in addition to or as an alternative to geographic proximity.

1. Introduction

This article explores the knowledge exchange dynamics occurring between HEIs (Higher Education Institutions) and small and medium-sized enterprises (SMEs) in the biotechnology sector in the Inland County of Norway, a peripheral region. More specifically, we are interested in understanding what elements drive or, conversely, hinder these possible and fruitful collaborations. Considering the perspective of SMEs, through a spatial and relational perspective, and adopting a qualitative methodological approach and in-depth interviews, we also investigate several dimensions of proximity to better understand the ways in which local SMEs interact with academic partners at various geographic scales.

Presently, the expectation that universities contribute to the governance and innovation policy decisions at the regional level continues to grow (Fonseca & Nieth, 2021). This has been referred to as the 'third mission' (Gunasekara, 2006) and captures the shift that has occurred by situating universities in more of a partnership-role with regional governments. While this shift has been demonstrated in central regions, this collaboration is particularly important in peripheral regions where the role of universities can extend beyond knowledge transfer and business development (Calignano and Quarta 2014).

This shift is also recognized and supported by the regional government of Inland, Norway. Recent policy reports state that one of the regional governments' priorities is to improve interactions between actors in the innovation sector, among them universities and research institutes and industry. With two key HEIs located in the largest cities in the region the Inland Norway University of Applied Sciences (HINN) located in the city of Hamar and the Norwegian University of Science and technology (NTNU) branch campus located in Gjøvik. Historically an agricultural and forestry region located in the east of the country, the Inland region is separated from the economic and cultural capital of Oslo to the south and distant from the oil producing regions to the west. Research has shown the region has fallen behind other Nordic regions in innovativeness and faces a population decline, technological advancements in its lumber industry and a better utilization of its biotech industry are seen as priority areas by the regional government and key drivers to reverse the population declines and lack of innovativeness (Nilsen et al., 2024). As such, the regional government of Inland has implemented policies to increase innovation and collaboration in its biotechnology sector, which is now focused on SMEs in food production and related research (The Inland region, 2017).

Figure 1. *Map showing the Inland region of Norway*

This article describes the benefits deriving from university-industry (U-I) linkages and how universities may serve as hubs for the objectives and functions illustrated above (Hall et al. 2010), with a special focus on how such interactions take place in peripheral areas. Based on this, we explore the role of universities in peripheral regions and detail how these roles and specific types of universities can be even more impactful in isolated and lower income regions (see Boucher et al., 2003; Trippl et al., 2015).

Using Boschma's (2005) dimensions of proximity from geographical to institutional, this article takes a well-established, but not yet fully explored approach in the literature by specifically applying these forms of proximity to U-I linkages (see, e.g., Alpaydin, 2019; D'Este et al., 2013; Shi & Wang, 2023). Interviews conducted with CEOs and managers focused on the frequency and intensity of collaboration at various product life stages, barriers, and enablers, exploring various knowledge channels and the roles of cluster administrators in facilitating these linkages.

Based on these premises, this article addresses the following research question: How are different dimensions of proximity (e.g., geographic, cognitive, social, organizational, and institutional) related to collaboration choices and patterns between biotechnology-based small and medium-sized enterprises (SMEs) and local and non-local higher education institutions (HEIs)?

Our empirical analysis has uncovered several findings with which we intend to contribute to theoretical and policy discussions on this topic. First, our study confirms the importance of different dimensions of proximity in U-I interactions, although geographic proximity to the local HEIs appears to be particularly important for older and larger firms operating in the broader field of agricultural sciences i.e. the sciences concerned with the study of plants, soil and agricultural techniques (Busch, 2001). In contrast, newer and smaller firms operating in the more specialized agricultural biotechnology subsector i.e. the use of a collection of scientific techniques used to improve the production of plants and livestock (Hefferon, 2016) collaborate more often and effectively with geographically more distant partners. Despite this difference, it should be noted that many of the firms have similar goals which may overlap. However, the smaller newer ones are more technologically focused and narrow in their scope than the larger older ones. We were able to relate these findings to the socio-institutional environment in which the target Norwegian firms operate and the mode of innovation they primarily employ (e.g., Doing-Using-Interacting [DUI] vs Science-Technology-Innovation [STI]). On this basis, we reflect on possible indirect (networking) policy actions to be implemented in the target cluster and regional area, which should aim to improve different models of collaboration based on the characteristics of the firms, their predispositions, and the challenges encountered.

2. Theoretical background

Universities play a key role in regional development dynamics for several reasons. Not only do they improve human capital and provide skilled workers to local labor markets, but they also contribute to community services and the intellectual life of local and regional areas (e.g., Archibugi & Filippetti, 2018; Fonseca & Nieth, 2021; Goddard & Vallance, 2013).

Universities are generally considered important partners for regional businesses, whose goal is to innovate to remain competitive in their respective markets (Lazzarotti et al., 2023). Nowadays, knowledge-intensive activities play a key role in the economy, and innovation – which is one of the keys to maintain competitiveness – is often the result of "open" methodologies (Chesbrough, 2003) and frequent exchanges between industrial and academic spheres (Giuliani & Arza, 2009; Zhang & Wang, 2017). This is the so-called 'third mission' of universities, that is, the social, economic, and cultural contribution to local and regional development through the transfer of technology and knowledge to industry (Etzkowitz & Leydesdorff, 2000; Gunasekara, 2006). Along with teaching and research, this is one of the key activities carried out by HEIs.

Although important everywhere, the role of universities is even more critical in the case of peripheral regions (e.g., Calignano & Quarta, 2014; Evers, 2019). Previous research from Boucher et al. (2003) have classified academic institutions in peripheral regions as either single-player or multi-player universities. While the role of the former is to encourage entrepreneurship and technology transfer, the main roles of the latter are to foster regional consortia, participate in cultural networks, support the health care system (through the exchange of knowledge and new technological solutions), and trigger new paths of development by attracting knowledge-based extra-regional SMEs.

A further useful taxonomy was provided by Trippl et al. (2015), who distinguished universities according to their different contributions to regional economic and social development. Specifically, entrepreneurial university models contribute to regional development by actively commercializing the knowledge they produce through spin-offs, patents, and licensing. Regional innovation system (RIS) university models focus on systemic innovation and interactions with other RIS actors, while they do not focus exclusively on commercializing research activities, but use more diverse channels of knowledge exchange, which include research and development (R&D) cooperation, supply of skilled labor to local markets, and informal contacts. Mode 2 university models are characterized by applied, transdisciplinary and heterogeneous research, usually related to their respective environments, and collaborative research projects with other HEIs. Finally, engaged university models focus on the specific needs of the regional areas in which they are located, and their research activities are strongly linked to local industries and society. These four types of universities aim to shape regional identity and exchange knowledge with other local stakeholders in various forms, such as offering regionally focused teaching programs, providing locally qualified students and future workers, integrating regional needs into their strategic development, and aiding and supporting local businesses.

As mentioned above, U-I interactions occur through various knowledge exchange channels. These may include research contracts, other types of contracts (e.g., consulting, experimentation, activities), partnerships in national and international consortia, and informal contacts (see, e.g., Calignano & Quarta, 2014; Trippl et al., 2015). These channels are decidedly influenced by the type of companies involved and the industrial sector they belong to.

Similarly, the geography of U-I interactions is influenced by the type of industry and knowledge base that characterizes a particular SME (Asheim & Gertler, 2005).

The case study presented in this article considers biotechnology SMEs located in a peripheral region of Norway. Although not exclusively, biotechnology is primarily a scientific field characterized by an analytical knowledge base (Asheim & Gertler, 2005). According to many scholars (Boschma et al., 2014; Martin & Moodysson, 2013), companies in this type of industry exchange codified knowledge (e.g., scientific articles or reports and patents) and use a Science-Technology-Innovation (STI) mode making their knowledge exchange less sensitive to geographic proximity (Jensen et al., 2007). That is, biotechnology companies can potentially source the knowledge they need from more geographically distant academic institutions. However, it should be underscored that frequent interactions with local universities are equally advantageous in the case of broadly defined biotech SMEs that have their roots in agriculture, forestry or animal husbandry and tend to use more tacit knowledge and apply the Doing-Using-Interacting (DUI) mode of innovation (Aslesen & Pettersen, 2017). Despite some notable exceptions (e.g., Asheim et al., 2011), the possible combination of STI and DUI modes of innovation in biotechnology and its implications for U-I interactions is a topic seemingly neglected by economic geographers and regional scientists. On the contrary, we believe that focusing on this aspect can lead to interesting and original results on the relational and geographical dynamics underlying possible collaborations between the industrial and academic spheres. The frequency and intensity of interactions between co-located organizations, as in the case of SMEs and HEIs, appear to be particularly important in the initial stages of the product life cycle, that is, when creativity is key and less standardized activities are performed (Feldman & Kogler, 2010). However, other factors such as government incentives (e.g., tax breaks; see Mercuri & Birbeck, 2020) or specific policy actions (joint participation in research consortia or targeted funding programs; e.g., Schulze-Krogh & Calignano, 2020) can help stimulate interactions between local SMEs and co-located HEIs.

Geographical proximity is, however, only one of the possible forms of proximity that can generate satisfactory collaborations (Boschma, 2005). In this regard, it is worth noting that geographical proximity makes U-I linkages easier, faster, and cheaper (Kogler & Feldman, 2010), but it is not in itself a sufficient condition for U-I interactions to take place. In other words, geographical proximity alone may not be enough to initiate collaborations with regional academic partners, suggesting that other equally relevant dimensions of proximity may be needed. In addition, other dimensions of proximity might trigger U-I interactions between distant organizations when a SME cannot locally secure the kind of skills, competencies, and abilities (but also tools or machinery) it is looking for. In this regard, Boschma's (2005) renowned work supports our empirical search for an association between U-I interactions and different dimensions of proximity. In addition to geographical proximity (i.e., cooperations facilitated by spatial proximity), Boschma (2005) refers to cognitive, social, organizational, and institutional proximity, which can be considered as possible critical factors for collaborations with geographically close and extra-regional universities.

Cognitive proximity occurs when two collaborating organizations share similar skills and expertise, facilitating knowledge exchange whereas social proximity refers to friendships, kinship, common knowledge, and previous positive collaborations that strengthen trust and lead to fruitful interactions between the two spheres of reference. Institutional proximity seems to be indirectly related to geographical proximity, as it corresponds to formal (laws and rules) and informal institutions (cultural norms and habits) that influence the outcomes of interactions and the way collaborating organizations interact. Finally, organizational proximity in Boschma's (2005) taxonomy is related to the hierarchical coordination of economic activities between establishments belonging to the same parent company (i.e., multinational SMEs, mergers, acquisitions, etc.) that allows SMEs to successfully manage complementary pieces of knowledge. In this article we interpret this type of proximity differently by looking at shared shareholdings on the same boards of scientific and industrial associations or cluster management as an expression of organizational proximity. Although predictable, it is worth clarifying at this point that all these forms of proximity, which can trigger successful U-I interactions, can be an obstacle to possible successful collaborations between the two spheres when they are lacking.

Economic geographers and regional scientists have shown a great interest in the topic of proximity in regional development (e.g., Calignano & De Siena, 2018; Koopman et al., 2021; Roth & Mattes, 2023; Torre & Wallet, 2014) and a relatively high number of studies has similarly applied this key approach to the study of U-I interactions. Among others, D'Este et al. (2013) found that geographical proximity is important in shaping collaborations between regional SMEs and HEIs in the United Kingdom, but that this effect is weakened when SMEs are in dense technology clusters. In this case, SMEs can ignore distance and collaborate frequently and effectively with more distant academic partners. Crescenzi et al. (2017) focused on co-patenting in the Italian context and found that geographic proximity can be a substitute for a lack of institutional proximity, while the reputation of both academic and industrial inventors is a key element in collaboration models. Nilsen and Lauvås (2018) found that social proximity and high levels of organizational proximity can overcome the lack of geographical proximity in the Nordic periphery. Finally, Calignano and Quarta (2014) examined the geographical distance of industrial partners who signed research contracts with a peripheral university in southern Italy and found that the frequency and value of such contracts varied significantly by the type of client i.e., that public clients are geographically concentrated in the regions concerned, while private clients are more geographically dispersed.

Previous studies have shown that the degree of satisfaction in U-I interactions varies significantly (see, e.g., Calignano & Jøsendal, 2018; Schulze-Krogh & Calignano, 2020). All the factors illustrated in this section (e.g., proximity dimensions, type of companies and universities involved, modes of innovation, etc.) can contribute to the success or hinder the positive outcomes of collaborations between academic institutions and private companies.

3. Methodology

Through seven qualitative interviews, this paper evaluates Boschma's (2005) concepts of proximity as it applies to HEIs and SMEs in peripheral regions, as well as exploring what drives collaboration between SMEs and HEIs in biotechnology and seeks to better understand the main enabling factors and barriers that SMEs face when trying to collaborate with local and non-local HEIs. We used deductive content analysis to test these concepts against the qualitative interview data collected. Our analytic framework was designed based on the deductive content analysis used by the urban studies researchers Sheydayi and Dadashpoor (2023). Following their five-step model we chose the type and theoretical fields of data; explained our objectives, how we conducted the data analysis and interpretation, as well as how we applied the interpretation results (Sheydayi & Dadashpoor, 2023 p. 9).

The seven participating SMEs were chosen for interviews based on their age, size, economic value, and industry sector. Participants were all based in or near the city of Hamar, Norway and had professional connections to the biotechnology sector and participants all had collaborative experience with local HEIs through research and business projects.

Participating SMEs were members of the Hamar based Heidner Biocluster and represented the approximate average of the more than 30 SME members of the Biocluster. Determining the average was based on the results of a survey conducted on the cluster members, we used this data to then choose the SMEs in which to interview. The two-part survey conducted in 2022 and 2023 collected data on the SMEs including basic information about the educational background of employees, economic data, age, stages of product development and collaborations with other members in the cluster (Chrisman, 2024)

Hour long semi-structured interviews were conducted based on concepts around proximity and university and industry linkages from Boschma (2005), Trippl et al. (2015), and Calignano and Quarta (2014). Questions focused on collaboration at different product development stages, research collaboration, cluster management evaluation, and organizational structure. Interviews were conducted in-person and written informed consent was obtained by all study participants following the Norwegian Center for Research Data enshrined in the General Data Protection Regulation (GDPR) as it pertains to the storage, anonymization, and use of the research data. After transcription we deductively coded the material and identified emergent themes based on Trippl et al. (2015), Calignano and Quarta (2014), and Boschma's (2005) concepts. The developing themes were discussed and then verified again through the data.

4. Case study description and results

A central theme emerging from the analysis was the differences in age, sector, and size of SMEs and their distinct DUI vs STI approaches. From this, SMEs could be divided into two groups, each with their own categories (Cash and Snider 2014). A table was created, and participating SMEs were divided into either of these groups and then evaluated again based on the data. To increase validity, we used secondary sources to contrast the findings.

The first group consists of larger, older SMEs (1, 7, 6, 3) founded before 2002. They are established actors in the region and highly embedded SMEs and are focused on the agricultural science sector i.e., animal and plant research. Embeddedness in this context relates to long and ongoing relationships with local universities, with employees and resources being based locally in the Inland region and overlap and partnerships in projects with other established SMEs in the area. The second group comprises smaller, newer SMEs (2, 4, 5) founded as startups post-2002, focused on agricultural biotechnology. While often also indirectly related to agriculture or the use of agriculture resources, they are less locally focused with partners and technology developed abroad. While the number of employees at the SMEs consisted of a wide range – from several to over two hundred – we were still able to categorize them into two groups.

Table I. *Demarcation of groups based on SME characteristics*

Type of SMEs	**Larger, Older, Established, Embedded SMEs**	**Smaller, Younger, Startups**
Sector	Agriculture sciences	Agricultural Biotechnology
Collaboration with universities	Mainly local	Mainly national and international
Innovation mode	Combination of DUI and STI	STI
Importance of geographical proximity	Yes	No
Importance of other forms of proximity	Cognitive; Social; Institutional; Organizational	Cognitive; Institutional
Collaboration phase	Early	Early
Enablers (collaborations w/local universities)	Participation in cluster activities; political activities; social events; embeddedness in local environment	Benefitting from activities carried out in local business incubator
Barriers (collaborations w/local universities)	Lack matching of expertise; Necessity to improve outreach, engagement, public-private partnerships	Lack matching of expertise; Necessity to improve outreach, engagement, public-private partnerships, lacking social ties and affinities with local established values and ways of doing things; different mentalities, lack of initiatives, less dynamic regional environment
Enablers (collaborations w/non-local universities)	Expertise, equipment, laboratories, internal funds which are not available regionally; possibility to apply for external funds (e.g., creation of EU consortia); culture of collaboration; perceived prestige of non-local universities	Expertise, equipment, laboratories, internal funds which are not available regionally; possibility to apply for external funds (e.g., creation of EU consortia); culture of collaboration; perceived prestige of non-local universities
Barriers (collaborations w/non-local universities)	Cultural differences (e.g., different languages, routines, etc.); Locally oriented projects and lack of international scopes; Lacking international networks; lack of trust	Small sized projects leading to lack of interest from nationally or internationally renowned universities; Too costly collaborations for startup companies with lacking financial resources; lack of trust
Financial incentives	No	No
Degree of satisfaction (collaborations w/ local universities)	Medium-High	Medium-Low
Degree of satisfaction (collaborations w/ non-local universities)	Medium-High	Medium-High

4.1. Type of firms, mode of innovation and the role of geographical proximity

As shown in Table I, the larger, older SMEs were more likely and more willing to collaborate with local universities, particularly with Inland University of Applied Sciences (HINN). The participant from SME stated: *"I have to say that the know-how and the level of the competence here in the HINN is very high"; SME 1, personal communication).* Responding to whether the quality of work provided by local universities has improved over time the participant from SME 3 said: "*Increased, absolutely. And they have been working very hard to be better and stronger" (SME 3, personal communication).* In contrast to the newer, smaller SMEs, larger, older SMEs have a more positive view of local university collaborations and are more likely to look to local universities when trying to establish long-running research projects. In contrast, they look to international universities to find specific expertise not available locally, most often the United Kingdom and the United States. The newer, smaller SMEs are more likely to search for national universities and/or international universities for business and research collaborations and have stated that new research collaborations can be challenging to set up locally.

As mentioned earlier, the importance of tacit knowledge in the innovation dynamics of this subset of biotechnology firms - which implies the adoption of the DUI mode in addition to the traditionally employed STI - is evidenced by several interviewees, who stated that "location [...] is important because the companies and the university [i.e., HINN, the local university of applied sciences] are in the same place and you can interact with them [i.e., university scholars] and recruit them in different ways, even allowing their students to conduct research in our company for their masters' thesis and things like that" (SME 1, personal communication). In addition, other informants explicitly mentioned the importance of local HEI in helping to solve specific technical problems, a typical feature of industries that primarily employ synthetic knowledge (e.g., Alhusen et al. 2021) and the DUI mode of innovation. Among other things, interviewees emphasized the importance of the role of universities in experimentation (SME 3), in recruiting students (SME1), in conducting specific analyses in the context of research projects (SME 3, 5) and, more generally, in receiving support in "practical things" (e.g., services, technical advice; SME 3 and 7), which is considered the main factor that drives SMEs in Inland Norway to cooperate with the local HEI. In this regard, there is a need to systematize how DUI takes shape: these U-I links are often based on tacit knowledge with local universities, and target SMEs operating in the agricultural sciences benefit from such exchanges through "doing" (i.e., testing), using (i.e., use of available laboratories and transfer of locally produced knowledge), and interacting (i.e., student recruitment, collaborations on master's thesis projects, informal interactions with university staff, and participation in joint projects). On the importance of the regional focus of universities, their interactions with local companies and the key role they play as service providers, see Harrington et al. (2015).

Biotechnology tends to be treated as a purely scientific industry, characterized by an analytical knowledge base and little tacit knowledge exchange (e.g., Asheim & Coenen, 2005; Guilhon, 2017), although Asheim et al. (2011, p. 10) explicitly state that "the DUI mode is not only found in industries based on synthetic or symbolic knowledge as also dominantly analytical-based industries (for example, pharmaceutical and biotechnology industries) make use of synthetic knowledge and interactive learning in specific phases of their innovation processes (Moodysson et al., 2008)". Our empirical analysis is an important contribution in this regard, as it confirms not only that biotechnology firms may use different knowledge bases and modes of innovation, but also originally suggests that, in the case of a subfield such as agricultural sciences, this occurs not only with customers or suppliers, as the literature on the topic suggests, but also when they collaborate and exchange different types of knowledge (including tacit and practical knowledge) with co-located HEIs.

Conversely, the newer, smaller SMEs are best described by the science-technology-innovation (STI) mode that underscores the importance of increasing the R&D capacity of SMEs. They are more focused on the commercialization of research results, establishing new R&D projects with universities, and increasing mobility between universities and SMEs (Isaksen & Nilsson, 2011).

The importance of geographical proximity was also stated to be higher among larger, older SMEs. These SMEs took pride in their long and sustained relationships with the local university and other local SMEs. These SMEs were more likely to attempt projects locally first. They did not see a benefit in the quality of work found at universities nationally or internationally. The younger, newer SMEs saw less importance in geographical proximity and were more open and likely to look to national and international partners to produce or improve their products and/or services: *"So there are advantages to working with a geographically close company. But these other types of proximity in terms of expertise, exposure, experience, the kind of business models that they have implemented in the company, and also their perception of themselves, all these things create, these are different types of proximity that can be real challenges working with local businesses (SME 4, personal communication).*

With regards to geographical proximity, despite the good opinion of larger, older firms towards collaborating with local HEIs, both groups (7, 6, 5, 4) did not consider proximity to be the most important aspect for collaboration. Instead, they attached greater importance to the research project's nature and its stated goals above the university research partner's location.

4.2. Barriers, enabling factors and the importance of other forms of proximity

Both the older, larger SMEs and younger, smaller SMEs valued cognitive and institutional proximity. However, the older, larger SMEs put more emphasis on social and organizational proximity, being more likely to participate in local cluster events, joining the boards of local SMEs, and having a stronger social connection to the region.

Enablers to foster collaboration with local universities also varied between the two groups. As stated above, the local Biocluster played a more of a key role for the older, larger SMEs which often had rotating cluster board membership and were even involved in the cluster's foundation and growth. Social events and embeddedness in the local environment also worked as enablers for local university collaboration with larger, older SMEs. In contrast, the smaller, newer SMEs saw the local business incubator as an enabler for local university collaboration.

The older, larger SMEs found barriers to local university collaboration in a lack of matching expertise. Often highly specialized, it was challenging to find this expertise locally. They stated a need to improve university outreach and a more streamlined and effective approach to establishing local universities and SMEs' partnerships and engagement. The newer, smaller SMEs also found it often challenging to source expertise locally, particularly with a lack of established social ties, less dynamic environment compared to national universities (*"Then we need to go nationally or abroad. It's maybe some small niches that they have competence on here, but otherwise we have to go nationally or international to find that competence"*; SME 5, personal communication). SME 5 found local universities to have a lack of interest in developing innovative technologies and products and believed with improvements that effective collaboration could lead to spinoffs, funding, and publications for local universities.

In terms of enablers and barriers for collaboration with non-local universities, the larger, older SMEs cited the benefits of equipment, expertise, and university funding that was not found locally, a culture of collaboration, and the necessity of international collaboration to apply for EU (European Union) funding. The smaller, newer SMEs (4, 5) stated that both culture and language play a significant role in a collaboration's success: *"So it's like if you come from the local, geographically the same local proximity, then you probably have a good idea of how things are done because you've been exposed to it your whole life. But if you're coming into that local ecosystem from a foreign place, you don't have that local proximity, then you're almost certainly bound to have a lot of surprises" (SME 4, personal communication).* Like the older and larger SMEs, the enablers for smaller, newer SMEs were also access to larger, more diverse university departments that were not available locally, access to the international collaboration needed to apply for EU grants, a culture of collaboration with the private sector, the perceived prestige of non-local universities, and the potential for an expanded network. Barriers to these collaborations for the larger, older SMEs were the cultural differences including routines and languages, as well as their engagement in projects that were locally oriented and did not have an international scope. To the contrary, the smaller, newer SMEs found barriers to collaboration to be a lack of funding or interest from national or international universities, the cost of initiating collaborations, and lack of trust. Financial incentives for staying local such as municipal or regional grants were not described by either group as an incentive for working with local universities.

For older, larger SMEs the degree of satisfaction with local universities was medium-high. They reported a long record of collaboration and, when expertise was available, the quality of work was considered high: "*I have to say that the know-how and the level of the competence here in the HINN [the local university; authors' note] is very high" (SME 1, personal communication).* Shared culture and high levels of trust were also important. Similar, medium-high levels of satisfaction were experienced with non-local universities especially when the research fields are narrow. For the smaller, newer SMEs' the degree of satisfaction regarding local university collaboration was medium-low, citing challenges in establishing projects and meeting the pace needed to complete the project.

5. Discussion of the main results and concluding remarks

Focusing on biotechnology allowed us to provide some clear and hopefully interesting results from empirical, theoretical and policy perspectives. Our article confirms how geographic proximity per se – although important for some specific firms – "*is neither a necessary nor a sufficient condition for learning to take place*" (Boschma, 2005, p. 62). As emphasized by our interviewees, other forms of proximity (e.g., cognitive, social, institutional, organizational) are essential complements in the case of co-located partners or vital alternatives for generating fruitful knowledge exchange in the case of collaborations with more distant, non-local academic institutions (on this topic, see also, e.g., Alpaydin, 2019; D'Este et al., 2013; Shi & Wang, 2023). Although this result could not seem particularly original at first glance since already observed in many other empirical analyses (e.g., Fitjar & Rodrìguez-Pose, 2011; Hansen, 2015; Nilsen & Lauvås, 2018; Wilke & Pyka, 2024), the factors underlying it (e.g., combination of innovation modes in the biotechnology sector leading to unusual or less frequently observed knowledge exchange dynamics in U-I interactions) could represent important elements of novelty that we will try to delineate and discuss more accurately below.

From an empirical perspective, our study has shown that significantly different drivers and barriers can be observed in the case of collaborations with local and non-local HEIs, and that this seems to be clearly attributable to the characteristics of the target firms and the biotechnology sub-group to which they belong (i.e., agricultural science vs. agricultural biotechnology; see Section 4 and Table 1 above for details).

The greater importance of geographic proximity for larger, older firms is determined by their degree of embeddedness in the region in which they operate. This is a relevant finding as it clearly highlights the importance of informal institutions (e.g., trust; see Edquist, 1997). More specifically, these types of firms consider participation in cluster activities, political participation, social events, and existing social recognition in the local environment as key factors for their collaboration with local HEIs. In other words, a higher level of social and institutional engagement is likely to make collaborations between larger, older firms and local HEIs more frequent and stronger than those established by smaller, younger firms. We can speculate that bonding social capital plays a critical role in this regard (e.g., Gordon & Jack, 2010; Grzegorczyk, 2019; Sormani & Rossano-Rivero, 2023), while this can similarly represent a sign of what scholars in other fields call 'insider-outsider' theory (Snower & Lindbeck, 2001), i.e., larger, older and more connected SMEs occupy a dominant position by benefitting from long-standing informal interactions and formal collaborations with the local university. This aspect may have an influence on the regional innovation agenda, significantly affect collaborations patterns, and somehow exclude newer and smaller SMEs from the existing consolidated regional networks. The consequence is that such a relatively 'closed' environment could push them to search for the knowledge they need elsewhere (i.e., nationally or internationally).

As sketched out above, the clear distinction between older, larger firms and smaller, younger firms implies that other dimensions of proximity influence collaboration patterns with HEIs (e.g., cognitive, social, institutional, and organizational). In this regard, our article demonstrates how, despite the analytical knowledge base that primarily characterizes biotechnology (Asheim & Gertler, 2005), SMEs are different, even when they operate in the same industry, and can employ different innovation modes depending on the sub-sector in which they operate (in our case, firms in agricultural science combine DUI and STI, while firms operating in agricultural biotechnology tend to favor STI). As the literature on the topic suggests, different innovation modes may lead to different type of exchanged knowledge (tacit vs. codified), knowledge exchange dynamics and geographical collaboration patterns (e.g., Martin and Moodysson, 2013; Plum & Hassink, 2011). What our paper critically adds to this broad strand of literature is that, conversely to what previous studies largely seem to suggest (e.g., Fitjar & Rodrìguez-Pose, 2013; Marchese & Potter, 2011; Parrilli & Radicic, 2021), STI is not an exclusive feature of U-I interactions, since some biotechnology firms can effectively combine it with DUI, even in case of interactions between industrial and academic spheres, particularly when they are embedded in long-lasting webs of relations and informal exchanges with local academics.

Interestingly, biotechnology firms operating in the agricultural sciences that adopt the DUI mode in addition to STI frequently benefit from tacit knowledge and synthetic knowledge to solve specific technical problems (Asheim & Gertler, 2005) when they collaborate with HEIs. In addition to confirm what recently published studies discovered in similar contexts with regard to the importance of the engagement of regional universities and their critical role in providing services and support to local businesses (see Harrington et al., 2015, in this regard), ours is another relevant finding in terms of theoretical contribution since customers and suppliers are generally considered the most important and frequent partners in the case of DUI mode-driven collaborations (Jensen et al., 2007; conversely, on some theoretical considerations about the possibility for biotechnology firms to effectively combine DUI and STI; see Asheim et. al., 2011).

Finally, some policy lessons can be learnt from our study. First, a single university can certainly play a key role in peripheral regions (see, e.g., Boucher et al., 2003; Calignano & Quarta, 2014; Evers, 2019) but apparently this happens in the case of older, well-established and industrially more traditional firms that know well the social context and institutional environment in which they operate, thus benefitting from broader networking and long-lasting interactions with local academics. Considering the knowledge bases and the innovation modes primarily employed or their combination, i.e., one of the main elements of novelty brought to light by this paper, could represent an interesting starting point for future policy ideas potentially enhancing further the effects of the current and future regional and cluster actions. More in detail, and with specific regard to problems concerning collaborations between SMEs and local HEI, policymakers and academics should take into duly consideration the fact that – in addition to social ties – newer and smaller firms report lacking matching of expertise, initiatives, and dynamic regional innovation environment among the main factors hindering quantity and quality of collaborations with the local academic institution. Although it is clearly not easy to deal with all these combined issues, the regional and local authorities, Heidner biocluster to which these firms belong, and the local university of applied sciences (HINN) itself have to consider the invocation of these young SMEs by possibly launching new or improving existing indirect (networking) policy actions comprising more engaging and effective social events engendering or strengthening ties and potentially fostering new collaborations, coordinated activities for possible participation in joint research projects and, more generally, new socio-institutional conditions fostering collaborations between local HEI and the sub-group of biotechnology firms operating in the agricultural biotechnology sector (e.g., aligning with the firms' expectations and possibly de-institutionalizing some of the existing habits, routines and practices). On the potential positive effects of indirect policy measures compared with more direct financial support in clusters and related regions, see e.g., Calignano and Fitjar (2017) and Nishimura and Okamuro (2011).

In conclusion, despite the several findings discussed above, we must duly acknowledge that our article is not exempt from limitations. For example, while the age, size and industry of the seven firms interviewed are like the makeup of the entire cluster, our study focuses on only a few qualitative interviews of seven firms, in addition it examines one single industry and one region and does not consider the point of view of the academic sphere on the matter or the potential generalizability of the findings. Further studies could continue to refine and evaluate the barriers and enablers, add more firms and re-interview the SMEs to confirm and validate the findings. Conducting a comparative analysis of the findings in other regional clusters, whose sector is generally attributed to a certain knowledge base and mode of innovation (Asheim & Gertler, 2005), like, for example, the local timber industry, could be one such analytical project.

6. References

Alhusen H, Bennat T, Bizer K, Cantner U, Horstmann E, Kalthaus M, Proeger T, Sternberg R, Töpfer S (2021) A new measurement conception for the 'doing-using-interacting' mode of innovation. Research Policy 50(4):104214. https://doi.org/10.1016/j.respol.2021.104214

Alpaydin UAR (2019) Exploring the spatial reach of co-publication partnerships of multinational enterprises: to what extent does geographical proximity matter? Regional Stud Reg Sci 6:1, 281-298. https://doi.org/10.1080/21681376.2019.1583601

Archibugi D, Filippetti A (2018) The retreat of public research and its adverse consequences on innovation. Technol Forecast Soc Change 127:97-111. https://doi.org/10.1016/j.techfore.2017.05.022

Asheim BT, Boschma R, Cooke P (2011) Constructing regional advantage: Platform policies based on related variety and differentiated knowledge bases. Regional Studies 45(7):893-904. https://doi.org/10.1080/00343404.2010.543126

Asheim BT, Coenen L (2005) Knowledge bases and regional innovation systems: Comparing Nordic clusters. Research Policy 34(8):1173-1190. https://doi.org/10.1016/j.respol.2005.03.013

Asheim BT, Gertler MS (2005) Regional innovation systems and the geographical foundations of innovation.

Aslesen HW, Pettersen IB (2017) Entrepreneurial firms in STI and DUI mode clusters: do they need differentiated cluster facilitation? Eur Plan Stud 25(6):904-922. https://doi.org/10.1080/09654313.2017.1300238

Boucher G, Conway C, Meer E (2003) Tiers of Engagement by Universities in their Region's Development. Reg Stud 37:887-897. https://doi.org/10.1080/0034340032000143896

Boschma R (2005) Proximity and Innovation: A Critical Assessment. Reg Stud 39:61-74. https://doi.org/10.1080/0034340052000320887

Boschma R, Balland PA, de Vaan M (2014) The formation of economic networks: A proximity approach. In: Regional development and proximity relations. Edward Elgar Publishing, pp 243-266. https://doi.org/10.4337/9781781002896.00016

Busch L (2001) Agricultural Sciences and Technology. In: Smelser NJ, Baltes PB (eds) International Encyclopedia of the Social & Behavioral Sciences. Pergamon, pp 333-337. ISBN 9780080430768. https://doi.org/10.1016/B0-08-043076-7/03146-6

Calignano G, De Siena L (2018) "I want to shake your hand before…": The role of clients, knowledge exchange and market dynamics in southern Italian software firms. Cogent Soc Sci 4(1):1435604. https://doi.org/10.1080/23311886.2018.1435604

Calignano G, Fitjar RD (2017) Strengthening relationships in clusters: How effective is an indirect policy measure carried out in a peripheral technology district? The Annals of Regional Science 59:139-169. https://doi.org/10.1007/s00168-017-0821-x

Calignano G, Jøsendal K (2018) Does the nature of interactions with higher education institutions influence the innovative capabilities of creative firms? The case of a south-western norwegian county. Quaestiones Geogr 37(4):67-79. https://doi.org/10.2478/quageo-2018-0040

Calignano G, Quarta CA (2014) University of Salento's transactional relations: Assessing the knowledge transfer of a public university in Italy. Erdkunde 68(2):109-123. http://www.jstor.org/stable/24365197

Cash P, Snider C (2014) Investigating design: A comparison of manifest and latent approaches. Des Stud 35(5):441-472. https://doi.org/10.1016/j.destud.2014.02.005

Chesbrough HW (2003) Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press. https://doi.org/10.1108/14601060410565074

Chrisman JE (2024) More frequent and stronger ties? Using QCA to assess the effects of policy in a Norwegian biotech cluster. manuscript submitted for publication.

Crescenzi R, Filippetti A, Iammarino S (2017) Academic inventors: collaboration and proximity with industry. J Technol Transf 42:730-762. https://doi.org/10.1007/s10961-016-9550-z

D'Este P, Guy F, Iammarino S (2013) Shaping the formation of university–industry research collaborations: What type of proximity does really matter? J Econ Geogr 13(4):537-558. https://doi.org/10.1093/jeg/lbs010

Edquist C (1997) Systems of Innovation: Technologies, Institutions and Organizations.

Etzkowitz H, Leydesdorff L (2000) The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. Res Policy 29(2):109-123. https://doi.org/10.1016/S0048-7333(99)00055-4

Evers G (2019) The impact of the establishment of a university in a peripheral region on the local labour market for graduates. Reg Stud Reg Sci 6(1):319-330. https://doi.org/10.1080/21681376.2019.1584051

Feldman MP, Kogler DF (2010) Stylized facts in the geography of innovation. Handb Econ Innov 1:381-410. https://doi.org/10.1016/S0169-7218(10)01008-7

Fitjar RD, Rodríguez-Pose A (2011) Innovating in the periphery: Firms, values and innovation in Southwest Norway. European Planning Studies 19(4):555-574. https://doi.org/10.1080/09654313.2011.548467

Fitjar RD, Rodríguez-Pose A (2013) Firm collaboration and modes of innovation in Norway. Research Policy 42(1):128-138. https://doi.org/10.1016/j.respol.2012.05.009

Fonseca L, Nieth L (2021) The role of universities in regional development strategies: A comparison across actors and policy stages. Eur Urban Reg Stud 28(3):298-315. https://doi.org/10.1177/0969776421999743

Foray D, Lissoni F (2010) University research and public–private interaction. In: Hall BH, Rosenberg N (eds) Handb Econ Innov Vol. 1, pp 275-314. North-Holland. https://doi.org/10.1016/S0169-7218(10)01006-3

Giuliani E, Arza V (2009) What drives the formation of ‘valuable’ university–industry linkages?: Insights from the wine industry. Res Policy 38(6):906-921. https://doi.org/10.1016/j.respol.2009.02.006

Goddard J, Vallance P (2013) The university and the city. Routledge. https://doi.org/10.1007/s10734-013-9686-9

Gordon I, Jack S (2010) HEI engagement with SMEs: developing social capital. International Journal of Entrepreneurial Behavior & Research 16(6):517-539. https://doi.org/10.1108/13552551011082489

Grzegorczyk M (2019) The role of culture-moderated social capital in technology transfer–insights from Asia and America. Technological Forecasting and Social Change 143:132-141. https://doi.org/10.1016/j.techfore.2019.01.021

Gunasekara C (2006) Reframing the Role of Universities in the Development of Regional Innovation Systems. J Technol Transf 31:101-113. https://doi.org/10.1007/s10961-005-5016-4

Guilhon B (2017) Innovation and production ecosystems (Vol. 2). John Wiley & Sons.

Foray D, Lissoni F (2010) University research and public–private interaction. In: Hall BH, Rosenberg N (eds) Handbook of the Economics of Innovation, Vol. 1. North-Holland, pp 275-314. https://doi.org/10.1016/S0169-7218(10)01006-3

Hansen T, Coenen L (2015) The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. Environmental innovation and societal transitions 17:92-109. https://doi.org/10.1016/j.eist.2014.11.001

Harrington C, Maysami R (2015) Entrepreneurship education and the role of the regional university. Journal of Entrepreneurship Education 18(2):29.

Hefferon KL (2016) Food Security of Genetically Modified Foods. Reference Module in Food Science. Elsevier. ISBN 9780081005965. https://doi.org/10.1016/B978-0-08-100596-5.03532-0

Isaksen A, Nilsson M (2013) Combined Innovation Policy: Linking Scientific and Practical Knowledge in Innovation Systems. Eur Plan Stud 21(12):1919-1936. https://doi.org/10.1080/09654313.2012.722966

Jensen MB, Johnson B, Lorenz E, Lundvall BÅ (2007) Forms of knowledge and modes of innovation. Research Policy 36(5):680-693. https://doi.org/10.1016/j.respol.2007.01.006

Kathleen LH (2016) Food Security of Genetically Modified Foods. Reference Module in Food Science. Elsevier. ISBN 9780081005965. https://doi.org/10.1016/B978-0-08-100596-5.03532-0

Koopmann T, Stubbemann M, Kapa M, Paris M, Buenstorf G, Hanika T, Hotho A, Jäschke R, Stumme G (2021) Proximity dimensions and the emergence of collaboration: a HypTrails study on German AI research. Scientometrics 126:9847-9868. https://doi.org/10.1007/s11192-021-03922-1

Lazzarotti V, Puliga G, Manzini R, Tallarico S, Pellegrini L, Eslami MH, Boer H (2023) Collaboration with universities and innovation efficiency: do relationship depth and organizational routines matter? Eur J Innov Manag. https://doi.org/10.1108/EJIM-03-2023-0241

Lindbeck A, Snower DJ (2001) Insiders versus outsiders. Journal of Economic Perspectives 15(1):165-188. https://doi.org/10.1257/jep.15.1.165

Marchese M, Potter J (2011) Entrepreneurship, SMEs and local development in Andalusia, Spain. OECD Local Economic and Employment Development (LEED) Papers, No. 2011/03, OECD Publishing, Paris. https://doi.org/10.1787/5kgdt917nvs5-en

Martin R, Moodysson J (2011) Innovation in symbolic industries: The geography and organization of knowledge sourcing. Eur Plan Stud 19(7):1183-1203. https://doi.org/10.1080/09654313.2011.573131

Martin R, Moodysson J (2013) Comparing knowledge bases: on the geography and organization of knowledge sourcing in the regional innovation system of Scania, Sweden. European Urban and Regional Studies 20(2):170-187. https://doi.org/10.1177/0969776411427326

Mercuri E, Birbeck J (2020) Fostering Australian R&D activity through industry-university collaboration. Austl Tax F 35:171.

Moodysson J, Coenen L, Asheim B (2008) Explaining spatial patterns of innovation: analytical and synthetic modes of knowledge creation in the Medicon Valley life-science cluster. Environment and planning A 40(5):1040-1056. https://doi.org/10.1068/a39110

Nilsen T, Lauvås TA (2018) The Role of Proximity Dimensions in Facilitating University-Industry Collaboration in Peripheral Regions. Arct Rev Law Polit 9:312-331. https://doi.org/10.23865/arctic.v9.1378

Nilsen T, Calignano G, Lien S, Nordli AJ (2024) Norwegian wood, isn't it good? Narratives of the lumber industry and development paths in the Nordic periphery. Journal of Rural Studies 105:103182. https://doi.org/10.1016/j.jrurstud.2023.103182

Nishimura J, Okamuro H (2011) Subsidy and networking: The effects of direct and indirect support programs of the cluster policy. Research Policy 40(5):714-727. https://doi.org/10.1016/j.respol.2011.01.011

OpenStreetMap contributors (2024) Map of Innlandet. Retrieved from https://www.openstreetmap.org/copyright

Parrilli MD, Radicic D (2020) STI and DUI innovation modes in micro-, small-, medium- and large-sized firms: distinctive patterns across Europe and the U.S. European Planning Studies 29(2):346-368. https://doi.org/10.1080/09654313.2020.1754343

Plum O, Hassink R (2011) Comparing knowledge networking in different knowledge bases in Germany. Pap Reg Sci 90(2):355-371. https://doi.org/10.1111/j.1435-5957.2011.00362.x

Roth P, Mattes J (2023) Distance creates proximity: Unravelling the influence of geographical distance on social proximity in interorganizational collaborations. Environ Plan A Econ Space 0308518X221143115. https://doi.org/10.1177/0308518X221143115

Schulze-Krogh AC, Calignano G (2020) How do firms perceive interactions with researchers in small innovation projects? Advantages and barriers for satisfactory collaborations. J Knowl Econ 11(3):908-930. https://doi.org/10.1007/s13132-019-0581-1

Sheydayi A, Dadashpoor H (2023) Conducting qualitative content analysis in urban planning research and urban studies. Habitat Int 139:102878. https://doi.org/10.1016/j.habitatint.2023.102878

Shi L, Wang L (2023) Understanding university-industry collaboration from the perspective of proximity: insights from a case study in China. Technol Anal Strateg Manag. https://doi.org/10.1080/09537325.2023.2251606

Sormani E, Rossano-Rivero S (2023) Facilitating academic engagement with society: A bonding social capital approach to self-determination. Triple Helix 9(3):296-324. https://doi.org/10.1163/21971927-bja10036

The Inland region (2017) The Bioeconomy Strategy for the Inland Region 2017-2024: A business strategy and action plan.

Torre A, Wallet F (2014) Introduction: the role of proximity relations in regional and territorial development processes. In: Regional development and proximity relations. Edward Elgar Publishing, pp 1-44. https://hdl.handle.net/10419/124376

Trippl M, Sinozic T, Lawton Smith H (2015) The Role of Universities in Regional Development: Conceptual Models and Policy Institutions in the UK, Sweden and Austria. Eur Plan Stud. https://doi.org/10.1080/09654313.2015.1052782

Wilke U, Pyka A (2024) Sustainable innovations, knowledge and the role of proximity: A systematic literature review. Journal of economic surveys. https://doi.org/10.1111/joes.12617

Zhang B, Wang X (2017) Empirical study on influence of university-industry collaboration on research performance and moderating effect of social capital: evidence from engineering academics in China. Scientometrics 113:257-277. https://doi.org/10.1007/s11192-017-2464-1

This project is an exploratory study of the Inland bioeconomy landscape and its relationship with regional development, with a specific focus on the collaboration between Small and Medium-Sized Enterprises (SMEs) and Higher Education Institutions (HEIs) in the biotechnology sector in Norway. Through the lens of Regional Innovation Systems (RISs) in combination with novel approaches to the analysis of clusters, this case-based research analyzes the enablers and barriers contributing to SME and HEI collaboration for knowledge transfer. In-depth interviews and surveys with one of Norway's Centers of Expertise (NCE), Heidner Biocluster and its members, reveal the nuanced role of geographic and other forms of proximity in fostering university-industry collaborations.

The project emphasizes the importance of proximity for SMEs in the biotechnology sector, demonstrating that geographic proximity may benefit larger, more established SMEs, though it is not as important for smaller, more internationally focused ones. It further highlights how innovation clusters exemplify effective place-based leadership in peripheral RISs, contributing to the Inland region's transition to a circular bioeconomy through strategic cluster governance and administration. Doing so, the project further contributes to broader knowledge on the dynamics of RISs, offering insights into the conditions under which collaboration between the private sector and academic institutions can thrive, thereby enhancing regional competitiveness and innovation. These findings extend to policymaking, strategic planning, and research on the implementation of the bioeconomy.

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