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Reconsidering actor roles in regional innovation systems: transformative industrial change in the forest-based bioeconomy

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ABSTRACT

This paper reconsiders the roles of actors in regional innovation systems in the context of transformative industrial change. Empirically, it draws on evidence from the Värmland region of Sweden, where regional innovation system actors, with partial funding from the Swedish Innovation Agency, are striving to build a bioeconomy upon the traditional forest-related industries. The main findings include that transformative industrial change adds a variety of responsibilities to regional actors, including the provision of change legitimacy, influencing the industry's innovation directionality and achieving social acceptance for change. A combined perspective on sociotechnical transitions and path development in regional innovation systems theoretically informs the case.

KEYWORDS

regional innovation systems; actors; transformative change; path development; sociotechnical transitions; technological innovation systems; bioeconomy

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1. INTRODUCTION

During the past three decades, the regional innovation system (RIS) approach has developed into one of the most influential general analytical and policy frameworks for innovation-based regional development (Asheim et al., 2019; Asheim & Gertler, 2005). As one of its strengths, the RIS literature has brought about a conception regarding the actors involved in regional innovation (Autio, 1998; Doloreux, 2002) and has more recently also contributed with a dynamic view on actors and regional innovation capacities in the context of industry development over time (Martin & Martin, 2017; Tödtling & Trippl, 2013; Trippl et al., 2018).

In this paper we argue that the understanding of actors and the roles they take in regional innovation requires reconsideration in light of current challenges such as climate change and environmental degradation. Tackling these requires transformative change, which puts new demands on the directionality of innovation, and which necessitates a more critical reflection about normative aspects (Weber & Rohracher, 2012). An increasing number of contributions engages in the need and potential of the RIS literature to address these matters (e.g., Coenen & Morgan, 2020; Martin, 2016; Strambach & Pflitsch, 2018; Tödtling et al., 2021; Trippl et al., 2020). However, only little attention has been paid to regional actors' changing roles in this regard so far (Grundel & Dahlström, 2016; Martin, 2020; Mattes et al., 2015; Rohe & Chlebna, 2022). We argue that these changing context conditions have a bearing on the roles of regional actors to influence innovation-based regional development and identify this as research area worth of reflection and analysis. Our aim is thus to contribute with a novel perspective on RIS actors in the context of grand societal challenges. A revised understanding of actors is crucial for updating the prominently used concept of RIS, which originates from the 1990s, to being better applicable on regional transformative change; and moreover, for designing and implementing corresponding regional innovation policies.

In theoretical terms, the paper takes a dynamic view on regional economic transformation through the lens of industrial path development in RISs (e.g., Isaksen & Trippl, 2016; Trippl et al., 2020). To embed industrial path development in its broader societal context and to

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address the need for transformative change, we complement this perspective with insights from the research field of sociotechnical transitions. In particular, we use the functions of the technological innovation system (TIS) approach (Bergek et al., 2008; Carlsson & Stankiewicz, 1991; Hekkert et al., 2007) which point out activities that are crucial for technological change in an innovation system. This integration allows us to identify and define roles of actors in RIS when addressing current societal challenges. The empirical application of our framework to a qualitative case study on regional industrial transformation renders possible the attribution of roles to RIS actors that have been less discussed so far.

Our empirical case focuses on the RIS built around the forest industry in the Värmland region of Sweden. Värmland has a long forest industry history, especially pulp and paper manufacturing. Ongoing attempts of RIS actors, supported by partial funding from the Swedish Innovation Agency (Vinnova), are striving yet to build a bioeconomy upon the traditional regional forest-related industries. Thereby, a 'forest-based bioeconomy' involves the production and use of forest resources and their conversion into an increasing number of by-products (i.e., materials, fuels and energy). The forest industry is assumed to possess high potential to contribute to a major societal transformation to a fossil-free society (European Commission, 2018) and is a relevant example of transformative regional industrial change.[1] In the presented case, transformative change addresses conversion of the industrial production system towards a reduced environmental impact and reduced use of fossil resources. During the past two decades, the regional forest industry has evolved from narrowly focusing on a few incumbent pulp mills, to building a RIS around many forest-related extensions that increase value-added revenue. We map key RIS actors to show how their roles have evolved in the course of the region's attempts to transform into a forest-based bioeconomy. Thus, we argue that transformative change alters regional actors' roles in the innovation system.

We specifically address the following research questions:

- What roles can be ascribed to the actors who drive change towards the development of Värmland's forest-based bioeconomy?
- What can we learn about RISs actors' roles during transformative regional industrial change by combing the RIS and TIS approaches?

The remainder of the paper is structured as follows. We begin by reviewing contributions in the fields of regional and technological innovation systems (TIS) and contribute with a novel theoretical perspective on RIS actors in section 2. Section 3 introduces our methodological approach and presents the empirical case. We conclude with a general discussion of our findings, policy implications and future research avenues in section 4.

2. THEORETICAL FRAMEWORK

2.1. Actors' roles in RISs and path development

RISs are in line with the broader innovation systems literature (Edquist, 1997; Lundvall, 1992) in that they consider private and public actors, capturing firms, industry associations, government agencies, research institutes, universities and other institutes for higher education as actor groups that shape innovation (Brazcyk et al., 2004). RISs generally comprise several clusters, which rely on both public innovation commitment and institutional support from private actors (Cooke & Morgan, 1998; Cooke, 2001). Thereby, RISs are not considered isolated, self-sustaining units, but instead are seen as embedded into broader national and international policy and knowledge contexts (Asheim et al., 2011).

The literature on regional innovation is increasingly addressing how new industries emerge and evolve, a research stream generally referred to as 'new regional industrial path development' (Hassink et al., 2019). Inspired by evolutionary economic geography (Boschma & Frenken, 2006; Boschma & Martin, 2010), RISs have been recognized as a framework holding great potential to advance our mechanistic understanding of regional economic evolution (e.g., Asheim et al., 2019; Trippl et al., 2018). Recent work by RIS scholars distinguishes between different forms of path development, pointing out a variety of directions regional industries can take (e.g., Asheim et al., 2019; Isaksen et al., 2018). This strand of literature has long ignored environmental challenges. Recently, however, a number of RIS contributions have attempted to capture the transformation of established industries to produce more environmentally friendly products (Tödtling et al., 2021; Trippl et al., 2020).

Actors' roles in the regional path development process align closely with the conceptualization of RIS as consisting of knowledge exploration and exploitation subsystems (Autio, 1998). Firms in related sectors compete for resources (i.e., labour, knowledge, capital) and are inherently responsible for exploiting knowledge and turning it into innovations. They also collaborate with research organizations to address scientific questions. Industry-specific cluster organizations stimulate innovation activities by advancing local collaboration and learning processes, technological knowledge spillovers and the creation of localized forms of knowledge (Isaksen, 2011; Skålholt & Thune, 2014). Actors within the knowledge infrastructure, such as universities and research institutes, are important for inputting knowledge into this system. Other areas within the knowledge infrastructure play roles in providing higher education and are crucial for providing competences, skills and training (Doloreux, 2002) for both the private and public sectors (Trippl et al., 2015). Other research organizations contribute by finding applied solutions to firms' (technological) problems. Firms may also be involved in improving universities' study programmes to secure a future labour force (e.g., Goddard & Vallance, 2013). Regional policymakers might promote

path development by creating arenas for knowledge exchange and by setting up schemes for attracting actors with complementary skills and resources to the region; they may also hinder new constellations by political inertia (Isaksen & Trippl, 2016; Tödtling & Trippl, 2005).

Cumulatively, regional path development is considered progressive in the presence of complementary (technological) knowledge spillovers between collocated firms, a strong scientific knowledge base and/or firms with the capabilities and resources to make use of this knowledge (Trippl et al., 2018). Knowledge exchange and learning processes between firms, and with knowledge providers, are considered essential triggers for different forms of path development. Public authorities' role in shaping innovation policies for new path development has largely focused on the support of knowledge combination and recombination between firms and the RIS knowledge infrastructure (Isaksen & Trippl, 2016).

Recently, Smart Specialisation and the related EU Research and Innovation Smart Specialisation Strategies (RIS3) have become tools for strengthening regional authorities' roles; they also push regional actors to draw on their unique resources to strengthen pre-existing specializations (Foray et al., 2012). RIS3 includes entrepreneurial discovery processes, or interactions among RIS actors (Asheim et al., 2017) that encourage bottom-up research and innovation processes. This is consistent with a recent, emerging, focus in the literature on how actors shape and alter regional industrial development (Grillitsch & Sotarauta, 2020; Isaksen et al., 2018; Jolly et al., 2020; Simmie, 2012). These contributions focus primarily on pioneering individuals but can include universities, companies and/or governments that change regional economic development by purposive action. Furthermore, contributions highlight that actors and activities in RIS are affected by higher level structures (Asheim et al., 2019). Increasingly emphasized are system building processes that depend on collective and coordinated multi-actor activities and that are crucial for adapting to novel and relevant innovation system arrangements (Gong et al., 2022). This has a specific bearing on RIS actor groups insofar as it highlights the importance, yet also difficulties of broad stakeholder participation, including the integration of previously neglected actors, such as civil society actors (i.e., labour unions, non-governmental organizations, associations, etc.) (Kopczynska & Ferreira, 2020).

2.2. Transformative change through the lens of TISs and sociotechnical transitions

The traditional RIS literature faces some conceptual challenges regarding its application to transformative change. Partly, these challenges are rooted in the literature's focus on production systems (Truffer, 2008), which consider technological development to be the main force driving innovation. Furthermore, RISs centre on the internal functioning of the system, which implicates a lack of focus on their embeddedness in a broader societal context (Martin, 2016). During the past decade, scholars have increasingly acknowledged the value of incorporating insights from sociotechnical transitions for studying regional transformations in general (Truffer & Coenen, 2012), and industrial path development in particular (Coenen et al., 2015). Some recent publications explicitly engage in the RIS concept (Coenen & Morgan, 2020; Tödtling et al., 2021; Trippl et al., 2020); however, none of them addresses changing actor roles in context of transformative industrial change.

In order to investigate changing actor roles, we argue that the RIS approach can particularly benefit from integration with a functional perspective on TIS. A TIS can be defined as 'a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product' (Markard & Truffer, 2008, p. 611). The strength of the TIS framework is that it allows taking a dynamic process view on industries through a focus on system functions. Its core assumption is that several defined functions must be carried out in an innovation system for a new technology to diffuse and induce industry (trans-) formation (Bergek et al., 2008; Carlsson & Stankiewicz, 1991; Hekkert et al., 2007). Put differently, the functions provide important insights into the innovation activities that are key to transformative change (Hekkert et al., 2007). We argue, therefore, that this functional approach will allow us to aggregate and define actors' roles in the light of transformative regional industrial change. We draw on the description of six functions used by Bauer et al. (2017), which closely relates to the initial suggestion of TIS functions by Johnson and Jacobsson (2001) and Bergek et al. (2008):

- *Knowledge development and diffusion*: the generation, diffusion and combination of knowledge in the innovation system in breadth and depth.
- *Influence of the direction of search*: Incentives and/or pressures for organizations to enter the technological field (e.g., visions, regulations, policy targets, customers' demand articulations, existing businesses' crises).
- *Entrepreneurial experimentation*: Reducing uncertainty by probing and applying a technology, creation of new opportunities and learning processes.
- *Resource mobilization*: TIS actors' mobilization of financial and human capital; also includes complementary asset mobilization, such as network infrastructure.
- *Market formation*: Factors targeting market development for emerging technologies (e.g., customers' demand articulations, institutional change, price changes); market formation often progresses through various stages of market size.
- *Legitimation*: Exerting influence on public opinion about a new technology; targets social acceptance and compliance with institutions; must be actively formed by individuals' and/or organizations' actions.

Some contributions to TIS use these system functions to map actors' activities in transformation processes (Foxon et al., 2010; Warnke et al., 2016). The theoretical

integration that we seek follows the same reasoning. Namely, that TIS functions become manifested in activities of actors that are involved in transformative change at the regional level. So far, only a few contributions integrate such a functional approach into a regional development perspective (Martin & Coenen, 2015; Rohe, 2020). The role of actors remains thereby unaddressed.

TISs are prevalently applied in research that relates to sociotechnical system transitions (e.g., Markard & Truffer, 2008; Weber & Rohracher, 2012). Sociotechnical transitions denote technological change processes in light of their embedding in a broader social, cultural and economic context (e.g., Geels et al., 2008). They are often conceptualized by a dynamic perspective on sociotechnical regimes, niches and landscapes (e.g., Geels, 2002) and capture long-term change that is, technologically seen, radical in nature. The transformation from a fossil-based economy to a bioeconomy is an example of such a transformation. It implies the replacement of a long-established complex of production practices and technologies, demands and user needs, skills, scientific knowledge, product characteristics, infrastructures and regulatory frameworks (Rip & Kemp, 1998) centred on a fossil paradigm by one centred on a bioeconomy. Against the background of sociotechnical transitions, TIS constitutes a framework that allows us to zoom in on (required) innovation dynamics in one technological field. These dynamics and importantly, TIS actors' actions, are situated in a broader context of change (Warnke et al., 2016; Weber & Rohracher, 2012).

The TIS framework is usually applied to the study of a single technology. In the broader research fields of bioeconomy and biorefining however, TISs have been used as an umbrella concept for a range of related technologies (Bauer et al., 2017). Thereby, TIS can span different firms and factories that are geographically collocated (e.g., Lopolito et al., 2011; Martin & Coenen, 2015). This renders possible the application of TIS in our regional case study on transformative change in context of a forest-based bioeconomy.

2.3. Towards an integrated view of actors

We propose that complementing RIS by a functional perspective on TIS entails benefits for investigating actors' roles in the context of transformative regional industrial change. Viewing TIS functions through a general lens of sociotechnical transitions suggests that activities in the innovation system take place in the light of broader societal change. We therefore consider RIS and their actors as embedded in a larger, dynamic societal context. To form a functioning innovation system, actors seek to put in place new alignments between a technology and various institutional factors.

The TIS functions allow us to zoom in on the actions needed for shaping a functioning innovation system in a new technological field. Recalling the functions in light of actors' roles described in the RIS literature, it becomes evident that the TIS functions incorporate a broader activity range. Legitimation and influence of the direction of search imply a deviation of innovation activities from 'established mainstream'. This adds further focal responsibilities to actors in that they are required to counteract probable resistance to change and generate legitimacy for a new technological trajectory (Hekkert et al., 2007). Contributions on regional innovation emphasize that to achieve change, actors need to break from existing social rules and technological paradigms (Grillitsch & Sotarauta, 2020). This requires the participation of a multiplicity of actors (Steen & Hansen, 2018) and hence presumes according capacities of RIS actors to induce and retain change (Kopczynska & Ferreira, 2020; Martin & Martin, 2017). Creating demand and markets constitute important functions in TIS, but are less addressed as actors' fields of activity in the regional innovation literature (Martin et al., 2019). A few recent studies, however, provide evidence regarding the importance of demand for green transformations of regional industries (Martin & Martin, 2021; Uyarra & Flanagan, 2022). The notions of the remaining functions, that is, the development and diffusion of knowledge, entrepreneurship, and the mobilization of financial and human capital are well-established also in the RIS terminology (e.g., Pyka et al., 2019). However, they cannot be simply transferred to RIS because the TIS functions have to be seen in close interrelation with one another (Bergek et al., 2008). Hence, knowledge development and diffusion, entrepreneurial experimentation and the mobilization of financial and human capital must be seen in the context of regime change. Entrepreneurial activities might include technological areas that are highly uncertain, without prospects regarding future profitability or societal acceptance (Coenen et al., 2015). They might, therefore, take different foci than those addressed by the RIS literature so far. For instance, they might involve a broader societal debate regarding the needs of a transformation (Trippl et al., 2020) and might necessitate the involvement of new actor groups such as non-governmental organizations or civil society (organizations) (Foray et al., 2012; Grundel & Dahlström, 2016) for achieving acceptance and making a larger societal transformation. However, this is also a dual relationship, meaning that the role of civil society and social interactions based on shared norms, values, routines and practices among RIS actors also can have positive effects on regional development, innovation and renewal (Aragón Amonarriz et al., 2019; MacGregor et al., 2010).

Our integrative approach implicates theory-led expectations on RIS actors' activities in the context of transformative change, which differ from those described in the RIS framework so far. For giving momentum to transformative industrial change, our framework suggests that RIS actors need to take active roles in fulfilling TIS functions. Our elaborations indicate a stronger focus on so-far less discussed aspects such as legitimation, the influence of the direction of search and market creation, as well as a new interpretation of roles that address the development and diffusion of knowledge in a broader sense. Taking and performing new roles involves action by pioneering actors to steer away from existing rules and paradigms;

and by implication, presumes capacities of actors to induce and retain change.

Our theoretical perspective thus provides insights regarding the roles and particular activities that RIS actors, striving to promote transformative regional industrial change, need to incorporate. At the same time, our approach comes with indications that (some) of the actor roles are likely to involve links beyond the RIS: We consider RIS being embedded in a broader sociotechnical context, which is rooted in the understanding that RIS and TIS operate at different scales. Concretely, this view implies that by taking new actor roles (of which some may exceed the RIS context), regional actors are likely to also engage in the development and shaping of the TIS beyond the regional context.

We take these theoretical considerations with us to the next section where we further investigate what roles can be ascribed to the actors who drive change towards the development of Värmland's forest-based bioeconomy.

3. METHODS AND EMPIRICAL ANALYSIS

Our analysis is primarily based on a combination of qualitative research methods; however, we substantiate some industrial characteristics with statistical evidence. Fifteen individual semi-structured, in-depth interviews with key regional stakeholders collaborating in a triple helix system on the forest-based bioeconomy were conducted between January 2015 and June 2019. The interviewees included four regional officials, nine firms and industry representatives, and two researchers. Our interview guides were theoretically informed and thematically organized. Interview contents concerned the actor-networks and collaborations within (and beyond) the RIS, their participation in activities and events targeting transformation, as well as the actors' specific work towards transformative change. Our qualitative approach puts central that capturing people's experiences is crucial for obtaining a holistic understanding of a social context; and further, that a variety of experiences is needed to develop knowledge for tackling challenges (Brink, 1999). We transcribed our interviews verbatim; important quotes have been translated from Swedish into English. To ensure truthfulness and consistency of our research, we, authors, commonly and in discussion with one another searched for a common line of agreement among the interview respondents' statements. The interviewees were given the possibility to read the paper manuscript and to approve or mention disagreement regarding contents and direct quotes used. To strengthen the embedding of our interviews with their context, we conducted an extensive analysis of this regional case's documentation, including websites, policy reports and other strategy documents. Furthermore, and to include knowledge and empirical data from a broader range of the region's actors on the challenges and advantages of a forest-based bioeconomy, we organized five workshops between October 2015 and August 2019. These spanned civil society organizations, regional authorities', firms and cluster organizations, and the university. Between 2015 and 2021, we also participated in a variety of bioeconomy activities such as workshops, conferences, fairs and study visits also serving as a platform for participatory observation and interaction with key stakeholders in the region. We ourselves can, therefore, be regarded as part of the RIS under study, based on the motive of multidimensionality of societal challenges, which makes it necessary to include knowledge from a variety of actors. Another motive for this research was to transfer the results back into the innovation system.

4. TRANSFORMATIVE REGIONAL INDUSTRIAL CHANGE: TOWARDS A FOREST-BASED BIOECONOMY IN VÄRMLAND

Värmland is one of Sweden's 21 counties, located in western parts of the country, bordering Norway. It is a thinly populated area with about 16 inhabitants/km^2. The forest industry has historically been important for Värmland, economically and in terms of regional identity. Even in the mid-19th century, the forest industry consisted of more than 50 mills. From the 1950s on, pulp and paper producers were affected by increased international competition, leading to structural change in the industry shifting from small mills to large-scale production facilities. The industry was severely challenged during the 1990s, with growing awareness of its energy-intensiveness and polluting character (Bergquist & Söderholm, 2011). These common challenges led to collaborations among some of the dominant pulp producers in Värmland, culminating in targeted actions during the late 1990s, also crucial for further industry development of the forest sector in the region.

Today there are about 200 core companies within the pulp and paper industry in Värmland, including major mills, machinery suppliers, sawmills and consulting services in the paper and pulp arena (Mikkola et al., 2016). However, only seven of the original 50 pulp mills remain. Both small and large local and global firms are present, providing technology, engineering, market pulp or finished paper products for the global market (Bjurulf & Olsson, 2010). In 2018, the exports of the industry amounted to 15,600 million SEK (Fineman & Claesson, 2020) and the industry employs a labour force of approximately 12,000 (Mikkola et al., 2016) with generally constant, yet slightly decreasing levels in the period 2011–17 (Statistics Sweden, 2018). Of the 200 companies, more than 120 are today members of a regional business cluster targeting the forest bioeconomy (Paper Province, 2021). The traditional regional industry niche is packaging, an advantage when the Scandinavian paper industry is challenged by rapidly decreasing global demand for paper products such as newspapers (Coenen et al., 2015). The regional transformation goes along with a diversification into a larger variety of branches, which increasingly challenges capturing all companies that contribute to the forest-based bioeconomy. A collaboration between Statistics Sweden and the Swedish regional governments in 2018 assessed the value added by the Värmland

forest-based bioeconomy to be constantly increasing, amounting to plus 29.1% between 2008 and 2017. During the same period, fossil emissions by the regional industry were assessed as a decrease of 17.9% (Statistics Sweden, 2018).

4.1. RIS actors from the late 1990s to the late 2000s

A central player in the Värmland RIS has been the cluster organization Paper Province. Founded as a membership organization by seven firms in 1999, its goal was to solve industry-spanning challenges such as difficulties with attracting and hiring skilled labour (Paper Province, 2019a). From the early 2000s on, the cluster's strong focus was to promote general interest in the industry. This included an emphasis on packaging through strengthened industry innovation environments, which allowed companies to test new packaging-related products and services. An additional focus was on increasing industry energy efficiency, achieved by founding the worldwide pulp and paper industry's first centre for energy efficiency in 2007 (Paper Province, 2019a). From the late 1990s until the late 2000s, the cluster organization was predominantly oriented towards the exchange of technology-related knowledge, networking, collaboration and industry-focused information dissemination as pointed out in the RIS literature (Isaksen, 2011; Skålholt & Thune, 2014). Firms' responsibilities have been strongly associated with innovating by exploiting according to available knowledge (Autio, 1998; Paper Province, 2019a).

Since the beginning of the 2000s, the regional authority, Region Värmland, is another major actor in the RIS. Over the years, their scope of responsibility has increased to include a broad spectrum of regional development issues, with the main task to promote growth and favourable conditions for regional development. Another important actor is Karlstad University, with several early established research projects between the university and the paper and pulp industry. The collaborative projects incorporated the paper, pulp and printing technology fields, as well as materials and chemical engineering (Van Vught et al., 2006). An Organisation for Economic Co-operation and Development (OECD) project on the contribution of universities to regional development, in which both Region Värmland and Karlstad University took part from 2005 to 2007 led to a more focused regional policy strategy, with significant RIS engagement and a formal collaboration agreement between these two actors (Circle & CURDS, 2013; Jolly et al., 2020; Kempton, 2015). During this early period, RIS collaborations were developed and facilitated; however, they were mainly limited to the three above named actors and a few paper mills. Interactions predominantly targeted knowledge combination and recombination between firms and the RIS knowledge infrastructure (Isaksen & Trippl, 2016).

From 2010 onwards, collaborations between these actors intensified and gave momentum to further arenas for knowledge exchange and learning processes, counteracting inertia in a traditional industry (Isaksen & Trippl, 2016; Tödtling & Trippl, 2005). The aim was to generate further research and innovation funding by directly linking university research and the regional firms' research needs (Circle & CURDS, 2013).

4.2. Joint efforts to build a forest-based bioeconomy

Around 2011, the cluster organization, in collaboration with the regional authority, decided to apply for Vinnova's (the Swedish Innovation Agency's) programme 'Vinnväxt – Regional Growth through Dynamic Innovation Systems' (Vinnova, 2016), the aim of which is to promote sustainable growth in Swedish regions by developing internationally competitive research and innovation environments (Vinnova, 2019). The main reason to prioritize a forest-based bioeconomy was the common desire by the cluster organization and regional authority to broaden the focus from the vulnerable forest industry to a larger variety of industrial sectors. What we talked about back then was to start from the felled tree, it was there the Vinnväxt initiative started. And then what we could do is value-creating (senior official, regional authority). This implied an expansion to include more forest-related sectors, such as sawmills and energy companies. In 2013, the bid to Vinnova was successful and resulted in a 10-year, 130 million SEK initiative named 'Paper Province 2.0'. It runs until 2023 and is collaboratively funded by Vinnova (50%) and a triple helix partnership (50%) consisting of Paper Province and its members, Värmland's regional and several local authorities, Karlstad University, Research Institutes of Sweden (RISE) and the Swedish Forest Agency. In contrast to other Vinnova-funded initiatives, which often address technological development in specific sectors, Paper Province 2.0 also addresses the larger societal transition towards a forest-based bioeconomy. This means that transformation initiatives should involve a broad range of actors from across society, including civil society actors, consumers and users (Grundel & Dahlström, 2016). The successful Vinnova bid would likely have been impossible without the previous formation of the region's intensive triple helix collaboration (Circle & CURDS, 2013; Kempton, 2015).

Shortly after receiving the Vinnväxt grant, Region Värmland developed a regional research and innovation strategy for Smart Specialisation: Värmland's Research and Innovation Strategy for Smart Specialization 2015–2020 (VRIS3) (Region Värmland, 2015). Development of this strategy occurred through close collaboration with previously named RIS actors, and explicitly addressed societal challenges including those related to the environment and climate change (Region Värmland, 2015). Vinnväxt funding and the close collaboration between Region Värmland and Paper Province were crucial to the decision to make forest-based bioeconomy the top Smart Specialisation priority. Hence, Vinnväxt has been fundamental to stimulating transformative change in many ways. It serves as an umbrella that provides change legitimacy and directionality, under which regional authorities in close collaboration with other RIS actors purposively alter regional

economic development (Asheim et al., 2017; Isaksen et al., 2018). The initiative also supports entrepreneurial experimentation as well as knowledge development and diffusion throughout the bioeconomy theme, both for incumbents and new industry actors (Jolly et al., 2020). It also provides important financial resources for change momentum for firms as well as for Karlstad University.

4.3. Changing actor roles

The endeavour to address societal challenges and transform the forest industry in Värmland into a forest-based bioeconomy has changed RIS actors' roles. Instead of predominantly tackling incumbent forest companies' problems (e.g., obtaining a skilled labour supply), the cluster organization is now addressing broader transformation; in TIS contributions expressed as exerting influence on public opinion regarding the industry (Bergek et al., 2008):

> From the beginning, Paper Province was a corporate cluster and worked for the companies and their issues … work with skills supply, networking, and certain theme issues and so on. … [Now] it's about being a system player. … We mission much more, I think, than we have done before, about the role of the forest and such.
>
> (senior industry representative, cluster initiative)

Thus, the intention to work towards public acceptance of a forest-based bioeconomy has accelerated. This work requires providing information about multiple forest uses and working to change the industry's previously negative image. Municipality workshops that span a broad range of actors, including those in civil society, have served to increase awareness of a regional bioeconomy, support local innovations and create an innovation platform for the developing bioeconomy.

> We try to get closer to civil society, for example, through these municipal workshops. … We have invited associations and so because there is also a great power in it, for knowledge development and idea generation.
>
> (senior industry representative, cluster initiative)

> [I]t is an important group of players. They are, nevertheless, end consumers and those who receive the information. The negative information also, so we have to give the counter-arguments – that is important.
>
> (senior industry representative, cluster initiative)

Paper Province thus provides new platforms within which a variety of actors meet. It encourages confrontation with different societal opinions, recognizing that legitimacy is not given but must be formed (Bauer et al., 2017). The development and diffusion of knowledge include the civil society (Grundel & Dahlström, 2016) and by implication, captures a so-far less addressed breadth and depth in the RIS. The latter also implicates the cluster organization's involvement in supporting institutional change and demand articulation.

The cluster organization has become an important industrial transformation reference for companies in the region. These are aware of the general environmental debate and the potential innovation opportunities it brings for the industry. However, Paper Province clearly influences the companies' direction of search (Bauer et al., 2017) and provides an umbrella creating overall legitimacy for change (Hekkert et al., 2007).

> And we feel very much that this global societal challenge, that it is a reality today. … [I]t is a strong, strong driving force that also drives the forest industry companies.
>
> (senior official, regional authority)

> Paper Province is very much trying to inspire companies to change and re-think. To be that inspiring partner, and also the enlightening partner.
>
> (business consultant in the forest industry)

Transformation spans both incumbent and new companies (Jolly et al., 2020). With its traditional packaging focus, Värmland industry has found a niche in sustainable packaging products, as well as in reduced material inputs in their production. An example is the €700 million investment by Billerud Korsnäs in a state-of-the-art board-making machine (Paper Province, 2019b). In addition, companies are involved in research on possible by-products from lumber, as well as paper and pulp production that might replace fossil-based products. Examples include the design and production of 3D-printed kayaks from bio-based waste (Melker of Sweden, 2021). An incumbent mill, Nordic Paper, supplies lignin to a test bed where companies in collaboration with research develop new fossil-free products such as bioplastics (Lignocity, 2021). Improving the industry's energy efficiency is still a field of innovation, while also timber-based construction has become a more pronounced regional stronghold. An example is the new production line for cross-laminated timber, a Stora Enso investment of €45 million (Stora Enso, 2019). While a few incumbent mills traditionally dominated the company landscape of the Värmland RIS, initiatives to support entrepreneurship and start-ups have been central during the past decade.

> It is important that the large companies participate in different types of consortia and network collaborations with smaller and innovative companies. It is already happening to some extent.
>
> (senior representative, research services for the forest industry)

> In [another region] for example, it can often be difficult to go from research to a start-up company. Then it can sometimes be better to move that research result here to make the start-up company. And now we have also started such an incubator that will be able to help with that.
>
> (senior official, regional authority)

Forest industry companies perceive the adjustment to consumer norms and values as increasingly relevant for securing their market share and improving their image. Closely related, they are aware that tackling environmental issues is crucial for attracting a young labour force to their operations (Forsmark Karlsson & Östberg, 2016).

Our analysis supports that in the context of transformative industrial change, companies' innovation activities change directionality. Companies' central roles in the RIS still lie in exploiting, combining, and recombining knowledge and turning it into innovations (Autio, 1998; Isaksen & Trippl, 2016). The influence of the direction of search and legitimacy of change provided by pioneering organizations (Grillitsch & Sotarauta, 2020), such as Paper Province, additionally supports their identification with the environmental debate.

Karlstad University has benefitted from the Vinnväxt grant by gaining a growing technological research environment for forest-based bioeconomy. Vinnväxt and the Smart Specialisation Strategy have also strengthened social science research in this field. Forest industry-related research has thus broadened, going beyond technology and the physical sciences. Social science research is increasingly important for conveying knowledge about this transformation, and how to strengthen the RIS and build new collaborations:

> It is incredibly important that [the university] grows, even when it comes to the bioeconomy side with both technology and CTF [Service Research Centre] and CRS [Centre for Research on Sustainable Societal Transformation], that we get a greater critical mass, that we become known as the bioeconomy project.
>
> (senior industry representative, cluster initiative)

This informant stresses that both in-depth knowledge development (i.e., about specific technological matters) and breadth are important to transformation, and lead to a broader view of societal dynamics. This can also take a non-technological entrepreneurial experimentation form, in which new learning processes are created (Bauer et al., 2017).

Region Värmland's scope of responsibility has increased over the years, as have its in-house expertise and capacity to address a broad spectrum of regional development issues. This case's regional economic development clearly benefits from related variety (Neffke et al., 2011) among forest-related branches. However, the regional authority takes an active role in facilitating collaboration between actors and companies under the bioeconomy banner. The regional authority is involved in entrepreneurial experimentation by stimulating new learning processes between companies, and by influencing the direction of search through its Smart Specialisation Strategy.

> It is in these spaces in between [companies] where we can enter. These are, for example, about creating side streams, there we can go in.
>
> (senior official, regional authority)

Combined with Vinnväxt funding, this creates an overall development goal and vision. Region Värmland's authority actions also provide change legitimation (Bauer et al., 2017). Through research projects, Region Värmland is involved in several aspects of financial capital mobilization, which are important for building a TIS (Hekkert et al., 2007); it has also mobilized in-house human capital.

Another aspect of targeting change legitimacy (Bergek et al., 2008) is improving regional branding to increase global visibility. The regional actors, led by Region Värmland, commonly engage in supra-regional decision-making processes. For example, Region Värmland is actively working to create a stronger awareness of forest industry potential in northern Europe. This is simultaneously a form of market creation, acknowledging that full transformation depends on the establishment of larger, international markets for bio-based products. It also points to the need for changes in the broader sociotechnical context (Bauer et al., 2017), and reveals that green regional transformations do not end at the regional boundaries (Martin, 2020).

> [With the forest-based bioeconomy,] I think that maybe we can make a bigger impact at the European Commission than the forest industry can because we are not talking about ourselves as an industry, but the [European] Commission may have a tendency to listen more to us, perhaps, because we have a broader perspective on a question. So that's also one aspect regarding the market.
>
> (senior official, regional authority)

A full description of all actors who have contributed to this regional transformation, and additional activities that have taken place within the RIS, would be beyond the scope of this paper. Indeed, the number of actors involved in the regional forest-based bioeconomy endeavour has steadily increased. Our analysis suggests that actors' roles during transformative change differ from the conventional roles usually ascribed to RIS actors. Previous contributions have mainly focused on knowledge combination and recombination between firms and the knowledge infrastructure, with a dominant technological focus. The present case suggests a broadening from a purely technological focus to increased consideration of societal factors and challenges. Table 1 gives an overview of our empirical findings by summarizing how actors in Värmland have changed their roles to promote transformative change.

Our analysis however also reveals that challenges exist that limit a full transformation. For example, there remain conflicts between biological diversity and forest clearing for economic purposes, and the environmental impact of the forest industry is not unproblematic (Holmgren et al., 2022). Further, civil society involvement in the transformation process has not gained much momentum over the past several years. This is also in line with MacGregor et al. (2010) showing that a well-developed triple helix system can lead to lock-ins rather than an inclusion of civil society in RISs.

Table 1. Regional innovation system (RIS) actors' conventional roles in path development and additional roles during transformative change.

Actors in RIS	Conventional roles in path development	Additional roles during transformative change
Cluster organization (representing industry)	Promoting innovation by: • Advancing local collaboration and learning • Supporting (technological) knowledge exchange • Providing collaboration platforms	• Exerting influence on the public opinion regarding the industry and transformation at large; social acceptance for change is not given but must be formed • Influencing the innovation direction of the industry and providing incentives to contribute to transformation (and by doing so, reducing uncertainty) • Advancing learning and collaboration in breadth and in depth: facilitating new learning processes and new actor constellations • Facilitating market formation through supporting institutional change and demand articulation
Authorities	Promoting innovation by: • Creating arenas for (technological) knowledge exchange • Attracting financial and complementary human resources/ skills to the region	• Providing legitimacy for societal and technological change • Influencing the direction of search of RIS actors • Mobilizing financial and human (in-house) resources • Market formation, e.g., by engaging in supra-regional policy-impact activities • Diffusing and combining knowledge in breadth and in depth, involving new actors and triggering new collaborations • Experimenting through creating new learning opportunities around new technologies; reducing uncertainty
Research institutes and higher education	• Providing education (i. e. human capital) • Providing technological research	• Development of knowledge in breadth additional to a technological focus; social science research becomes more important • Providing science-based legitimacy for change by communicating the need for combined sociotechnical change
Firms	• Innovating through technological knowledge exploitation • Market creation (although less emphasized)	• Technological knowledge exploitation and market creation targeting transformative change (new directionality) • Anchoring with and consideration of societal challenges in innovation (novel breadth and depth in knowledge exploitation)

5. DISCUSSION AND CONCLUSIONS

This paper aims to contribute with a novel perspective on RIS actors in the context of grand societal challenges. By complementing a dynamic perspective on RIS with a functional approach to TIS, the paper advances the understanding of RIS actors' roles during transformative regional industrial change.

Our empirical investigation of actors who drive change in Värmland's forest-based bioeconomy reveals that transformative change does alter RIS actors' roles; and particularly, that it broadens actors' spectrum of responsibilities. We find that RIS actors carry out TIS functions for giving momentum to regional transformation in a particular technological field. Regional key actors are increasingly involved in knowledge development activities and learning processes that go beyond a technological focus. Influencing the direction of search and providing change legitimacy for a transformation are further roles that add to the RIS actor's responsibilities. In our empirical case, we identify a stronger weight of societal research regarding a regional university's role in the RIS knowledge development and diffusion. Furthermore, a cluster organization is engaged in knowledge diffusion about conflicting interests concerning the use of forests. Simultaneously, the civil society becomes important in the cluster organization's

knowledge development, pointing to the importance of new actor constellations for learning processes, for example, about societal values. Closely connected, we reveal new roles of the cluster organization in providing change legitimacy, and by implication, influencing innovation directionality of the industry towards environmental sensitivity. Companies' central roles in innovating remain, technological knowledge exploitation however caters a new directionality and is increasingly oriented on discourse regarding societal development challenges. Similar responsibilities regarding the search direction of RIS actors and legitimacy provision for societal and technological change can be ascribed to the regional authorities. However, in our case, their role lies stronger on technological experimentation aspects and the mobilization of financial and human capital resources. The regional authorities and the cluster organization also take roles in demand articulation and market creation. Taking the regional authority's actions as an example, it becomes evident that transformative change also implies new responsibilities regarding how RIS actors work to create legitimacy on higher spatial scales. A complete regional transformation will not only depend on internal action, but also on changes within the broader national and international arenas (i.e., the supra-regional sociotechnical context). By implication, RIS actors also influence TIS development beyond the regional context.

The combined view on RIS and TIS thus suggests that for giving momentum to transformative industrial change in a certain technological field, RIS actors need to take and perform active roles in fulfilling TIS functions. This presumes the capacities of actors to induce and retain change by continuously aligning expectations and by mobilizing a multiplicity of actors (Gong et al., 2022; Martin & Martin, 2017; Steen & Hansen, 2018). It emphasizes the previously named abilities of actors to break from existing paradigms, both in technological and social terms (Coenen & Morgan, 2020; Grillitsch & Sotarauta, 2020; Isaksen & Jakobsen, 2017). Historically grown collaborations can be considered crucial for the successful Vinnova bid; and at later stages, the Vinnväxt initiative provided an umbrella for change legitimacy.

This paper brings about a novel perspective on regions' capacities for innovation and transformation, and also for regional policy to support transformative industrial change in particular technological areas. It shifts focus away from firms' innovation capacities and the capacities of research to a more comprehensive view, including a larger variety of actors and responsibilities. The creation of new sociotechnical alignments both within the RIS and beyond its boundaries becomes fundamental as technological development needs to consider and be aligned with societal development challenges. In this regard, our investigation advocates for stronger roles of RIS actors in providing change legitimacy, influencing the direction of search and market creation, as well as in enabling novel forms of knowledge development and diffusion. Regional policies can thus actively support transformative industrial change in a particular technological field through encouraging the exerting of TIS functions by RIS actors. Thereby, regional actors also need to be considered as agents who convey within the supra-regional policy context.

Our contribution highlights the need for a revised (theoretical and empirical) understanding of regional actor roles for addressing and achieving transformative change of industries in regions. The findings from our Värmland case provide knowledge and inspiration for regional actors and decision-makers regarding the roles and specific actions to be taken to promote transformative industrial change. We however do not intend to ascribe a fixed set of roles to specific actors or actor groups in RIS. The boundaries between actors and their responsibilities might blur (Warnke et al., 2016). Additional case studies on different types of regions and industries, spanning an even larger variety of actors, will undoubtedly be needed for investigating whether it is possible, if at all desirable, to ascribe more consistent roles to regional actors in the context of transformative change. Further research avenues lie in improving our understanding of a dynamic view of regional actor roles. We see an importance in more closely investigating different agents' capacities and capabilities that enable (or hinder) change. We suggest that the roles and capacities of firms in contributing to the transformative industrial change of regional industries warrant additional attention. Particularly, we see potential in a stronger exploration of the literature on business innovation modes, which can be helpful to further zoom in on how firms (and other actors) conceive their innovation strategies (Parrilli et al., 2020). Likewise, regional authorities are another actor group of particular interest. Evidence from our case suggests that knowledgeable public actors in regions may compensate for a dearth of knowledge spillovers and branching processes between related industries, by actively engaging in knowledge exchange between different branches and across geographical scales. This also links to the strengthened role of regional authorities in shaping valuable interactions of RIS actors in the context of Smart Specialisation Strategies.

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NOTE

1. Yet, the environmental impact of the forest industry is not unproblematic (Holmgren et al., 2022).

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