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Abstract

This paper unpacks resource mobilisation for biorefineries by studying investment decisions of incumbent pulp and paper firms in Sweden and Finland. The analysis highlights that the limited adoption of biorefinery technologies can be attributed to both insufficient abilities (lack of needed competencies and partnerships) and interests (preference for improving existing technologies) by pulp and paper incumbents. Drawing on the technological innovation system perspective complemented with insights from the management literature on the role of incumbents in technological change, four issues are empirically identified as important for improving resource mobilisation for biorefinery technologies: establishing loosely-coupled divisions in pulp and paper firms; creating internal markets for new bioproducts aimed at further technological development; entering purchasing agreements with downstream actors; and investing in new managerial competencies.

Keywords

Biorefineries; technological innovation system; pulp and paper industry; incumbents

1. Introduction

Fostering a viable bio-based economy is considered a crucial element in the transition to a low carbon society (European Commission 2012). A bio-based economy can be understood as an economy where building blocks for materials, chemicals and energy are derived from renewable biological resources instead of fossil resources (McCormick and Kautto 2013). Today, bio-based goods replace just 0.2% of petroleum-based goods, but alternatives such as biopolypropylene, biobutanol, and biocrude exist for over 90% of them (Bünger 2010).

A key enabling factor for transitioning to bio-based economies concerns development and diffusion of biorefinery systems (OECD 2009). Following the IEA (2009, 2) we define biorefineries as *'the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials and chemicals) and energy (fuels, power and heat).'* Studies underline that biorefining is particularly relevant to the pulp and paper industry in its efforts to extract and appropriate greater value from biomass (Stuart 2006; Pu et al. 2008). Instead of using the forest biomass exclusively for the production of pulp and paper, biorefining allows for biomass conversion into products such as low-carbon fuels (e.g. DME and biodiesel), green chemicals (e.g. organic acids and furfural), substances used in the construction industry (e.g. lignin-concrete mixes), viscose for clothing, or ingredients for the food and pharmaceutical industry; while making more efficient use of the heat in the production process. As such, biorefining allows for the production of both high-value low-volume and low-value high-volume products (Kamm et al. 2006; Ragauskas et al. 2006; Cherubini and Strømman 2011).

Observers consider biorefining as a promising strategy for forest industries to diversify into new markets and, thus, increase their long-term profitability. This is particularly the case for North American and Scandinavian pulp and paper firms due to increasing global competition. Due to decreasing demand for certain core products and the entrance of competitors from the Southern hemisphere with fast-growing forests, it is arguably even more pressing to move towards biorefining in order to secure long-term profitability (Karltorp and Sandén 2012). Thus, competing on quality and product differentiation still appears as the preferred strategic response. The outcome of which may be an industry which is smaller in terms of employment, but stronger in terms of economic competitiveness and resilience.

However, studies find that the adoption of biorefinery technologies in pulp and paper industry in practice is limited. Identified reasons include lack of competencies, high capital intensity of the industry and difficulties in establishing strategic partnerships with actors from industries along the value-chain (Hansen and Coenen 2013; Novotny and Laestadius 2014; Näyhä and Pesonen 2014; Palgan and McCormick 2016).

Studies analysing and synthesising the development and adoption of biorefinery technologies have primarily taken a technological innovation system (TIS) perspective (Negro and Hekkert 2008; Novotny and Laestadius 2014; Swedish Energy Agency 2014; Bauer et al. in press). This approach foregrounds the role of networks of actors and institutions in the development and diffusion of novel technology and, in doing so, emphasises institutional and collective aspects of innovation. A recent review paper on TISs for biorefinery technologies highlights that important insights have been achieved, but that further research on certain topics is highly needed. One topic of particular importance is to improve our understanding of resource mobilisation by pulp and paper firms for biorefinery technologies (Bauer et al. in press). While this is described as (p. 15) *'one of the major problems for the development of forest biorefineries'*, our understanding of this issue is currently limited.

Consequently, the aim of this paper is to analyse resource mobilisation in the area of biorefineries by studying investment decisions of incumbent pulp and paper firms. Such investment decisions seem to constitute a critical bottle-neck for upscaling of biorefinery technologies in pulp and paper industries (Cohen et al. 2010). A recent TIS study of biorefinery technologies in Sweden identifies resource mobilisation as a central weakness of the innovation system (Swedish Energy Agency 2014). Contrary to e.g. knowledge development related to biorefining, which is assessed as well-developed, the amount of resources allocated to the commercialisation of biorefinery technologies remains scarce. With a focus on Sweden and Finland, we specifically direct our attention to retrofitting of existing production facilities in the pulp and paper industry. In order to provide a detailed understanding of this issue, we complement the TIS perspective with insights from the management literature on the role of incumbents in technological change.

The remainder of the paper is organised as follows. The following section presents the analysis' conceptual framework, and section 3 describes the methodology. Sections 4 and 5 analyse resource mobilisation of incumbent pulp and paper firms around biorefinery technologies, while the final section concludes and discusses implications for policy and future research.

2. Systems and actor perspectives on technological change

2.1. Technological Innovation Systems

The TIS perspective has become a popular analytical tool to explain the success and failure of the development and diffusion of emerging renewable technologies. A TIS is defined as *'a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilisation of technology'* (Carlsson and Stankiewicz 1991, 93). These actors, networks, institutions and technology constitute the structural components of the TIS. A novel and quintessential aspect of the TIS perspective concerns its attention for the functional performance that emerges as a result of the interactions between the innovation system's components.[1] This dynamic perspective on innovation systems is conceptualised through a set of functions, as defined in two closely related programmatic papers (Hekkert et al. 2007; Bergek et al. 2008)[2]. A TIS analysis distinguishes between the ability of innovation systems to support entrepreneurial experimentation, knowledge development and diffusion, influence on the direction of search, market formation, resource mobilisation and creation of legitimacy[3].

A recent TIS study offers important insights for the development and diffusion of biorefinery technologies in Sweden (Swedish Energy Agency 2014; Hellsmark et al. 2016). This study provides an overview of system strengths and weaknesses for a range of renewable energy technologies, including biorefining. Here, it is found that knowledge development and diffusion in the area of biorefining is relatively strong. Research and development in biorefinery technologies have received substantial financial support in Sweden and have created a strong research infrastructure across Swedish universities and research institutes in the field. As a consequence, Sweden has acquired a key position globally in many platform technologies in the area of biorefining (Ulmanen 2013). Other innovation system functions are, on the other hand, much less developed. Notably, resource

[1] A recent contribution underlines that the functioning of a TIS is also significantly affected by its context (Bergek et al. 2015).
[2] For a discussion of these papers and their respective differences see Markard and Truffer (2008b).
[3] We draw on the set of functions suggested in Bergek et al. (2008) excluding the development of positive externalities. In our view, the built-up of externalities are a generic function of innovation systems that could relate to knowledge diffusion as well as legitimacy (see also Binz et al. 2016).

mobilisation and market formation are considered to be weak aspects of the innovation system around biorefineries.

Market formation is considered weak due to external competition from fossil fuels and alternative use of raw materials; lack of policy instruments in niche markets and the commercial growth phase; and weak coordination between ministries, agencies and regional actors. These findings are in line with a study on the development and diffusion of biorefineries in the region around Örnsköldsvik, Sweden (Coenen et al. 2015). Even though (the lack of) market formation is primarily framed as a problem of deployment policy, Hellsmark et al. (2016) note that such policy is needed precisely because *'major investments in new technologies with long payback periods must be made by mature industries that have alternative investment opportunities at hand'* (p. 711). This, in turn, relates directly to the second major functional weakness namely resource mobilisation. This refers to the (lack of) mobilisation and allocation of resources that are necessary to make the various processes in the innovation system, as described above, possible. Primarily they refer to financial and human capital. Apart from weak deployment policies, the study identifies (1) weak industrial participation and industrial absorptive capacity and (2) weak collaboration across knowledge and organisational boundaries (e.g. with energy or chemical industries) as key underpinnings for the lack of resource mobilisation (Swedish Energy Agency 2014). Other studies have also pointed to mobilisation of resources as one of the major problems for the development and deployment of forest biorefineries in Europe and North America (Näyhä and Pesonen 2012; 2014). They find that pulp and paper industries are no longer profitable enough to shoulder the costs for developing and deploying biorefineries. While considered necessary there is a reluctance to engage in partnership across industries as pulp and paper firms find it difficult to create partnerships which manage to distribute costs and potential profits fairly (Chambost et al. 2009; Hansen 2016).

These observations demonstrate that the development and diffusion of biorefineries can be characterised as a typical case of systemic lock-in. The challenge to move biorefining from an RD&D-focused formative phase towards a growth phase suffers from a set of interrelated barriers that involve co-evolving changes in markets, policies and regulation, technologies and industrial strategies and capabilities, which are typical for a process of socio-technical transition (Geels et al. 2008). Still, firm-internal processes may be important to understand the overall system development (Farla et al. 2012). Various authors have therefore argued for an explicit (re-)conceptualisation of actor strategies and resources in innovation and transition processes[4] and consequently in TIS studies (Markard and Truffer 2008a).

2.2. Incumbents and technological change

In order to provide a detailed understanding of the reasons behind the limited resource mobilisation for biorefinery technologies, we complement the TIS perspective with insights from the management literature on the role of incumbents in technological change. The literature on incumbents and technological change highlights that incumbents in general have both limited interest and ability to mobilise resources around emerging technologies (Leonard-Barton 1992; Chandy and Tellis 2000). Concerning the *interest* in emerging technologies, incumbents have lower incentives to prioritise radical innovations since profit streams come from established and proven technologies. Knowledge unrelated to the current technology base is often not prioritised since profitability depends on specialisation in certain competence fields, which allow incumbents to solve challenges related to

[4] The TIS approach has been developed on the basis of a micro-level understanding of firm behaviour rooted in evolutionary economics, industrial dynamics and the resource based view of the firm (Carlsson and Stankiewicz 1991). At the same time, micro-meso couplings in TIS need greater attention, see recent calls by Farla et al. (2012) and Markard and Truffer (2008b).

existing products and processes. Concerning the *ability* to mobilise resources around emerging technologies, incumbents' organisational routines will be built around existing production systems. This creates efficiency in producing and innovating on existing product designs, but may also lead to myopia. Additionally, incumbents are often large firms where bureaucratic inertia is an additional factor that hinders resource mobilisation around emerging technologies.

However, not all incumbents remain stuck in old technological paradigms. Synthetizing achieved insights, four factors can be identified as important in explaining the success of some incumbents in moving into new technological fields.

Firstly, incumbent firms must overcome internal forces of inertia and resistance of change based on routine systems that produce predictability and reliability. Technological and organisational innovations are highly interrelated, and radical transformations are, fundamentally, political processes (Brown and Duguid 1998; Francis et al. 2003). Thus, loosely coupled, stand-alone divisions focused on commercialising new technology contribute to creating legitimacy within the firm for autonomous action, if business unit managers have sufficient degrees of authority (Hill and Rothaermel 2003; Chang et al. 2012).

Secondly, incumbents who develop knowledge on new technology components[5] are more likely to neutralise the incumbents' inflexibility when facing disruptive technological change (Henderson and Clark 1990; Hill and Rothaermel 2003). Incumbents who at an early stage start experimenting with components of the new technological paradigm are better positioned to overcome internal forces of inertia and transition into new technological fields. This stresses the importance of organisational slack understood as *'the cushion of actual or potential resources which allows an organization to adapt successfully to […] external pressures for change in policy, as well as to initiate changes in strategy with respect to the external environment'* (Bourgeois 1981, 30). Consequently, incumbents with access to relevant knowledge on new components are more innovative, mobilise resources more quickly for new product markets and abandon old product markets faster (Roy and Sarkar 2016).

Thirdly, lack of market knowledge for novel products is a central barrier. Therefore incumbent firms that strategically seek to gain market knowledge and improve product development and marketing capacities introduce radical innovations more frequently (Hill and Rothaermel 2003; Chang et al. 2012). This calls attention for the strategic advantage of possessing (or engaging in strategic alliances to access) downstream complementary assets that are critical to the commercialisation of the new technology (Roy and Sarkar 2016).

Finally, the importance of adding new competencies to the management team is highlighted in the literature on incumbents and technological change. Leadership which is not influenced by existing ways of developing and commercialising technologies is suggested to be more inclined to mobilise resources for new technological fields (Rosenbloom 2000). Indeed, changes in management may be expected to precede strategic decisions by incumbents to establish designated new divisions, invest in developing knowledge on new technology components and knowledge about new markets.

3. Methodology

In order to understand resource mobilisation processes around biorefinery technologies in Swedish and Finnish pulp and paper firms, we explicitly focus on investment decisions around the commercialisation of such technologies. Background material for this analysis consists of written

[5] New technology components may refer to both new processes, tools, machineries and the associated skills.

sources in the form of academic papers, grey literature and secondary data such as yearly reports by firms. Additionally, the authors have carried out interviews covering various aspects of the transformation of the Swedish and Finnish pulp and paper industry since 2012. The main source of empirical material for this paper, however, consists of 21 interviews (for details see appendix A) carried out in the period March-September 2014 with a specific focus on investment decisions.

While interview guides were tailored to the individual respondents, key topics were similar throughout the interviews: firstly, the interest and abilities of pulp and paper firms to mobilise resources for commercialisation of biorefinery technologies; and secondly, the factors that can increase the interest and abilities of pulp and paper incumbents in mobilising resources. Interviews with informants from pulp and paper firms focused on investments which had (not) been carried through in the firms they represent, while interviews with other actors focused on the pulp and paper firms with whom they had interacted in relation to development and commercialisation of biorefinery technologies and their own role in the biorefinery TIS. Interviews were recorded and the material processed immediately following each interview by highlighting notable relationships and quotes. To the extent possible, interview data were cross-checked with written background material. After completion of all 21 interviews, inputs from the informants were sorted according to the key aspects derived from the literature on incumbents and technological change. The authors individually analysed and synthesised the material, before discussing and agreeing upon the analysis of the role of micro-level factors in blocking the built-up of a TIS and the strategies to address there barriers. Representative quotes from the interviews are included in the analysis.

4. Interest and ability of incumbent pulp and paper firms to mobilise resources around biorefinery technologies

4.1. Interest

Pulp and paper firms have focused on building capabilities around core activities and thus lack competencies in areas outside pulp and paper. Even pulp and paper firms which have committed to significant investments in biorefineries continue to focus on mature product groups in their competence development (I21). Interviews highlighted that the management of pulp and paper firms are hesitant to set aside resources for biorefining. An informant (I20) explains that while the top-level management is not completely uninterested in the biorefinery technologies presented to them *'…they don't really understand the field. They might have a vague idea that it is something worth betting on.'* Consequently, investments are concentrated in traditional activities aimed at for instance expanding paperboard and pulp production capacity (I18): *'I really cannot say that [top-level management] is good at [investing in biorefinery technologies rather than traditional pulp and paper technologies].'*

The limited interest in mobilising resources for biorefinery technologies is associated with required changes in business models. Core activities are characterised by economies of scale, bulk production of commodities and price-based competition. Contrary to this, biorefinery technologies require a focus on economies of scope and a competitive strategy based on product differentiation and quality (Novotny and Laestadius 2014; Coenen et al. 2015). It is consequently suggested that pulp and paper firms may not be the right actor to take biorefinery technologies to the commercial stage (I18). Thus, in the competition for investment funds internally in pulp and paper firms between biorefinery technologies and traditional pulp and paper technologies, the latter continues to be prioritised. As explained by an informant (I8): *'Traditional business areas and business activities are considered the major business for the foreseeable future. They will always be the biggest business areas […] biorefinery activities are still small and will take decades to get bigger.'* Thus, while an informant (I18)

emphasised that there are individuals in the top-level managements, which are positive towards investments in biorefineries, this informants also noted that most top-level managers, including those responsible for operations, are not receptive to such ideas.

4.2. Ability

In addition to a rather low interest in biorefinery technologies, the ability of incumbent pulp and paper firms to mobilise resources for biorefineries was also questioned. Interviewees highlighted the inability to move beyond limited search and invest in products and processes that are not closely relating to the existing portfolio. As illustrated by an informant discussing the potential for moving into bio-based chemicals (I8): *'Our core competence is the processing of biomass. We know how to purchase wood, how to transport it, how to process it further. But our knowledge on chemicals is very limited.'* Furthermore, pulp and paper firms were found to face significant difficulties in establishing strategic partnerships with actors from downstream industries (see also Chambost et al. 2008; Karltorp and Sandén 2012; Näyhä and Pesonen 2014). In summary, these combined characteristics imply that the ability of Swedish and Finnish pulp and paper firms to innovate outside existing products and processes is generally limited. In the following section we analyse to which extent the four factors identified in the literature on incumbents and technological change are important in understanding the possibility for pulp and paper firms to overcome these barriers.

5. Beyond incumbency – investing in biorefineries

5.1. Establishing new divisions

As emphasised above, stand-alone divisions in charge of commercialising new technologies may be an important step for incumbents to mobilise resources for commercialisation of radical new technologies. Some Swedish and Finnish pulp and paper firms have recently established designated biorefinery business units, e.g. UPM Biorefining and Stora Enso Biomaterials, and informants highlighted this as an important step towards further commercialisation of biorefinery technologies (I3; I18; I20; I21). To exemplify, an informant (I3) representing a technology supplier to the pulp and paper industry notes that *'You need to have designated divisions within the company. The people from the traditional departments will not take decisions to invest in biorefining technologies, these processes step on their own feet.'* Similarly, when describing a potential biorefinery investment, a representative (I21) from a pulp and paper firm notes that *'it must also impact the investment budgets of the other business areas […] they are not fully happy.'*

While it was generally agreed that such organisational changes strengthen the position of biorefining within the firms, they are not sufficient. For instance, while Holmen established Holmen Biorefinery Center in 2009, the firm is yet to make its first major biorefinery investment (Novotny and Laestadius 2014), and describes itself as *'people committed to paper'* (Matthis 2014, no page) who continue to concentrate investment on product development of paper. This also reflects that the size of biorefinery investments[6] necessitates decision taking at by top-level management. To exemplify, while decisions by two pulp and paper firms to support the development of a biorefinery technology could initially be taken by the head of R&D groups, follow-up decisions to support investments in a demo-plant had to be taken by the divisional management, and decisions to invest in full commercialisation (which did not materialise) by top-level management (I8; I17; I18). Similarly, an informant (I20) representing another pulp and paper firm explains that investments in improvements of existing technologies such as the manufacturing of packaging can often be taken at the divisional level, while investments in commercialisation of biorefinery technologies needs to be decided by top-level management. Thus, it is simply easier to take decisions to invest in incumbent technologies,

[6] To exemplify, the recent Metsä investment in Äänekoski amounts to €1.2 billion (Metsä 2015).

than to move across the 'valley of death' from RD&D to full-scale commercial investments for new technologies which hold significant market and technological risks.

In summary, establishment of biorefinery divisions within pulp and paper firms are an important step towards further commercialisation of biorefinery technologies, but they do not guarantee increasing investments in commercialisation of biorefinery technologies, as these investment decisions are taken by the top-level management due to their size and risk. As stated by an informant (I7) commenting on a recently released strategy by the biorefining division of the firm he represents: *'Top management probably looks differently at things'*. This corroborates the suggestion by Chang et al. (2012) that establishing new business units will only have real effect when business units managers have significant authority.

5.2. Developing knowledge on new technology components

The Swedish and Finnish pulp and paper firms were generally described to mobilise considerable resources for R&D related to biorefining technologies; however, as described in section 5, decisions to invest in commercialisation of these technologies are often sidestepped. Thus, as a general rule, efforts to develop knowledge on new components do not necessarily imply that they will also mobilise resources around commercialising biorefinery technologies.

That being said, there are several examples of commercialisation of biorefinery technologies by Swedish and Finnish pulp and paper firms where the possibility of further-development of component knowledge has been central to carrying through the investment decision (I7; I8; I10; I18). In these cases, the firms identify an internal use, which allows the firms to start experimenting with the processes at full scale. As described by a firm representative (I7), talking on such an investment: *'It is actually an R&D investment. Many other investments would have been much more profitable.'* The signalling effect towards potential customers is of particular importance. To exemplify, (I7) *'[this investment] gives access to lignin; we did not have this so far and therefore we were not taken seriously by downstream lignin product developers. Now we have cards to play… We will use the lignin to develop new products.'* Similarly, describing the background for an investment in a comparable technology by another firm, an informant explains (I18): *'If you want the customers to buy lignin, you first have to show that you can produce it – otherwise you are not trustworthy […] you have to show that you are serious with biorefining, and that you have a product which you can offer to collaborators every day, not just once in a while.'* In this way, investing in full-scale biorefinery technologies may be motivated by internal use of the products, which allows the firms to experiment with developing components necessary in new value chains (see section 6.3).

Summarising, efforts aimed at developing knowledge on new technology components may create a new internal market for products, which are used as input to such R&D activities. In essence, these are examples of R&D investments, which are easier investment cases to argue, since there are no immediate commercial requirements. Consequently, the challenge of eventually securing an external market for the products remains, however, as expressed by an informant (I10): *'It may sound conservative as a first step, but when you are putting tens-of-millions of euros into it, you have to be careful.'*

5.3. Developing new market knowledge

As suggested by Hill and Rothaermel (2003), an important facilitator for investments in commercial scale biorefinery technologies is efforts aimed at gaining knowledge about new markets for biobased products. Interviewees highlight that partnerships across industries are crucial in this respect. To exemplify, an informant (I8) argues that pulp and paper firms' knowledge on the chemical industry is insufficient while, conversely, *'…it is the opposite for chemical industry. They have higher competence*

in processing of different organic molecules and they know the rules of the game in chemical markets […] but they have very limited knowledge about handling of biomass.' Thus, across the interviews, partnerships with firms from industries such as chemicals, gas, oil, automotive and textile were considered key to investment decisions in biorefinery technologies as they can open doors to new markets outside traditional forestry products.

As the pulp and paper firms are looking to enter markets that are significantly different from current product portfolios, accessing knowledge *about* new markets was found to be insufficient to secure resource mobilisation for commercialisation of biorefinery technologies. Rather, *certainty* for the existence of new markets in the form of commitments to purchasing agreements, were often required. As expressed by an informant (I19): *'It is very difficult. We have people that can sell 100,000 tons of paper but no chemicals. We don't have the competencies. Before we can make these investments, we need to secure demand. And we don't know these customers […] But it is not just about knowing them, it is also about creating trust, because these are very large investments.'* Similarly, another informant (I10) explains how a purchasing agreement with a gas company helped the investment decision in the commercialisation of a gasification technology by a pulp and paper firm. In fact, due to the capital intensity of biorefinery developments, such agreements may even be necessary for demonstration plants. In one case, the construction of a demonstration plant for a lignin technology was only feasible due to the commitment of a customer to purchase the produced lignin for a period of three years (I18).

In light of this, an important challenge is that pulp and paper firms often find it difficult to initiate cooperative relations with partners from downstream industries (Näyhä and Pesonen 2014). Our interviews also highlighted this issue, which appears to reflect a concern for becoming locked into value chain relationships where the pulp and paper firms are considered as mere suppliers of raw material with little value added. For instance, a representative of a pulp and paper firm (I20) explains that collaboration with a composite producer was terminated due to disagreements concerning who should be responsible for the various steps in the processing of the wood: *'It is difficult to reach an agreement on the responsibility for the processing. The business model is crucial.'* This informant notes that the chemicals industry has so far mostly considered pulp and paper firms as suppliers of raw material, but that there are some signs that this is changing, acknowledging that pulp and paper firms should be responsible for more steps in the production process.

In summary, the importance of new market knowledge and even new market certainty in the form of downstream purchasing agreements is evident from the interviews. A number of informants (I7; I8; I20; I21) put it very simply: top-level management will not decide to invest in full-scale biorefinery technologies before agreements with downstream producers are signed. If such agreements are absent, top-level management will be likely to reject or postpone such investments.

5.4. Developing new managerial competencies

The role of changes in leadership for mobilising resources for commercialisation of biorefinery technologies is evident in a number of key examples in the Swedish-Finnish context. To exemplify, the retrofitting of the pulp and paper mill in the city of Örnsköldsvik, which is currently considered the most advanced biorefinery in the two countries, only happened after changes in ownership and management in 1999, when the previous owners had decided to close down the plant (Novotny and Laestadius 2014). Similarly, an interviewed representative of a pulp and paper firm, which has undergone a significant transformation during the last decade through divestments, conversions and closures of paper mills, as well as investments in commercialisation of biorefinery technologies, notes that this process has only been possible due to a significant change of staff at multiple levels including the highest level in the firm (I21): *'Many people had to leave the company on the way.'*

Conversely, such changes in leadership are the exception rather than the norm in Swedish and Finnish pulp and paper firms. An informant (I2) explains that the management of Swedish pulp and paper firms are found to be interested when new technologies are presented to them, but *'then they go back and change nothing'* (I2). This is contrasted to Brazilian firms, which are found to be much more receptive: *'They are younger firms, so they are not so locked in their way of thinking, their grandparents didn't work in the same mill as themselves.'*

6. Conclusions and implications for policymakers and managers

In this paper, we study resource mobilisation in relation to biorefineries, by analysing investment decisions in the Swedish and Finnish pulp and paper industry. Previous work has identified lack of absorptive capacity and weak collaboration across knowledge and organisational boundaries as the key underlying explanations for the lack of resource mobilisation (Swedish Energy Agency 2014). Indeed, our analysis also highlights that, due to limited absorptive capacity, the *ability* of pulp and paper incumbents to mobilise (human and financial) resources for scaling up biorefinery technologies is a central barrier blocking the build-up of the biorefinery TIS. However, in addition to this, of equal importance is the lack of *interest* in emerging biorefinery technologies by incumbent actors, which continue to focus attention on investments in improvements of existing technologies that are responsible for the main profit streams in the short run. Compared to previous research, this distinction between ability and interest provides an improved understanding of the limited resource mobilisation for biorefineries.

The analysis highlights the importance of drawing on insights from the management literature on the role of incumbents in technological change to better understand the development of the biorefinery TIS. Specifically, our empirical analysis points to four issues, which increase the ability and interest of pulp and paper firms to mobilise resources for biorefinery technologies (see summary table 1). Firstly, our study underlines the importance of room for autonomous action in large pulp and paper firms, e.g. by establishing new divisions that are only loosely coupled to the core competencies of the firm. Secondly, it highlights that investments in full-scale production facilities related to new biorefinery products may initially be motivated by internal use of the products for further technological development. Thirdly, learning about markets for new bioproducts is important, but insufficient to ensure resource mobilisation for biorefinery technologies in pulp and paper firms. Rather, certainty for new markets in the form of purchasing agreements with downstream actors is often necessary to unlock capital for biorefinery investments. Finally, it draws specific attention to the competences and (vested) interests of management and leadership in pulp and paper firms beyond established products, markets and technologies. Here, our study demonstrated that investment decisions for resource mobilisation are substantially hampered by path-dependency. Breaking away from business-as-usual may require new managerial competencies and rationales for decision-making.

Table 1. Factors improving the ability and interest of pulp and paper firms to mobilise resources for biorefinery technologies

	Ability	*Interest*
Establishing new biorefinery divisions	Allows building competences outside traditional process and product groups	**Creates room for autonomous action; gives priority to new bioproduct innovations**
Developing knowledge on biorefining technologies	Supports competence development in non-traditional bioproducts and processes	**Internal use provides motivation for initial full-scale biorefinery investments**
Developing knowledge on new bioproduct markets	**Reduces risk associated with full-scale biorefinery investments**	Supports corporate interest in non-traditional bioproducts
Developing new managerial competencies in pulp and paper firms	Introduces managerial competencies outside traditional pulp and paper fields	**Reduces tendency to prioritise incremental innovations in traditional bioproducts and processes**

Bold text refers to principal effect

In terms of wider implications for the sustainability transitions literature, our study also contributes to the understudied topic of the role of incumbents and regime-level actors in transition processes (Geels 2014). While a lot of work in the transitions literature focuses on the systemic institutional conditions that inhibit incumbents in becoming a progressive force for sustainability transitions, we highlight that intra-organisational aspects – the interests and abilities of incumbents – are also important in this respect. Thus, our paper underlines the value of explicitly giving attention to intra-organisational aspects in order to understand the development of a TIS.

Our study found that investment decisions that would mobilise resources for upscaling of biorefineries are blocked or postponed due to a misalignment with prevalent business models in pulp and paper incumbents. A transition to biorefining for this industry is indeed not only a matter of disruptive technological change but also about co-evolving institutions, business models and organisational innovations (Boons and Lüdeke-Freund 2013). These topics constitute important avenues for future research in the literature on biorefineries.

Our findings question the emphasis in policy making on support for the development of new technologies. This emphasis seems to implicitly assume that technologies will more or less automatically be taken up by firms and commercialised once they are sufficiently developed (see also O'Connell and Haritos 2010), ignoring the so-called 'valley of death' between RD&D and commercialisation. The analysis pointed to the central role of organisational innovations in the form of new divisions and creation of new value chain relations for the commercialisation of biorefinery technologies. Thus, policies aimed at upscaling of biorefinery technologies should consider the possibilities for supporting such organisational innovations in pulp and paper firms (Coenen et al. 2015). Firstly, regarding new divisions, we suggest that it is important that policymakers are aware of potential conflicts within firms in order to optimise the pay-off from public investments in RD&D. Employees from R&D departments may often write applications for support to public research and

innovation programs, and more generally be the main point of contact in the firms to policymakers. However, if top-level management has limited interest in commercialisation of emerging technologies, then it is questionable if the public resources allocated to knowledge and technology generation in R&D department are sufficiently exploited by these firms. This highlights the need for involving top-level management as a target for learning processes. Demand-side policies focusing on market creation may also be important in order to increase the interest of incumbent pulp and paper firms' managers in new product markets.

Secondly, regarding new value chain relations, the analysis suggests that facilitation of contact to downstream actors is very important for the commercialisation of biorefinery technologies, especially in light of the emphasis on product diversification. Thus, policy can potentially play an important role in facilitating network formation by creating arenas for interaction between pulp and paper firms and potential downstream actors. While such venues are often organised according to single industry platforms, this suggests that it might be more important to take prospective value chains as a starting point.

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Appendix

Interviewees were selected as they are engaged in decision-making processes in pulp and paper firms or interact with pulp and paper firms in relation to development and commercialisation of biorefinery technologies. Due to the sensitivity of the interview topic, informants and the organisations they represent were promised anonymity, however, appendix table A1 provides an overview of the types of organisations represented by the interviewees. Regarding the position of the private sector informants, we interviewed both top-level managers (e.g. vice presidents), which are heavily involved in taking investment decisions, and managers at the intermediate level (e.g. of R&D activities), as well as technical experts without management responsibilities. Three of the five interviewees representing pulp and paper firms are top-level managers. All five interviewees represent firms in the global top-15 of the pulp and paper industry, measured by sales (RISI 2014).

Table A1. Characteristics of interviewees

	Organisation type represented	*Position of interviewee*
I1	Research institute	Technical expert
I2	University	Associate Professor
I3	Technology supplier	Top-level manager
I4	Chemical firm	Intermediate-level manager
I5	University	Intermediate-level manager
I6	Chemical firm	Top-level manager
I7	Pulp and paper firm	Intermediate-level manager
I8	Pulp and paper firm	Top-level manager
I9	Intermediary	Top-level manager
I10	Intermediary	Top-level manager
I11	University	Associate Professor
I12	Technology supplier	Technical expert
I13	University	Researcher
I14	University	Researcher
I15	Consulting firm	Intermediate-level manager
I16	University	Researcher
I17	Research institute	Intermediate-level manager
I18	Research institute	Intermediate-level manager
I19	Pulp and paper firm	Top-level manager
I20	Pulp and paper firm	Intermediate-level manager

I21	Pulp and paper firm	Top-level manager

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