# Sustainable transitions in an old industrial region? Path renewal and regional innovation policy in the paper and pulp industry

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**Abstract**
The objective of this paper is to further insights on the potentials, barriers and limitations for policy to facilitate industrial renewal in locked-in regions and industries. The paper conducts a qualitative in-depth case study of the Swedish policy program 'Biorefinery of the Future' (BioF) an initiative geared to develop a strong regional innovation environment for forestry-based biorefinery development in the area of Örnsköldsvik and Umeå in Northern Sweden. Theoretically, the paper draws on concepts from evolutionary economic geography regarding path-dependence, related variety and lock-in, and combines these with institutional approaches found in science and technology studies to explain disruptive shifts or transitions in socio-technical systems.

## Introduction

Following an increased attention for and usage of evolutionary economics in economic geography (BOSCHMA AND FRENKEN, 2006; BOSCHMA AND MARTIN, 2010; ESSLETZBICHLER AND RIGBY, 2007; MARTIN AND SUNLEY, 2007) there is a growing interest in lock-in and industrial renewal in the context of regional development (STORPER, 2011; HASSINK, 2010). Since the early 1990s there has been an ongoing engagement in the sub-discipline with the particular problems, challenges and strategies of old industries and old industrial regions (HASSINK AND SHIN, 2005; HUDSON, 1989, 2005). In this body of work there has been a particular focus on how such industries and regions may, or may not, be able to break out of locked-in paths of development by pursuing innovation and new technological pathways. More recently this debate has gained further momentum through the introduction of the concept of related variety (FRENKEN et al., 2007). Instead of juxtaposing regional specialization versus regional diversity as guiding principles for economic development, it draws attention to the economic importance of bringing different but complementary pieces of knowledge together. More specifically, it offers a new way to consider opportunities for regions to diversify into new industries and contribute to dynamic processes of economic renewal (ASHEIM et al., 2011).

At the same time, various scholars have articulated critique that an overriding focus has been attributed to micro-level firm routines in evolutionary economic geography at the expense of other actors and institutions (such as the state) (MACKINNON et al., 2009; MORGAN, 2012). This reflects a more fundamental concern about how to combine and relate overlapping economic, institutional and political approaches in the context of evolutionary economic geography. Departing from an institutional perspective, GERTLER (2010) asserts that there is a need to better understand processes of institutional evolution and change over time in light of regional economic change. This requires paying close attention to both agency to change by firms, individuals, organizations, consortia, etc. and structural factors, i.e. institutions, sectoral, national and regional framework conditions. Especially the role of policy has so far been relatively neglected in standard work on evolutionary economic geography on regional development issues (Asheim et al., 2012; Rodriguez Pose, 2013)

The objective of this paper is to further insights on the potentials, barriers and limitations for policy to facilitate industrial renewal in locked-in regions and industries by building on a combined institutional-evolutionary approach. To do so, the paper analyzes the Swedish VINNVÄXT program 'Biorefinery of the Future' (BioF). VINNVÄXT is one of VINNOVAs (the Swedish Agency for Innovation Systems) regional support programs which aims to promote sustainable regional growth by developing internationally competitive research and innovation environments in specific growth fields. More specifically, the BioF initiative is geared to develop a strong innovation environment for biorefinery development from renewable, forest-based resources provided in the area of Örnsköldsvik and Umeå in Northern Sweden. The forest industry is a traditionally important and large industry in this region in terms of employment opportunities. However, due to shrinking global demand for paper products and tightening global competition, scarcity and increased prices of forest raw materials, and increased requirements on more sustainable production methods, the industry is facing challenges to remain competitive. Being strongly dependent on this industry, the future development of this region is heavily tied to the competitiveness of this industry (as well as many other peripheral regions in Sweden). In recent years the industry is increasingly seeking new, alternative ways to extract and appropriate greater value from biomass, while at the same time improving its energy-efficiency, carbon emission impact and overall environmental performance. A biorefinery can be seen as a platform technology that integrates biomass conversion processes and equipment to produce a portfolio of environmentally friendly fuels, power, heat, and value-added chemicals from biomass (NREL 2009). Instead of primarily using the forest biomass (i.e. lignocellulose) for the production of paper and pulp, biorefinery technologies allow its conversion into additional or substitute products such as low-carbon fuels (e.g. $2^{nd}$ generation bio-ethanol, DME and biodiesel), green chemicals, substances used in the construction industry, viscose for clothing, or ingredients for the food and pharmaceutical industry; while making more efficient use of the heat in the production process. The notion of a biorefinery is comparable to that of an oil refinery, yet, replacing fossil oil by renewable, low-carbon resources (i.e. biomass). As such, a biorefinery offers a possibility for forest related industries to increase their efficiency and diversify into different markets. This often requires establishing linkages to other industries. In doing so, biorefineries have the potential to contribute to renewal of the pulp and paper industries (Karlstorp and Sanden, 2012; Ottosson and Magnusson, 2013). Against this context the BioF initiative can be seen both as an attempt to address regional lock-in but also as a way to promote renewal of industries which, if successful, would have far reaching positive (environmental and economic) impacts beyond the region.

From an evolutionary economic geography perspective, the BioF initiative makes a relevant and interesting case for studying the emergence and adoption of radical (and partly disruptive) novel technology in a mature industry and, as a consequence, renewal of an old industrial, peripherally located, region. More specifically it analyzes the role of policy in this process. The BioF initiative pertains to a large extent to the introduction and bridging of new scientific and technological knowledge into what is considered by many as a conservative and risk-averse industry, located in an area where traditional forest related industries such as pulp and paper to a large extent have defined the economic identity of the region. Previous studies have shown that there has been a fair deal of resistance in the forest industry against what is considered to be a radical and disruptive technological pathway (LAESTADIUS, 2000; OTTOSSON, 2011). The research question guiding this analysis is:

*How can a regional innovation support program, and its efforts to foster the adoption of science-based knowledge creation and exploitation, contribute to the renewal of mature industries? How is such ability constrained and/or enabled by the regional context?*

To cater for an evolutionary and institutional perspective, the paper draws on a theoretical framework that borrows concepts from evolutionary economic geography regarding path-dependence, related variety and lock-in, and combines these with insights from institutional approaches to science and technology studies concerning the co-evolution of technologies and institutions in light of disruptive shifts or transitions in socio-technical systems (GEELS, 2002, 2004; TRUFFER and COENEN, 2012).

The paper concludes that biorefineries constitute promising possibilities for the forest industry to renew itself and, by implication, to diversify into new markets. The BioF initiative has shown considerable success in developing and implementing novel technologies as well as bringing together different but related competences, and in shaping a stable network of actors by drawing on public-private partnerships (triple-helix). As such, the analysis reveals that regional innovation support programs have the potential to contribute to the renewal of mature industries although challenges regarding the industries' location in a peripheral region exist. However and at the same time, path-reinforcing tendencies persist which transcend the regional scale. In particular, it is revealed that broader, industry exogenous, institutional conditions on the demand-side are not sufficiently developed yet in order to allow making use of the technological potential, and thus, to lead to industrial renewal.

The remainder of the paper is organized as follows. The next section presents the theoretical framework of the study, drawing on literature on industrial and regional path dependence, knowledge complementarities, and socio-technical transitions. Section three provides a short outline to the research design and methods applied in the study, followed by the empirical case study and analysis in section four. The paper ends with conclusions and suggestions for future research.

## Theoretical framework: path-dependence, knowledge complementarities and socio-technical transitions in old industrial regions

As the focus of this paper deals with renewal of mature industries in a regional context,, the theoretical discussion departs from the existing literature on old industrial regions. This literature is primarily geared to identify typical problems found in the innovation system of such regions focusing on issues related to path-dependence and lock-in. Subsequently, this section seeks to combine and integrate this literature with a transitions perspective to account for an analytical framework geared to understanding transformative systemic change and the role that policy plays in facilitating this.

### *Regional challenges to industrial renewal*

Old industrial regions are typically considered as regions overspecialized in mature industries experiencing decline. TÖDTLING and TRIPPL (2005) provide a stylized 'problem description' of the regional innovation system usually found in these regions. Innovation activities in old industrial areas often follow mature technological trajectories mainly of an incremental character. Efforts to introduce radically new products into the market tend to be limited compared to process optimization and other efficiency-oriented activities. Even though, as TÖDTLING and TRIPPL (2005) observe, the region may have a highly developed and specialized knowledge generation and diffusion system, this is usually oriented towards traditional industries and technology fields. Moreover, small firm innovation and entrepreneurial activity tends to be low given the dominance of larger firms, incumbent to the established and mature industrial and technological specialization (STEINER, 1985). Examples of old industrial regions are frequently found in regions specialized in heavy industries like the Ruhr area in Germany (GRABHER, 1993), the North East of England (HUDSON, 1994; COENEN, 2007) or Wales (MORGAN, 2012). It is interesting to note in the context of this paper, that these regions are also well-known for being sites with severe difficulties dealing with waste and pollution (such as e.g. carbon emissions) (GONZÁLEZ-EGUINO et al., 2012).

As TÖDTLING and TRIPPL (2005) acknowledge, regions may face a mix of regional innovation systems deficiencies (failures) as suggested in their typology. We therefore also draw partly on a second type of 'problem description' related to regional innovation systems, namely that of 'peripheral regions'. Given the location of the BioF initiative in the Northern, sparsely populated part of Sweden, it is reasonable to assume that the region also faces challenges related to its location. A main characteristic of many peripheral regions is that important regional innovation system conditions are poorly developed due to 'organizational and institutional thinness'. Similar to the old industrial region typology, the emphasis is on incremental innovation and on process innovations. But now, the main explanation for a lower level of innovation activity is tied to low density as well as a 'thin' and less specialized structure of knowledge suppliers, technology transfer organizations and educational organizations.

On a general level, the key problem of old industrial regions can be characterized as negative lock-in (HASSINK 2010). Lock-in is closely connected to path-dependence, a concept originating from the literature on evolutionary economics and technological change (DAVID, 1985). The notion of lock-in highlights the importance and impact of history on (future) economic development. In this context, MARTIN (2010, p. 3) defines lock-in as "the idea that the combination of historical contingency and the emergence of self-reinforcing effects steers a technology, industry or regional economy along one 'path' rather than another". Here, it is important to note that lock-in does not by default need to have a negative impact on the regional economy (HASSINK, 1997; ESSLETZBICHLER and WINTHER, 1999). Strong specialization in specific industries is a classic feature of clusters and regional competitive advantage (PORTER, 2000). Lock-in becomes problematic when its direction steers to (over)specialization in long-established technologies and industries with little scope for further economic exploration of knowledge while, often simultaneously, curtailing efforts by novel industries or technologies to emerge and develop.

The notion of lock-in provides an important concept to analyze (barriers to) renewal of industry in a region. Different dimensions of lock-in are usually highlighted in the literature. GRABHER (1993) distinguishes between three types of interrelated lock-in; functional, cognitive and political lock-in, and states that regional lock-in results from the interplay between these three types of lock-in. The first dimension, functional lock-in, primarily addresses problems related to value chain organization and network formation, pointing at close inter-firm relationships that hinder their suppliers to focus on higher value-added activities such as marketing and R&D – and by doing so, to switch to new markets. In other words, it refers to a process by which firms remain locked-in to low value added activities such as standardized manufacturing or undifferentiated service provision with little opportunity for innovation and upgrading. The second and third type of lock-in take a broader orientation by addressing challenges that are often not directly under control of single actors or groups of firms but which are embedded in the socio-cultural milieu of the region. Cognitive lock-in relates to a common mindset or shared worldview of actors that induces group-think and conformity and may lead to turning a blind eye to alternative solutions and reflexivity thus restraining the articulation of a variety of problem definitions, development strategies and processes of collective learning. The notion of political lock-in refers to thick associative public-private networks and institutions aiming at the conservation of existing traditional industrial structures and, thus, hampering renewal (GRABHER, 1993)

Despite being used in various analyses of regional development strategies (COOKE and MORGAN, 1998; TÖDTLING and TRIPPL, 2005), HASSINK (2010) remains wary that the term regional lock-in mainly has had a strong intuitive appeal that lacks analytical precision. Similarly MARTIN and SUNLEY (2006) remain cautious in arguing that 'we need to understand regional "lock- in" as a multi-scaled process, and one which also has a high degree of place-dependence, rather than as a universal principle that applies everywhere and anywhere and that is inexorable in its emergence and consequences' (p. 414). In response to the question why it is that some regional economies become locked into development paths that lose dynamism, HASSINK (2010, p. 455) suggests a set of impact factors which, he argues, are expected to have the strongest effect on regional lock- ins:

'Economic-structural impact factors

1. A marked industrial mono- structure: the leading industry having an employment share of at least 30 per cent of the total manufacturing employment in the region as a rough indicator for a mono- structure.
2. A specific leading industry: capital- intensive, high entry and exit barriers, above average company size, oligopolistic market structure, and influential trade unions.

Political- institutional impact factors

3. An institutional tissue at the regional level, consisting of local, regional policymakers, captains of industry, regional trade unionists, representatives of industry associations, that is strongly focused on the leading industry and hence weakly on external relations.
4. A national- political system, which enables regional actors to influence political questions concerning industrial policy.
5. Supra- national institutions that strongly affect the conditions of industrial policy relevant to the leading industry.

By explicitly considering the unique development of regions over time, this evolutionary perspective has particularly contributed to an understanding that policies should reflect the specific conditions in regional economies (HASSINK and KLAERDING, 2011). How policies should respond to regional lock-in remains however open for discussion. In a recent paper, SIMMIE (2012) draws attention to the need for new path creation on the basis of new technological pathways in order to overcome barriers related to path dependent lock-in. He conceptualizes new path creation as an iterative process in which innovators mindfully deviate from past practices while introducing and diffusing new technologies (see also GARUD and KARNÖE, 2001). Three mechanisms are suggested by which such new technologies are able to induce transformative path-breaking change:

(1) displacement where the salience of subordinate technologies increases to overtake that of the dominant technology, (2) layering, where new technologies are added to those already present and (3) conversion where old technologies are changed. In his work SIMMIE (2012) is explicitly drawing on the work conducted within the socio-technical transition literature (GEELS, 2002; RIP and KEMP, 1998; VERBONG et al., 2008) and mobilizes its concepts of regimes and niches to understand new path creation.

A central tenet in the socio-technical transitions framework concerns the stabilizing influence of a socio-technical regime on innovation dynamics and technological change. Here, a regime is defined as "the coherent complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures'" (RIP and KEMP, 1998, p. 338). The 'structuration' of this complex is high, providing stable rules and coordinating effects on the actors that are implied by the regime. By its very nature a regime seeks to retain its configuration, allowing only for incremental, path-following innovation that 'resists' the broad, transformative and structural change implied by a transition. Regime pressure or selection thus provides an explanation for technological lock-in (UNRUH, 2000) and path retention.

'Niches', on the other hand, acts as 'incubation spaces' for novel yet immature, emergent technologies. A niche is defined as an application context in which novel technology is temporarily shielded off from the rules found in a regime and thus functions as an important minority selection environment in which the process of new path creation may be started. "They provide locations for learning processes, e.g. about technological applications, user preferences, public policies, symbolic meanings. Niches are locations where it is possible to deviate from the rules of the existing regime" (GEELS, 2004, p. 912).

Drawing on these insights, the socio-technical transitions literature has also developed a more governance or policy-oriented framework under the name of 'strategic niche management'. This framework provides policy guidance to induce new path creation by nurturing technology and innovation in a niche context. KEMP et al. (1998, p. 186) defines strategic niche management as "the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation", with the aim of both learning about the desirability of the new technology and enhancing the further development and the rate of application of the new technology. The focus on experimentation is important in this context as it also relates to the current discussion in regional innovation policy on regions as living labs for experimentation with new technologies and practices (HEALY and MORGAN, 2012). Regions are seen as key sites to carry out such experimentation due to various proximity effects that compensate for the inherent uncertainties connected to new path creation.

RAVEN (2005) highlights three key processes in niche experiments to facilitate new path creation: (1) network formation, (2) alignment of expectations and (3) collective learning. Network formation refers to the creation of a heterogeneous but stable network of actors in the experiment (producers, users, regulators, societal groups, etc). Networks provide necessary resources, sustain development, carry expectations, articulate new requirements and demands and enable learning and diffusion of lessons and experiences between actors. Heterogeneity is partly considered important to allow for sufficient variety and cognitive distance between the actors in terms of knowledge and competences. This also resonates with the notion of related variety and skills relatedness as important conditions for innovation through the combination of different knowledge bases (FRENKEN et al., 2007). Learning in experiments is however not restricted to technical learning but also includes policy learning, learning about user characteristics and demand, learning about production aspects and maintenance to facilitate large-scale diffusion, and learning with regard to safety, energy and environmental aspects of the technology (HOOGMA et al., 2002). As such, learning also refers to the articulation and alignment of expectations and interests that different actors may have concerning a new technology. This is considered key to build legitimacy for actors to invest time and resources in a new but still immature technology that does not have any strong commercial value yet. Strategic niche management emphasizes that at the start of a niche experiment expectations and interests may diverge considerably among different stakeholders. Through an iterative process of learning these expectations and interests are however expected to align with each other gradually making the niche technology more mature and fit for more large-scale application and diffusion.

## Research design and methods

The following sections of this paper will use the BioF initiative in northern Sweden as an illustrative example of strategic niche management in a regional context, identifying a range of factors that serve as barriers and enablers for the adoption of biorefinery technologies for the renewal of the forest related industries in the region as well as in more general terms. Not only factors internal to the initiative itself are addressed, but also specific characteristics of the regional context (its location, industrial composition and history) and characteristics of its target industries (knowledge complementarities, geographic distribution of actors and activities, and the current and historical situation with regard to institutional aspects such as regulations, norms and conventions related to innovation and renewal). The analysis is based on a combination of qualitative research methods; document studies and personal in-depth interviews with key stakeholders being the two dominant data sources. Previous research on these and similar industries are used as reference cases, while primary data collection has been focused on publicly available documents such as websites, annual reports, strategy documents and publicly commissioned evaluations. A total number of 20 semi-structured interviews with representatives of the initiative and its target industries were conducted. The group of respondents includes representatives from the public sector (policy makers) as well as universities and industry. Eight interviews were conducted in October 2008 when the initiative in its current form was recently launched. Six more interviews were conducted in January 2012. While the first interviews primarily aimed at collecting information on the industries, the initiative and the various challenges that served as main rationale for the initiative, the second round of interviews focused more explicitly on activities, outcomes, and remaining problems/deficiencies. In addition to those interviews, which explicitly dealt with the initiative and its target industries another six interviews were made with actors doing research on or representing the industries but with no specific stake in the initiative as such. These interviews, carried out in the period March-July 2009, are used primarily for reference and cross-check purposes. The interviews revealed broad agreement between the interviewees' views with regard to the research questions studied in this paper. The interviews were in large part conducted in Swedish, transcribed and important quotes translated into English by the authors.

## Analysis

### *History of the regional forest industry*

The city of Örnsköldsvik is located at the Swedish east coast, more than 500 kilometers north of the capital Stockholm. Forest related industries have been important for the northern part of Sweden and the Örnsköldsvik area in particular, since the late 19th century. The regional industry has historically been dominated by a few large established companies producing pulp and paper as their main product. During the Second World war, and as a response to trade blockades and a resulting shortage of chemicals in Sweden, the paper and pulp industry in Örnsköldsvik made early attempts to broaden the range of products produced from forest raw materials. During these years, the production of chemicals, chlorine and ethanol entered the scene and led to unique experiences for the industry with regard to product diversification based on forest biomass. In the post war years, the chemicals production relocated to the west coast of Sweden, due to its proximity to major international ports, which was of strategic importance for the petro-chemical industry. The forest industry in the north returned to, and further strengthened, its specialization in pulp and paper production (its traditional value chain), with less emphasis on taking care of residual chemicals in its production. While the regional forest industry invested a lot of resources in R&D since the 1940s, the vast majority of these resources followed the dominant technological paradigm focusing on incremental quality improvements and process efficiency. Until the 1980s, the production was almost entirely based on traditional (environmentally polluting high pressure and high temperature) techniques for dissolving cellulose. At this time, a traditional conservative culture in the industry, its capital intensity and the resulting entry and exit barriers were causes for limited openness to renewal in general (LAESTADIUS, 2000).

### *Reorganization and industrial transformation*

In the mid-1990s, however, the regional forest-related industry experienced increasing openness to renewal. This change was due to factors (of largely global character) taking place that were starting to affect the industry. Firstly, an overall absolute decrease in the global demand for traditional paper products such as newspapers was occurring, implying a shift in demand patterns towards more fine quality products at the expense of the production of high volumes. Secondly, an increasing prize of forest raw material stemming from Swedish (and Nordic) forests could be identified which was due to an increasing competition from fast growing eucalyptus stemming from North and South America. Thirdly, environmental regulations in Sweden increased taxes on disposal which steered the industry's attention towards residuals as it created an incentive to refine its waste into products. Fourthly, the development towards what is sometimes referred to as ‘peak oil’ accentuated (i.e. the point in time when the maximum rate of global petroleum extraction is reached, after which the rate of production enters terminal decline). These processes triggered two main reactions in the industry and region. Firstly, it became obvious to the pulp and paper producers that they could not continue with their current technologies, only using approximately 40 percent of the raw material for value creation while burning the remainder as waste. Also the deposit of waste, in particular sludge, became too expensive and was a driving force for the industry to extend its value chain. Secondly, and strongly related, they realized that they had to diversify their product portfolios even more to get higher value out of their processes. This was manifested in attempts to reintroduce the diversification of the time during the Second World War, but now with modern technologies. In addition to bioethanol and specialty chemicals (e.g. various plastic products), high quality viscose became a new important market area. Often, paper mills joined forces to create a shared system of energy, water and waste management, which contributed both to environmental and economic efficiency.

The above mentioned factors (and their interplay) should thus be considered as processes stimulating renewal within the paper and pulp industry. They set in motion learning processes among the actors concerning a necessary long-term change towards output diversification as well as increased resource- and energy efficiency. At the same time, they brought about awareness with regard to a required replacement of established technologies. In the mid-1990s, new scientific breakthroughs in life science made it possible to start experiments with dissolving cellulose applying alternative technology (i.e. enzyme based biotechnology processes) and one of the paper mills in Örnsköldsvik was among the few actors worldwide entering into this field.

*The BioF initiative*

In consequence of the experiments and learning processes taking place during the mid-1990s, a technology park located at the site of the pulp and paper industry in Örnsköldsvik was established in 2003. Twelve SMEs related to research and development in pulp and paper technologies, chemicals and energy production started collaborating with two large companies specialized in various applications of forest and chemistry-related production. At these times, the prior focus of the actor’s efforts was on energy efficiency, i.e. energy was increasingly considered as a new market opportunity for the regional forest industry. The municipality, the county administration, a regional technology transfer agency and a privately owned funding foundation with its roots in the region’s forest-based industry provided financial support. Over time, linkages to the nearby universities in Luleå and Umeå were established and increasingly formalized. The technology-park evolved to a network of related firms and organizations (i.e. an innovation system) distributed over a territory much wider than the boundaries of the city in which it was initiated. A large grant from the Swedish Energy Agency was used to set up a pilot plant for alternative ethanol production, which gradually developed into a platform for several products based on forest- and agriculture-based lignocellulose. A central firm in this pilot plant is a regional producer and developer of ethanol, today considered to be a world leading actor in the field of bioethanol and green chemicals. The pilot plant, the ethanol firm, a small firm specialized in pulp and paper related R&D, a large forestry company, a sector specific industry support initiative, and the regional universities can today be seen as composing the nexus around which the biorefinery initiative evolves.

In 2008, VINNOVA (the Swedish Agency for Innovation Systems) launched a second call for regional industry development initiatives called VINNVÄXT targeting industrial renewal based on co-operation between industry, academia and public authorities (the so-called Triple Helix)The consortium with representatives from industry, academia and the regional public sector in Örnsköldsvik (i.e. the group of actors referred to above as the nexus of the initiative) made a successful application and received a ten year grant for their initiative “Biorefinery of the Furture” (BioF). The aim of this project was to become a leading initiative for developing biorefineries based on forest raw material and energy crops by combining historical and current strengths in traditional forestry with new cutting edge knowledge in science based technologies. Active promotion of the interplay between researchers, companies and the political public sector was set centre stage in the initiative. BioF thus had the aim to materialize the regional actor’s vision, i.e. to restructure the regional pulp and paper industry. Initially, (global) processes affecting the industry were stimulating social learning processes with regard to industrial renewal among the regional actors, and which subsequently led to common efforts and applications for funding. The BioF initiative itself should, however, be also considered as providing an incubation- and experimentation space for technological learning processes targeting biorefinery technologies. At the same time, it supported the alignment of expectations and the formation of networks that both constitute important requirements to counter (functional) lock-in, and by implication, enhance path renewal. By way of example, one immediate consequence of BioF was that the universities became more central actors; one of the regional universities established new professorships located at the industry site. An R&D board with the aim of supporting new development projects in the region was established, with two university professors, the head of R&D at the aforementioned ethanol firm, and the CEO of the pilot plant being responsible for evaluating applications, giving advice to entrepreneurs, and distributing resources for new R&D experiments. The success of the BioF initiative can thus be traced back to common learning processes of actors placed in one historically and geographically bounded area, as well as on the presence of related industry competences (i.e. energy, chemicals and forestry). Furthermore, it is noteworthy that the regional development program (VINNVÄXT) fitted very well the demands of the industry, i.e. both were aiming for industrial renewal.

*Challenges to new development paths*

However, despite the success of the initiative in providing funding for technology development (i.e. in enhancing technological learning) and facilitating network formation through public-private partnerships, some major challenges to further development and up-scaling, i.e. bringing inventions from the R&D lab to commercial production, have been identified. These challenges particularly target the production of ethanol from forest biomass residuals (i.e. second generation bio-ethanol).

One of the challenges has to do with sunk investments in conventional technology and production facilities. As typical for traditional industries, forest-related industries are very capital intensive, and massive resources have already been invested in facilities world-wide drawing on the old technological paradigm. These investments and the competences built up around them imply a structural resistance to alternative technologies since those may create a paradigm shift making the existing facilities less profitable in the long run.

> *"The fact that the investments are so huge leads automatically to inertia in the system."*(Officer, local research and development company)

Also the petrochemical industry (today dominant in both energy and specialty chemicals production world-wide) remains cautious with regard to further development of cellulose based biorefineries for the same reason.

Furthermore, other, more policy related factors can be identified. To achieve profitability, it is expected that a commercial biorefinery (e.g. a full scale version of the ethanol pilot plant/demonstration facility referred to above) requires new investments of approximately 3 billion SEK. Combined with the current lack of possibilities to employ premium pricing strategies for green chemicals and energy (i.e. an insufficiently developed market) this raises an urgent need for subsidies from the public sector.

> *"An issue that is challenging is up-scaling, to go into full industrial scale, this we have realized over the last 2-3 years. There is very interesting research, but how the rules stand today, it is very difficult to get a commercial viability. (...) The State and the EU should take a more active role. It has become clear to me that it is a political issue."*(Officer, biorefinery initiative)

While respective subsidies exist in Sweden today, they lack a long term horizon which makes them uncertain and create critical financial liabilities for investors.

> *"The problem with these systems and regulatory frameworks is that they are almost on one-year basis, and this is what limits us. (…) First they subsidize and then they take it away. Ethanol was in for a while, then it was biogas and now it is electric cars. It is impossible to see what is coming as consumer or producer."*(Officer, ethanol producer)

This is a striking illustration of political lock-in and a regime-based barrier to new technologies (KEMP et al., 1998); government policies providing unclear and contradictory signals concerning the needs for carbon reductions and a shift to renewable energy and at what costs such needs should be supported. As a result of this lack of clear future vision investors hesitate and entrepreneurs are reluctant to take the necessary risks.

Another, strongly related, barrier to the fulfillment of the aims of BioF has to do with perceived undesirable societal effects of the new technology. In the public opinion, the forest based biorefinery technology is hardly separated from agro based ditto, which implies resistance with reference to the crops for food or fuel debate.

> *"There is good ethanol and there is bad ethanol. There exists a risk of competition with the food production in the world, and you should not make ethanol from that. (…) These facts are communicated and presented, but it does not have any impact in the press."* (Officer, ethanol producer)

Also within the initiative itself, and in the regional context in which it takes place, there are mechanisms acting as barriers to radical renewal. The place bound historical legacy and current industrial structure is one example. Even if the experiment (materialized in the consortium of BioF) is composed by a fairly large number of independent and relatively young knowledge intensive small and medium sized firms, most of them have their roots in the dominant forest industry or chemical producer in the region. The same is true for a large share of the capital channelized through the private foundation, as well as the large forestry company acting as 'anchor firm' in the region. During the period from the late 19$^{th}$ century until the 1970s, they were all part of the same organization. This joint history and alliance with the established industry on the one hand provides stability and alignment of expectations, as well as high degree of cognitive proximity even though they over time have diverged into different fields of specialization. The social networks built up over generations thus provide important conditions enabling knowledge exchange and interactive learning (within and across sectoral boundaries), and it contributes to giving the actors a collective voice articulating needs and demand. But on the other hand it also contributes to retain path-dependence since the activities carried out by actors in this network, though striving for renewal, are ultimately structured by the dominant regime.

The location as such, a peripheral region in the north with, by Swedish standards, less developed transport infrastructure and, up till the last decade, negative migration trends and aging population, implies both benefits and drawbacks to the possibilities for industrial renewal. On the one hand the location is seen as an important (positive) factor behind the development of social networks of firms and individuals. This means that knowledge exchange both within and across sectoral boundaries in the region are facilitated by a high degree of interpersonal trust. On the other hand, this also leads to less integration in national and international networks since the regional actors are strongly focused on intra-regional networking and have less access to the outer world.

> *"I feel that we have a pretty good situation network-wise and in terms of contacts. (…) The disadvantage of a small town is that it some distance away, the advantage of a small town is that, with the right atmosphere, a lot of people help each other. (…) But it is a disadvantage that we always have to travel.* (Officer, biorefinery initiative)

This problem of intra-regional lock-in, however, tends to diminish, partly as a result of the BioF initiative. Recently, the dominant forestry company (i.e. the anchor firm) has been acquired by an Indian MNF which is leading to an increasing focus on high value added products and materials (e.g. textiles) in the initiative.R&D collaborations have been established between BioF members and universities in other parts of Sweden, and a strong future potential is seen in the use of forest biomass for the production of chemicals, implying an intensified collaboration with the petro-chemicals industry at the Swedish east coast. It has, however, to be assumed that the above identified barriers with regard to up-scaling of second generation ethanol may in similar manner apply to high value added products.

Another problem with the location which persists though has to do with the relatively weakly developed general knowledge infrastructure (except the strongholds previously referred). One concrete example is the lack of qualified engineers and scientists, as well as staff with management skills. While more centrally located regions can attract such human capital from neighboring regions, this region has to rely largely on own mobilization of resources. While this strategy so far seems to work for handling the current needs of the regional industry, the low degree of in-migration obviously leads to challenges with regard to dealing with path dependence and lock-in.

## Discussion

The above analysis conceptualized the BioF initiative in Örnsköldsvik in northern Sweden as niche strategies aiming to transform the region's forest related industries into becoming more competitive, resource-efficient and environmentally sustainable through combinatory efforts within the frame of biorefinery technologies.

Processes (of global character) affecting the regional industry were identified. These set in motion learning processes among the regional actors with regard to the need of long-term transformation. Thereupon, the establishment of the BioF initiative (targeting industrial renewal in the region), has considerably contributed to further learning processes by providing an application context and shielding off technology development from the existing regime. Moreover, and drawing on private-public partnerships (triple helix), the initiative has contributed to the development of a heterogeneous but stable network of actors (especially in terms of including actors outside the traditional forest-related paper and pulp value chain). An overlap of social and business relations in the network adds (positively) to the alignment (or at least convergence) of expectations and ambitions among the actors around a core set of activities (R&D, pilot-testing new technologies, developing new products from side-streams). Sector-transcending combinations of knowledge within the network contribute to collective learning processes, both with regard to technology and market. The historically more or less separated cognitive domains of the forest industry on the one hand and the energy and chemicals industries on the other have started to merge, giving rise to new but related knowledge specifically adapted to the emerging field of biorefineries.

However, major challenges to further development, particularly with regard to up-scaling to commercial production have been identified. These barriers include unclear signals from the public sector with regard to support of transformation processes to sustainability and industrial renewal. Short-term time horizons in subsidies and regulations, as well as shifting (political) priorities from one year to the next, create major barriers and uncertainty for private investment. Also the persistent attitudes among both manufacturers and consumers, partly related to sunk investments in traditional technology, and partly to a lack of perceived premium value of green technology (thus resulting in less or no willingness to pay more for such products), contributes to lock-in to the traditional value chains of respective industry.

Although challenges with regard to the industry's location in a peripheral region suffering from institutional and organizational thinness (TÖDTLING and TRIPPL, 2005) exist, the BioF initiative shows considerable success in terms of developing and implementing novel technologies, process improvements and new product portfolios. However, the analysis reveals that the initiative faces its major challenges to achieve industrial renewal and break path-dependence at geographical levels other than the regional scale. Learning processes targeting biorefinery technologies are limited to the initiative (i.e. the niche); however, these do not take place at policy levels at the national scale which motivates discussions regarding the scale of lock-in (and at which levels lock-ins are located) (HASSINK, 2010). BioF contributes to lend the actors in Örnsköldsvik a collective voice to raise needs and demands also on required institutional transformation; their possibilities to influence supra-regional industrial policy are, however, limited.

## Conclusions

The objective of this paper was to further insights on the potential and barriers for industrial renewal in locked-in regions and industries. More precisely, it aimed at closer investigating the role of regional innovation policy in fostering industrial transformation. To do so, the paper analyzed the 'Biorefinery of the Future' initiative in Örnsköldsvik in northern Sweden, seeking to foster science-based knowledge creation and exploitation in the forest industry. The research objective was motivated by the increased interest in industrial renewal in context with the recent 'evolutionary turn' in economic geography, yet pointing out the strong focus attributed to firm-level routines in this literature so far. In order to also account for an institutional perspective, insights from EEG were complemented with those of science and technology studies. In particular, a socio-technical transitions perspective was applied that conceptualized the regional initiative as niche strategies to renewal.

The analysis shows that regional support programs (i.e. local niche initiatives) clearly have potential in advancing path-breaking technological and industrial renewal. In the case of Örnsköldsvik, BioF has contibuted to steer the innovation system in the region away from its mature trajectory characterized by lock-in, and by doing so, facilitate path renewal of the industry. The initiative has shown to work against innovation system deficiencies that this region faces, i.e. those of 'old industrial regions' and 'peripheral regions';for example, by bringing together different but related pieces of knowledge (i.e. the knowledge bases of forestry, energy and specialty chemicals). Likewise, the initiative has promoted the interplay between researchers, companies and the political public sector (i.e. triple helix), also including new actors outside the traditional value chain.. Furthermore, the initiative has led to the establishment of collaborations (particularly with other Swedish universities) outside the regional boardersThe BioF initiative, conceptualized as niche, can thus be seen as fulfilling a pioneering role in shielding off

technology development and thus, providing a location for learning processes with regard to biorefinery technologies.
However and at the same time, the analysis shows that important path-reinforcing tendencies persist which transcend the regional scale. Important barriers to renewal remain present in a wider industry context that can neither be influenced by a regional support program nor by regional actors as such. While the above mentioned effects of the regional support program level down the institutional barriers that an old industrial and peripheral region faces, i.e. mainly addressing the supply side of innovation, important bottlenecks on the demand side remain that hinder transformation and renewal.

By way of concluding, we argue that a biorefinery represents a very promising new platform technology for environmentally sustainable and economically efficient production of a range of products, and that Örnsköldsvik with its regional initiative can be seen as fulfilling a pioneering role with regard to this development. However, crucial institutional barriers have been identified within the sphere of supra-regional (national, international) jurisdictions, demonstrating that institutional conditions are not yet sufficiently developed to allow making use of this potential on a wider level. Institutions are thus bottlenecks, not yet aligned to this new technology. The socio-technical transitions framework, as applied in this paper, illustrates this institutional mismatch and helps us specify these system deficiencies in a more precise way. It shows that there is still a lot of insecurity with regard to how new institutions more suitable for biorefinery technologies should look, not to mention how they should be achieved and who could/should influence them. As opposed to a one-dimensional focus on technological relatedness, mainly addressing supply-side aspects to production and development, the socio-technical transitions framework pays careful attention also to the demand and adoption side. Technology, while often being a necessary condition for industrial and regional renewal, is not sufficient. Institutions remain crucial, and the regional level only embraces a small fragment of the institutional framework that conditions such technological and social renewal and adoption.

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