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Second wind for exploitation: pursuing high degrees of product and process innovativeness in mature industries

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Abstract

This paper investigates to what extent and how an exploitation-oriented innovation logic can enable innovations characterised by a high degree of newness. The paper is based on an embedded case study of 11 innovation initiatives in the Swedish pulp and paper industry and uses a multi-dimensional framework that takes into account both product and process innovation dimensions as well as multiple stages in the value chain. The results show that the studied initiatives are characterised by new to the companies or new to the industry products and processes in the primary or final steps in the value chain (or both). It is also shown that such high degrees of novelty can be the result of an exploitation innovation logic, where novelty is enabled and facilitated by unchanged or slightly modified products and processes in other parts of the value chain. It can therefore be concluded that exploitation strategies can contribute to more than incremental innovation outcomes and, consequently, that mature industries hold considerably higher innovation potential than the previous literature assumes.

Keywords

Exploitation; pulp and paper industry; mature industries; innovation initiatives; product innovation; process innovation; supply chain.

I. Introduction

This paper investigates to what extent and how an exploitation-oriented innovation logic can enable companies in mature industries to develop innovations characterised by a high degree of newness rather than only incremental innovations.

Studies of the economic importance and performance of industrial sectors have shown that mature industries, such as automobiles, chemicals, pharmaceuticals, plastics and metal production, are important parts of the economy in many countries (Castaldi and Sapio, 2006). They have not only contributed to the historical development of many industrialized countries (Kurkkio, 2011, Barnett and Clark, 1998), but some of them (e.g. pulp and paper, chemicals and pharmaceuticals) have also experienced relatively high growth rates in recent times (Castaldi and Sapio, 2006).

They are, however, also faced with a rapidly changing environment in the form of increasing pressures by competition from emerging economies and by increasing demands for environmental sustainability – pressures of a kind that tends to force companies to transform themselves through innovation and product market diversification (Le Bas and Poussing, 2014). One case at hand is the pulp and paper industry, where declining local markets for pulp and printed paper and increasing global competition have forced pulp and paper companies to look for new product-markets and value chains (Kivimaa and Kautto, 2010).

Pulp and paper is a mature and resource-intensive process industry. Although Sweden has traditionally been one of the leading countries in terms of pulp and paper technology (Olander Roese, 2014), the Swedish pulp and paper industry has for decades been characterized by path dependent technological development, focused on incremental process innovation (Laestadius, 2000, Novotny and Laestadius, 2014). That is explained partially by the resource-intensive and large-scale character of the industry's operations, which results in a lack of flexibility to adopt new processes or products (Laestadius, 2000, Novotny and Nuur, 2013, Novotny and Laestadius, 2014), and partially by cognitive institutional rigidities caused by a dominant risk-averse and change-resistant culture (Novotny and Laestadius, 2014, Hansen, 2010). As a result, R&D activities have been focused mainly on enhancing process efficiency and companies have tended to adopt cost leadership strategies (Hansen, 2010, Olander Roese, 2014, Novotny and Nuur, 2013).

However, since the end of the 1990s, the industry has been subject to transformational pressures, such as an increased competition from Latin America and decreased demand in some traditional segments (Novotny and Nuur, 2013, Olander Roese, 2014). Together with scientific evidence that basically all materials and products currently produced from oil and fossil materials can be made from forest biomass, this has encouraged pulp and paper companies to engage in innovative activities outside their traditional business areas (Laestadius, 2000, Novotny and Laestadius, 2014). Thus, the industry's R&D focus has shifted towards new product development and companies have started to develop

differentiation strategies (Olander Roese, 2014). Networking and cooperation have expanded in recent years, and a growing number of initiatives now involve partners throughout the value chain within and outside the pulp and paper industry (Novotny and Laestadius, 2014), i.e. most companies innovation activities take place within an “innovation ecosystem” (Adner and Kapoor, 2010). However, the industry still works very much according to a goods-dominant logic (cf. Vargo and Lusch, 2004), where the focus is on process (and more recently also product) development rather than on service innovation.

In theory, several transformation strategies are available for companies in mature industries such as pulp and paper: to increase supply chain efficiency by modernizing production processes for existing products, to introduce new products within the current product portfolio, to develop new products aimed at entirely new markets, or to implement a mixture of the above strategies (Machani et al., 2015). However, according to previous literature they cannot be expected to achieve a lot in terms of the more innovative of these strategies, much due to the fact that their innovation strategies emphasize exploitation rather than exploration, i.e. local search to leverage their existing resources rather than more distant search for new opportunities (cf. March, 1991, Rothaermel and Deeds, 2004). Indeed, the technology and industry lifecycle literature concludes that once an industry has reached a mature phase, it is associated with stable specialization patterns, standardized products and highly efficient, capital-intensive production processes, is focused on further developing its established dominant design and can – at best – achieve cumulative, incremental product and process innovation (Tushman and Anderson, 1986, Christensen and Rosenbloom, 1995, Henderson and Clark, 1990, Abernathy and Utterback, 1978, Anderson and Tushman, 1990, Utterback and Abernathy, 1975, Malerba and Orsenigo, 1997). As described above, this also seems to be the case with the pulp and paper industry.

This implies that the general advice for companies in mature industries that face different kinds of transformational pressures, be it from discontinuous or disruptive technological advances by new entrants or increasing competitive or regulative pressures requiring innovative solutions, is to shift the strategic balance from exploitation to more exploration, i.e. to pursue innovative initiatives that imply a break with the past and the development of new resources that can be exploited at a later stage (Hill and Rothaermel, 2003, Rosenkopf and Nerkar, 2001, Herrmann et al., 2006).

However, this is easier said than done. Exploitation and exploration are difficult to reconcile since they compete for scarce organizational resources, require different mind sets and routines and are self-reinforcing (and therefore lock each other out) (Gupta et al., 2006). Thus, a shift in focus would require large organizational changes. Moreover, exploitation is at the heart of the competitive advantage of mature industries and it has been argued that companies in mature industries are more likely to succeed if they emphasize exploitation over exploration (Lumpkin and Dess, 2001). Downplaying it can, thus, result in decreased competitiveness in current business areas, e.g. have negative impact on a company’s ability to be cost-effective in production (Ford et al., 2014). Finally, exploration is inherently risky

(March, 1991, Greve, 2007) and is more often than not unsuccessful; indeed, the diversification literature has made a compelling case that related diversification is more likely to succeed than unrelated diversification (Helfat and Lieberman, 2002, Shin and Jalajas, 2010).

Taking all this into consideration, the purpose of this paper is to investigate to what extent an exploitation logic is consistent with the successful development of innovations characterized by a high degree of newness. This is done by analyzing a number of ongoing innovation initiatives in the Swedish pulp and paper industry in order to determine both their degree of newness and to what extent and how they originate from an ambition to leverage existing resources.

2. Innovation and exploitation in mature industries

The exploration – exploitation dichotomy was made popular by the seminal work of March (1991), which defines exploration as “experimentation with new alternatives” and exploitation as “the refinement and extension of existing competencies, technologies, and paradigms” (pp. 85). This definition has been interpreted in several different ways in subsequent writings (cf. Gupta et al., 2006, Koryak et al., 2018, Li et al., 2008). Most importantly, it does not imply that exploration is entirely competence-destroying or that exploitation does not require any new resources. Instead, the main difference between the two modes of learning is that they have different “precursors”: exploration is based on “the wish to discover something new”, whereas exploitation is based on an “exploitable set of resources, assets, or capabilities under the control of the firm”(Rothaermel and Deeds, 2004 p. 203). Considering the overall purpose of this paper, the following discussion focuses on exploitation and its relationship to innovation.

2.1 Exploitation and innovation: the established view

From an innovation point of view, the essence of exploitation is that a company focuses on using its existing resources when searching for new technological opportunities (Benner and Tushman, 2002). It thus involves ‘local’ search, i.e. search for knowledge that is familiar or related to what the company already knows rather than search for knowledge that is unfamiliar or unrelated to the company’s existing knowledge base (Li et al., 2008) and can thus be described as a strategy that deepens a company’s core knowledge base (Guan and Liu, 2016) in terms of product-, process- or marketing-related knowledge (Kazanjian and Drazin, 1987).

One dominant belief is that exploitation is primarily related to process development and marketing (cf. Li et al., 2008, Lavie et al., 2010). This is further reinforced by the proposition of some researchers that exploitation follows sequentially after exploration in the technology/product life cycle, i.e. that exploration provides potentially valuable resources that the company can exploit at a later stage (cf. Rothaermel and Deeds, 2004, Hollen et al., 2013).

However, findings in other strands of literature suggest that exploitation can be combined with a focus on product innovation. For example, Anderson and Tushman (1990) discuss the phenomenon of competence-enhancing product discontinuities, i.e. radically new or improved products that build on a company's existing competences, and studies of innovation in process industries have found that a common strategy is to integrate forward in the value chain and thus develop new products and applications based on existing input materials and process technologies (Lager and Blanco, 2010, Ford et al., 2014).

Much of the literature also associates exploitation with incremental improvements in existing products and processes (Li et al., 2008). For example, Bauer and Leker (2013) define exploitation as a company's ability to improve and refine key attributes of products already existing in its product portfolio or introduce new investments or goods into an existing production process and, similarly, a large number of researchers associate exploitation with small adaptations, refinements or improvements of existing components and products (cf., e.g., Wang and Hsu, 2014, Enkel et al., 2017, Benner and Tushman, 2002, O'Connor and Rice, 2013, Andriopoulos and Lewis, 2009).

There is, however, not much empirical evidence of a clear-cut association between exploitation and incremental innovation (Li et al., 2008, Enkel and Gassmann, 2010) and it has also been implicitly challenged both in the general innovation and marketing literature and in studies of process industries. In the general innovation literature, concepts such as "competence-enhancing discontinuities" (Anderson and Tushman, 1990), "creative accumulation" (Bergek et al., 2013b) and "competence-expanding innovation" (Geels, 2006) emphasize the importance of existing competences also for more radical types of innovation. In marketing, the resource-advantage theory describes how firms can attempt to neutralize or leapfrog a competitor's competitive advantage by better managing their existing resources in order to produce an offering with a substantially increased market value (Hunt and Morgan, 1996, Hunt and Duhan, 2002). In the process industry literature, Machani et al (2015) suggest that one of the transformation options for the pulp and paper industry could be intra-diversification strategy that would combine exploitation of competences related to existing business segments with development of innovative products for niche markets.

To sum up this brief literature review, there is reason to believe that the established view on exploitation as only resulting in incremental improvements of existing products and processes might not be sufficient to understand the mechanisms behind innovation and that a more open approach to what kinds of innovation is possible under an exploitation-oriented innovation logic might be warranted. Therefore, in the next section an analytical framework is developed, which enables the analysis of innovation initiatives in terms of their degree of newness and takes both product and process dimensions into consideration (cf. Bauer and Leker, 2013).

2.2 A framework for studying innovation in exploitation-oriented industries

Innovation can be defined and studied in many ways. This paper focuses on technological innovation, i.e. the development of new product and process technologies, rather than market innovation (cf. Vargo et al., 2015), even if these types often are interdependent and required for innovation to be considered truly successful. This focus is reasonable considering both that the pulp and paper industry (as described in the introduction) is characterized by a goods-oriented, rather than service-oriented, logic (cf. Vargo and Lusch, 2004, Vargo and Lusch, 2008) and because the focus of the paper as explained in the previous section is on the *precursors* to innovations of different levels of magnitude rather than the final *effects* of these innovations in terms of the value experienced by users in specific contexts (Lusch and Nambisan, 2015) or the institutionalization of new practices (Vargo et al., 2015).

2.2.1 Product and process dimensions of innovation

In the literature on technological innovation, an established practice is to distinguish between product innovation and process innovation. Both these are, however, quite broad categories, which include a broad range of different types of innovation, especially with regard to the degree of newness they imply (Bauer and Leker, 2013).

In the innovation literature, *product innovations* tend to be described in terms of either product architecture changes or product performance improvements (cf. Christensen and Rosenbloom, 1995, Clark, 1985, Henderson and Clark, 1990). Consequently, established measurements of the degree of newness (or radicalness) of such innovations tend to focus on whether technological changes occur in components or at the product architecture level or on the order of magnitude of the resulting product performance improvements (cf. Ehrnberg, 1995, Gatignon et al., 2002).

Both these types of measurements are, however, less relevant for non-assembled products, such as pulp and paper, since these cannot be decomposed into components and for which technological progress tends to concern several performance attributes at the same time (Barnett and Clark, 1996). Therefore, the further discussion builds on frameworks found in the process industry literature, which distinguish between innovations that imply changes in existing products and innovations that add new products to the product portfolio (often aimed at new markets) (cf. Bauer and Leker, 2013). With regard to *changes in existing products*, it is useful to further distinguish between initiatives that leave existing products largely unchanged and those that imply significant modifications to them, for example in terms of improvements in product properties, quality or performance (cf. Lager, 2002, Aylen, 2013, Reichstein and Salter, 2006). This distinction roughly corresponds to the traditional incremental-radical innovation distinction, although it broadens the scope from performance to also include other types of product properties. For example, making a product from renewable rather than fossil resources will not change its performance, but could nevertheless be considered a significant product modification from the point of view of a customer in need of becoming more sustainable. What constitutes a “significant modification” differs between industries and

product categories and, thus, has to be determined on a case-to-case basis. With regard to *addition of new products to the product portfolio*, product innovations that are new only to a particular company can be distinguished from those that are also “new to the world” (OECD/Eurostat, 2005), which in the context of this paper can be conceptualized as either new to the industry as a whole or new to the market in which the product is used.

Process innovations can involve changes of input materials (material substitution or modifications of input ratios), changes in production equipment and process control technologies (ranging from substitution of individual pieces to design of entire new facilities) or changes in process settings (changes in temperatures, times, rates etc.) (Barnett and Clark, 1998, Barnett and Clark, 1996, Hollen et al., 2013). In the general innovation literature, there are only a few categorizations of process innovations. These distinguish between incremental and discontinuous (radical) process technology changes based on the magnitude of the resulting product improvements: incremental process innovations maintain the current rate of improvement and discontinuous process innovations imply order-of-magnitude improvements in product cost or quality (Anderson and Tushman, 1990, Gatignon et al., 2002). In contrast, the process industry literature categorizes process innovations based on whether they can be implemented in an existing production design or require changes to it, for example in terms of investments in new equipment (Lager, 2002, Aylen, 2013, Bauer and Leker, 2013). **This categorization logic is similar to the hierarchy/architecture-based categorizations of product innovations.** Three levels of process innovations can be distinguished: innovations that leave the existing process design largely unchanged (i.e. that are in the “process window”), innovations that require some modification or addition to the existing design and innovations that require an entirely new process design (Lager, 2002). **Aylen (2013, p. 272) refers to the first two of these as “stretch”, i.e. “the mechanism by which established plants incorporate subsequent improvements in process and product technology and organisational innovation”.** Like for product innovations, a distinction can be made between process innovations that are new only to a particular company and those that are new to the industry as a whole (cf. Reichstein and Salter, 2006, Lager, 2002).

A particular feature of process industries is that product and process innovations are highly interrelated and complementary to each other (Barnett and Clark, 1996, Hullova et al., 2018, Bauer and Leker, 2013, Lager, 2002, Lager et al., 2013). On the one hand, product innovation often requires process innovation (Frishammar et al., 2012, Kurkkio, 2011); when it has been decided which application is in focus and what properties the final product should have to match it, one of the main challenges is to develop a working production process that actually delivers the specified product properties, either by designing an entire new facility or by changing equipment and setup characteristics (Barnett and Clark, 1996, Frishammar et al., 2012). This implies that the extent to which an existing process can be modified limits the range of possible new product introductions (Frishammar et al., 2012, Kurkkio, 2011). On the other hand, process changes often result in changed product features (Frishammar et al., 2012, Linton and Walsh, 2008), which means that process innovation can open up for new product concepts or applications that were previously impossible to implement (Kurkkio, 2011, Linton

and Walsh, 2008). This close relationship implies that both product and process development are often required in the same innovation projects and have to be considered simultaneously in order to manage innovation (Kurkkio, 2011, Lager, 2017, Storm et al., 2013). However, it remains unclear whether a high degree of newness in one dimension requires or is likely to result in a high degree of newness also in the other dimension.

2.2.2 Innovation in a complex value chain

The process industry literature has emphasized that process industries, i.e. industries producing non-assembled products from raw materials and other ingredients (Frishammar et al., 2012, Lager et al., 2013), differ from industries manufacturing products from components and sub-systems in terms of higher value chain complexity and interdependency and therefore require a specific consideration in innovation studies (Kurkkio, 2011, Lager et al., 2013, Hirsch-Kreinsen, 2008).

A simplified illustration of the process industry value chain is presented in Figure 1. The process starts with an ingoing supply of primary raw materials and other ingredients, which are gradually transformed in a number of continuous, interconnected process stages. As indicated in Figure 1, a primary and a final process steps can be distinguished. The primary process step results in a primary product, which is the final product delivered by a focal company to the next step in the value chain. However, it also tends to deliver several “intermediate” products (Storm et al., 2013), which sometimes can be sold directly to end users but most often function as an input to the next process stage. This creates value chain dependencies (Frishammar et al., 2012), especially considering that the value chain can be distributed between plants and companies (Storm et al., 2013, Hirsch-Kreinsen, 2008).

In most cases, the primary product is further developed in a final process stage (sometimes referred to as “post-processing”) to one or more final products aimed at particular applications and delivered to a particular segment of end users (cf. Lager and Blanco, 2010, Lager, 2002, Barnett and Clark, 1996, Frishammar et al., 2012, Storm et al., 2013). However, if the focal company is located far downstream, the primary product can also be the final product of the value chain. **In the case of the pulp and paper industry, raw materials can be forest products, which together with chemical ingredients are transformed to primary products such as pulp and final products such as different types of paper, packaging products etc.**

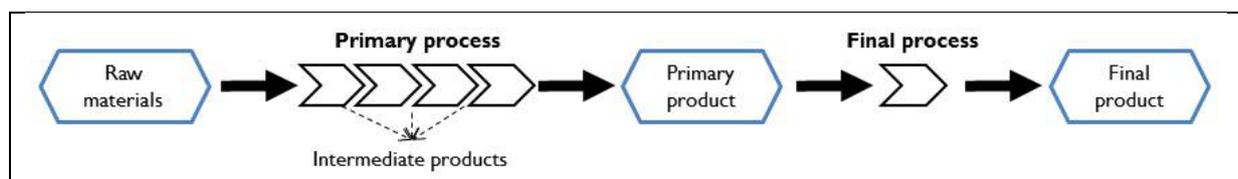


Figure 1: A simplified model of the process industry value chain (adapted from Storm et al. (2013))

The complexity of the transformation process, with its multiple process stages and intermediate products, implies that product innovation does not necessarily occur in relation only to the final product but can also concern intermediate and primary products. Similarly,

process innovation can involve technologies and equipment used either in the primary process or the final process stage (or both). Therefore, a study of innovation in process industries needs to take into consideration both the primary process stage with its resulting primary product and the final process stage with its resulting final product.

It also implies that several actors can be involved in an innovation process, especially when a focal company does not control the entire value chain. In particular, innovation in the final process or final product would by definition involve downstream actors, such as converters or brand owners. This means that in this context, the “exploitable set of resources” (Rothaermel and Deeds, 2004 p. 203) does not only consist of those controlled by an individual, focal firm but also those that are available downstream in the value chain.

2.2.3 Analytical framework and refined research question

To summarize the two aspects discussed above, the empirical study of innovation in a mature process industry requires considering both product and process innovation dimensions and recognising that the degree of newness can differ not only between these two dimensions but also between products and processes in different stages in the value chain. Based on this line of reasoning, the research question can now be formulated as follows:

To what extent and how can an exploitation-oriented innovation logic enable new-to-the-company/industry innovation considering: (a) both product and process dimensions and (b) multiple stages in the value chain?

This is reflected in the analytical framework, which is summarized in Table 1. The framework considers innovation in primary and final products (product dimension) and in primary and final processes (process dimension). Within each of these dimensions, it considers different degrees of newness: unchanged, modified or new. Each of these is judged from the point of view of the focal company which is involved in a particular innovation initiative, the industry as a whole and, as far as final products are concerned, the market in which it is to be used.

Table 1: Framework for analysing the degree of innovation newness in several product and process dimensions and steps in the value chain.

| Value chain stage | Product dimensions | | | | Process dimensions | | |
|-------------------|--|----------|--|--------|--|----------|--|
| | Primary product | | Final product | | Primary process | | Final process |
| Unit of analysis | Company | Industry | Industry | Market | Company | Industry | Industry |
| Degree of newness | <ul style="list-style-type: none"> ▪ Unchanged ▪ Modified ▪ New product | | <ul style="list-style-type: none"> ▪ Unchanged ▪ Modified ▪ New product | | <ul style="list-style-type: none"> ▪ Unchanged ▪ Modified ▪ New process | | <ul style="list-style-type: none"> ▪ Unchanged ▪ Modified ▪ New process |

This framework acknowledges that a particular innovation initiative can be highly innovative in one dimension and from one point of view, but not in others. For example, a product can remain unchanged while a new process is developed (and vice versa) and the first step in the

value chain can remain unchanged even if the final step is innovated (and vice versa). Thus, for each particular innovation, the framework has the potential to provide insight into the relationship between degrees of newness across different dimensions.

A qualitative analysis of the relationship between product and process dimensions and between the primary and final steps in the value chain is needed to understand what kind of innovation logic (exploration vs exploitation) is behind a particular innovation. The exploitation logic is revealed when unchanged/modified dimensions have an enabling influence on dimensions that are new to the company, the industry or the market. Thus, an exploitation logic would be indicated if the precursor of a new product is an intention to use existing processes (or vice versa) or if the precursor of high novelty in one step in the value chain is an ambition to take advantage of existing resources in another step. Figure 2 summarizes the exploitation precursors of novelty considered in this study.

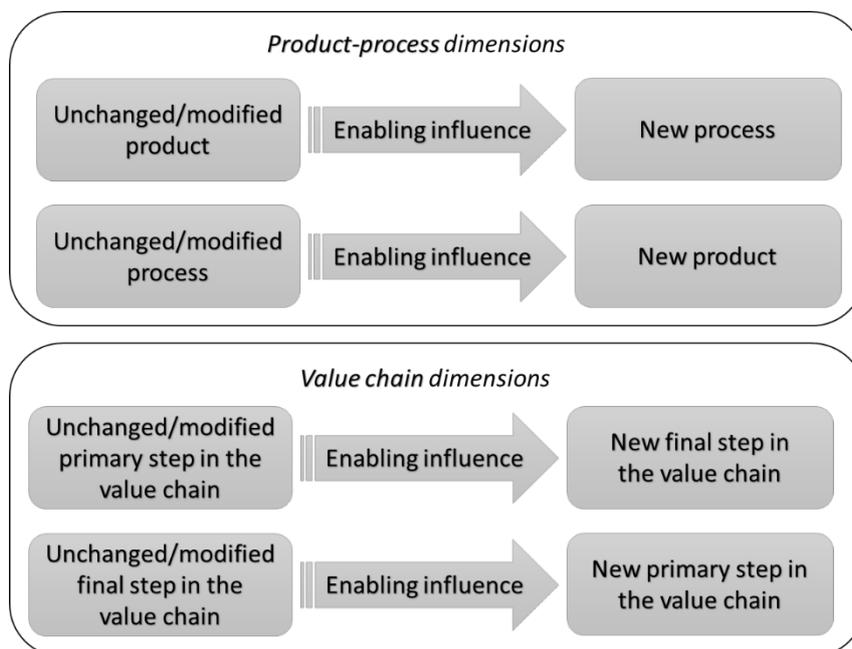


Figure 2. Summary of exploitation precursors of novelty.

3. Research design

3.1 Case selection

The paper is based on an embedded case study of 11 innovation initiatives in the Swedish pulp and paper industry. Case selection was performed at two levels:

- 1) The overall case of the Swedish pulp and paper industry was theoretically selected (a mature process industry with explicitly articulated innovation challenges and opportunities and some completed and ongoing innovation initiatives).
- 2) Six pulp and paper companies were contacted for overall interviews based on the presence of innovation activities outside traditional business areas, as described in annual reports and other publicly available company information. As a result of the overall interviews, innovation initiatives were selected. Among a total of 19

mentioned initiatives, those that showed newness according to at least one of the dimensions in the adopted categorization (see Section 2.2) were selected for further research and those with enough publicly available information were included in the study (11 projects, both completed and ongoing). Although this is probably a subset of all innovation initiatives in the pulp and paper industry, the initiatives that are made public are presumably not the most innovative of the companies' projects, which implies that the innovativeness of this industry is most likely not over-estimated.

3.2 Data collection and analysis

The study builds on (a) primary data in the form of twenty semi-structured interviews with six pulp and paper producers and three forest industry research institutes in Sweden (see Table 2) and (b) secondary data in the form of descriptions of initiatives, information letters, progress reports and other materials available on homepages of the involved organizations or, in some cases, websites specifically dedicated to specific initiatives.

3.2.1 Data collection

The range of interviewees includes heads or representatives from companies' divisions working with new business development as well as researchers and specialists involved in new product development projects. Interviews were conducted face-to-face or by telephone. All but two telephone interviews were recorded and all interviews were transcribed. In addition to the 20 main interviews, three additional follow-up interviews (including one with a downstream actor outside the pulp and paper industry) were conducted via telephone in order to clarify some questions that arose during data analysis.

Two main types of interviews were conducted. Overall interviews aimed at providing an overview of the companies' general approaches to innovation and their ways of handling transformational challenges and at distinguishing innovation initiatives for further investigation. Project-specific and follow-up interviews focused on the background, development and key decisions in relation to particular innovation initiatives as well as the kind of process and product changes they were expected to generate for the company or the industry.

The selected initiatives were also studied via annual reports and other publicly available secondary information from press releases, articles on companies' home pages, articles devoted to specific new materials and technologies and projects' dedicated websites. The secondary sources of data were used to support, complement and add details to the findings from the interviews. For example, some of the studied materials and products took part in and won innovation and design contests which resulted in a series of media publications about the related initiatives. These materials were used to complement the interview findings by providing details of process development and estimations of market potential for the new materials. Further, some initiatives had dedicated home pages, which, apart from the overall information about those projects, contained newsletters and progress reports describing the

main activities in those initiatives. Finally, annual reports of the involved companies provided data on the further development and updated status of the initiatives after the interviews were completed.

Table 2. List of the interviews in chronological order for each company

| Company | Interview mode | Type of interview |
|--|----------------|------------------------------|
| Company A | face-to-face | project-specific |
| | telephone | Overall |
| | telephone | project-specific |
| | face-to-face | project-specific |
| | face-to-face | project-specific |
| Company B | face-to-face | Overall |
| | face-to-face | Overall |
| | face-to-face | Overall |
| Company C | face-to-face | Overall |
| | telephone | project-specific (follow-up) |
| Company D | face-to-face | Overall |
| | telephone | Overall |
| Company E | face-to-face | Overall |
| | telephone | Overall |
| | face-to-face | Overall |
| Company F | face-to-face | Overall |
| | telephone | project-specific (follow-up) |
| Research Institute 1 | face-to-face | Overall |
| Research Institute 2 | face-to-face | project-specific |
| | face-to-face | Overall |
| | face-to-face | project-specific |
| Research Institute 3 | face-to-face | project-specific |
| Producer of tall oil-based diesel fuel | telephone | project-specific (follow-up) |

3.2.2 Data analysis

All gathered data (interviews transcripts and secondary materials) were analysed using the NVivo software. The analysis consisted of two main steps. First, the initiatives were categorised following the analytical framework presented in Section 2.2, i.e. each initiative was analysed and coded with regard to the degree of newness it implied in both the product and process dimensions in the primary and final steps of the value chain.

It should be noted that although this analysis was to a large extent based on data collected through interviews, it was the authors and not the interviewees who determined the degree of newness along the studied dimensions. The interviewees were asked to answer factual questions about the differences between their new and old products and processes and the activities undertaken in the course of developing the initiatives (e.g. acquiring new competences, establishing contact with new customers, modifying existing processes, reusing parts of existing infrastructure). Based on these descriptions together with the secondary materials, the authors summarized the product and process development needs in different stages of the value chain (see Appendix A) and matched these descriptions with the

definitions of innovation newness presented in the theoretical section. That was done in order to ensure that the evaluation of the initiatives' degree of newness did not represent a subjective assessment by the company representatives. Furthermore, data sources were triangulated (by asking several involved parties about the same project and consulting secondary data sources) and web searches were performed to find information about innovation initiatives similar to the ones discussed in the interviews.

The second analysis step aimed at investigating the innovation logic of the initiatives and identifying to what extent they were driven by an exploitation logic. In line with the definition of exploitation in Section 2, the exploitation logic was operationalized as a logic in which the precursor of a specific innovation initiative was an intention to take advantage of existing resources, capabilities and assets. To gain insight into the precursors of the selected innovation initiatives, interviewees were asked about (a) the reasons why these innovation initiatives were selected and why specific development alternatives were preferred to others, (b) the main strengths and weaknesses of the company with regard to these initiatives and (c) the influence (both positive and negative) of the company's existing resources on these initiatives. Thus, these precursors explained both why the studied initiatives were initially considered and why certain development directions were preferred to others within these initiatives (for example, why the development focused on particular applications). The precursors were coded as 'exploitation' if the answers to the abovementioned questions pointed at an intention to "build on", "maintain connection with", "expand" (or similar keywords) the use of existing resources (cf. Rothaermel and Deeds, 2004).

In combination, the two steps of analysis also provided input regarding interrelationships between the product and process dimensions and the primary and final steps of the value chain.

It should be noted that since the study was of qualitative character, the aim was not to make any statistical observations or conclusions (e.g. that all or most of the initiatives were characterised by a certain logic). Instead, examples of different innovation logics were used to demonstrate to what extent and how an exploitation-oriented innovation logic could contribute to high degrees of product or process newness in different steps of the value chain.

4. Empirical findings

4.1 The degree of newness of current innovation initiatives

A summary of the studied innovation initiatives is provided in Appendix A, which gives an overview of the development needs with regard to products and processes in the primary and final steps of the value chain. Nine of the initiatives are mostly concerned with the development of new materials and products and two can be described as essentially new process technologies (Lignin technology and Separation technology).

As a basis for the following analysis, all the studied initiatives have been categorized using the analytical framework developed in Section 2.2. Categorization results are summarized in Table 3, where dimensions with a high degree of newness are highlighted.

As the initial intention with the study was to consider initiatives that were new with respect to at least one dimension, it is not surprising that the results show a rather high level of degree of newness. However, it was neither apparent beforehand that the new aspects would be so widely distributed across categories (covering both products and processes as well as both primary and final steps of the value chain), nor that several new aspects would be combined within the same initiative.

It is also interesting to note that almost all initiatives were using existing resources to a large extent, which was evidenced by the fact that all initiatives were categorized as unchanged or modified with regard to at least one product and/or process step. Thus, the high level of newness revealed above could be driven by an exploitation innovation logic, since existing resources were certainly not abandoned.

Table 3. Categorization of new product development initiatives in the pulp and paper industry

| Innovation initiatives | Product | | | | Process | | |
|------------------------|-----------------|-----------|---------------|-----------|-----------------|-----------|---------------|
| | Primary product | | Final product | | Primary process | | Final process |
| | Company | Industry | Industry | Market | Company | Industry | Industry |
| Composite Material | New | New | New | Modified | Modified | Modified | New |
| Insulation Material | Unchanged | Unchanged | New | Modified | Modified | Modified | New |
| Dissolving cellulose | New | Unchanged | Unchanged | Unchanged | Modified | Unchanged | Unchanged |
| Tall oil | Unchanged | Unchanged | New | Modified | Unchanged | Unchanged | New |
| Single-cell protein | New | New | N.A. | Modified | Modified | Modified | N.A. |
| Separation Technology | New | New | Unchanged | Unchanged | New | New | Unchanged |
| Lignin Technology | New | Unchanged | Unchanged | Unchanged | New | Modified | Unchanged |
| Carbon fibre | New | New | New | Modified | New | New | New |
| Ligno-sulfonates | New | Unchanged | Unchanged | Unchanged | Modified | Unchanged | N.A. |
| Nano-cellulose | Modified | Modified | Modified | Modified | New | New | Unchanged |
| Shapeable packaging | Modified | Modified | Modified | Modified | Modified | Modified | New |

N.A. = Not Applicable.

However, in order to show whether an exploitation logic was indeed at play, the next sections will identify the precursors of the initiatives as well as analyse the interplay between different

dimensions. As explained above, an exploitation logic can be identified if the driving force behind an innovative initiative was an intention to use existing resources (i.e. resources related to unchanged or modified dimensions). Following the theoretical framework and the conceptualization of exploitation precursors of novelty summarized in Section 2.2.3 and Figure 2, the following sections will focus on investigating if *unchanged* or *modified* dimensions enabled novelty in dimensions categorised as *new*. The further analysis will first consider if exploiting the characteristics of existing products served as a precursor to process novelty, and vice versa. Then, the value chain dimension will be analysed, i.e. if exploiting resources within the primary step in the value chain served as a precursor to novelty in the final step, and vice versa.

4.2 Product and process dimensions

As indicated in Table 3, the studied initiatives were characterised by different degrees of product and process newness. In the product dimension, some products were new to the focal companies (e.g. the primary products in the Dissolving cellulose and Lignosulfonates initiatives), whereas others were new to the whole industry (e.g. the primary product in the Single-cell protein initiative and the primary and final products in the Composite material initiative). Similarly, in the process dimension some processes were new to the company (e.g. the primary process in the Lignin technology initiative) and others were new to the whole industry (e.g. the primary process in the Nanocellulose initiative and the final process in the Tall oil initiative).

Thus, the initiatives demonstrated high levels of newness (at least up to new to the industry level) in both product and process dimensions. Moreover, different combinations of degrees of product and process newness could be seen in the initiatives: initiatives could involve a new product, a new process or both (here, combinations between primary product and primary process and between final product and final process are considered). One case in which the levels of product and process innovativeness seemed to be coordinated was the development of carbon fibre, where a new to the company and industry product required the development of new to the company and industry processes. Similarly, the new process technologies in the Lignin and Separation technology cases were associated with new to the company products.

However, in many cases no clear relationship between the degrees of newness of products and processes was observed. Thus, new products could co-exist with unchanged or modified processes and vice versa. Such initiatives could potentially be driven by the exploitation logic. Therefore, it is important to understand to what extent and how an exploitation logic was indeed behind these initiatives, i.e. whether high level of newness in one dimension (product or process) was enabled by the exploitation of the other dimension (process or product, respectively).

In some cases, a completely new process was developed as an alternative way of producing an already existing product. For example, the Nanocellulose initiative was associated with the development of a new primary process, but only aimed at delivering a modified primary product. Case Box 1 illustrates the innovation logic and product-process interrelation in this

case. A similar pattern could be observed in the Shapeable packaging initiative: while the final product (cylindrical paper-based bottles) was categorised as a modified final product, a new final process equipment had to be specifically developed to produce it.

Case box 1. Nanocellulose

Nanocellulose is a strong fibre-based material which in theory can be used both in traditional business areas and in new to the industry applications. The Nanocellulose initiative does not imply any high levels of newness in the product dimension, since it focuses on traditional product segments (paper, packaging), although there is a possibility to develop microfibrillated cellulose as a new primary product later, but it still requires a new process to accomplish mechanical decomposition of the fibres.

The driving force for the involved company to take part in the Nanocellulose initiative was the possibility to use the modified, improved product offering to strengthen their existing packaging business. New process techniques required for nanocellulose production were interesting to investigate for this company since they can potentially be used in existing facilities to produce products for already known markets. Indeed, in this case a low level of newness of the primary product allowed for using the same value chain as before, i.e. use existing final process techniques to deliver a modified final product.

In another group of cases, small process changes could result in the introduction of new products. For example, dissolving cellulose, lignosulfonate, the single-cell protein and the composite material initiatives all focused on developing the product portfolios of the interviewed companies, but did not require more than modifications of existing primary processes. Case Box 2 provides an example of this type of innovation logic and product-process interaction through the Dissolving cellulose case.

Case box 2. Dissolving cellulose.

Dissolving cellulose is a wood pulp refined from lignin and hemicellulose. This primary product is produced using traditional pulp production processes with modified process parameters. Several of the interviewed companies have recently entered the dissolving cellulose business, which is a new market for them as this primary product is sold to the viscose, hygiene and medical products industries.

One of the companies had previous experience of producing dissolving cellulose, but in the 1970s the product was discontinued due to environmental considerations. In the end of the 1990s, this company underwent some ownership changes and was at risk of being closed down. At that time, the need to change the company's business profile became apparent. The shift towards dissolving cellulose was perceived as a natural one since the environmental considerations were resolved by then and the company had historically accumulated knowledge about dissolving cellulose. This knowledge was retained in the form of old reports, process descriptions and to some extent employees' experience (although many did not work at the facility any more due to a large time gap since the 1970s). Additionally, no large process changes were required and for some time both the old pulp and the new dissolving cellulose were produced in shifts. All of that enabled a quick, smooth and relatively certain transition into a new business area.

In summary, while some cases indeed involved changes in both product and process dimensions, many other examples showed that these two dimensions do not necessarily need to be synchronized (i.e. both new or both unchanged/modified). However, an important finding was that the lack of synchronization did not imply an absence of interrelationships between the two dimensions. On the contrary, the examples described in Case boxes 1-2 show that unchanged or modified products can in fact enable the development of completely new processes and that exploitation of process competences can enable product innovations. Thus,

these examples showed that the decision to exploit resources related to one dimension (product or process) can enable changes in the other one.

4.3 Complexity of the value chain

As shown in Table 3, the studied initiatives as a group demonstrated high levels of newness in both the primary and final steps of the value chain. Some were new to the involved companies or to the whole industry with respect to primary products and processes (e.g. the Separation technology initiative), whereas others implied final products and processes that were new to the industry (e.g. the Insulation material initiative).

However, most of the initiatives were new with respect to one of the two steps in the value chain (primary or final), but not both, which implies at least some degree of exploitation of existing resources in the other step (final or primary, respectively). In order to demonstrate that an exploitation logic was indeed present, i.e. that resource exploitation in the unchanged or modified step of the value chain enabled newness in the other step, interaction between the two steps in the value chain needs to be investigated more in detail.

In some cases, an unchanged or modified primary step of the value chain, where both the primary product and the primary process were unchanged/modified, were used as a basis for developing new final products based on new final processes. For example, several companies sold tall oil (an unchanged by-product of their primary production process) to biofuel producers that transformed it in a specialized unique facility into tall diesel and further into a new final product: second generation diesel fuel. Another similar example was the Insulation material initiative, which aimed at developing a new final product (a foam formed insulation material) based on an existing primary product (wood-based fibrous material) and an existing primary process.

In other cases, only one dimension (product or process) in only one step in the value chain (primary or final) was new, while all the other dimensions were unchanged or modified. The Shapeable packaging initiative was such an example where, as illustrated in Case Box 3, the primary product and process as well as the final product were only modified, but drove substantial process innovations in the final step.

Case box 3. Shapeable packaging

Shapeable packaging is an initiative resulted in the production of cylindrical bottles made of a highly elastic paper-based packaging material. From the point of view of a primary step in the value chain, it is neither a new product nor a new process, as parameters of existing production process were adjusted to produce packaging material that appeared to be 10-15 times more stretchable than the usual paper. Moreover, this shapeable packaging material can be used in existing final processes (converting using existing machinery), in which case shapeable packaging does not fulfil this study's criteria of an innovative initiative. However, in order to increase sales of the shapeable packaging material, the involved company entered a joint venture with an equipment producer with the aim to develop cylindrical paper-based bottles. This specially developed final process technology involves a number of unique converting steps, which is why it is categorised as a new final process. Thus, a modified primary product has enabled the creation of a new final process technology.

In other cases, new primary products and/or primary processes could be integrated in the existing final step of the value chain, i.e. with unchanged or modified final products and processes. Examples include the Dissolving cellulose initiative (new primary product), the Nanocellulose initiative (new primary process) and the Lignin and Separation technology initiatives (new primary products and new primary processes). Case Box 4 illustrates the logic behind the Separation technology initiative in more details.

Case box 4. Separation technology

Separation technology is a new primary process that transforms biomass into lignin and 5-6 carbon sugars, e.g. xylose. The involved company invested in the development and construction of a demonstration plant in order to validate the process of separation of high purity xylose. Previously xylose existed in a form of raw xylose-containing biomass extracted as a side product of the pulp process. This raw xylose had low purity and was extracted in low volumes, which is why it remained as an intermediate product and was not a separate commercial good in the industry. However, the Separation technology had a potential to extract pure, high-quality xylose in high volumes, which would make it a new primary product. At the same time, a value chain of transforming raw xylose into final products (such as xylitol) would also be compatible with the pure xylose, which meant that it could exploit the existing downstream part of the value chain. Although the exploitation of the final step of the value chain was not the key driver in the development of the primary step, it had still an enabling influence as the exploitation of the existing market considerably decreased the market challenge for the involved company.

An exception to the lack of coordination within the value chain described above is the Carbon fibre initiative, which involved changes in both primary and final products as well as in both primary and final processes. However, as illustrated in Case Box 5, carbon fibre did in fact still build on existing resources, if considering a historical perspective.

Case box 5. Carbon fibre and Lignin technology

Carbon fibre is an ongoing initiative in the pulp and paper industry that aims to develop carbon fibre based on lignin (material contained in wood fibres), which would be a substitution to the fossil-based carbon fibre. This initiative involves a large number of actors along the value chain (from a pulp producer to a car manufacturer) and requires an extensive product and process development along the whole value chain. Therefore, primary and final products as well as primary and final processes in this initiative are altogether characterised as new. However, the possibility to develop lignin-based carbon fibre depends on the access to high quality lignin. This access can be provided using the Lignin technology which was initially developed with the aim to increase the production output of the pulp process technologies (i.e. primary step in the value chain). High quality lignin was refined in that new process in order to decrease the load of the bottleneck equipment. Thus, the intention to increase the efficiency of the existing primary process enabled the extraction of pure lignin which in turn enabled the carbon fibre initiative which involves changes of a high level of newness across the whole value chain.

As a final observation, it can be noted that none of the initiatives were associated with final products that were new from the point of view of the end market. For example, single-cell protein cannot be seen as a completely new product for the industry, but in the end market it can only substitute other sources of fish feed in the fish-farming industry. However, the analysis shows that these innovation initiatives still implied high levels of newness from the point of view of the companies and/or the industry. They required extensive research and development efforts, both product- and process-wise, and resulted in products that are far different from the industry's traditional product portfolio. In many cases, they implied entry

into new markets and required new business models, which in itself is a great challenge for companies in a mature industry. Moreover, even if they were not new to the market the modified final products implied changes in very important aspects for the customers. In most cases, wood fibre-based products could provide more sustainable raw materials for existing applications. This was the case with the Singe-cell protein initiative, where the existing fish feed was clearly unsustainable and the fish-farming industry was explicitly looking for alternative solutions. Similarly, the Insulation material initiative aimed at replacing polyurethane-based insulation foams and the Tall oil initiative aimed at producing a more sustainable transportation fuel.

In summary, the observed patterns regarding the interaction between the primary and the final steps in the value chain give evidence of an exploitation logic in the development of the innovation initiatives. As illustrated in Case Boxes 3, 4 and 5, the intention to exploit resources in one step of the value chain can enhance or at least facilitate changes in the other step in the same or later initiatives.

5. Discussion

The initial overview of the studied initiatives categorised along different dimensions showed that the pulp and paper industry has a high innovation potential, which stands in contrast to the previous studies of mature industries in general (cf. Abernathy and Utterback, 1978, Anderson and Tushman, 1990) and the pulp and paper industry in particular (cf. Novotny and Laestadius, 2014, Kivimaa and Kautto, 2010).

Subsequently, a deeper analysis of the innovation initiatives provided two main insights with regard to the relationship between exploitation and high degrees of newness of product and process innovations in different steps in the value chain. First, innovations could be new with regard to one dimension (primary product, primary process, final product or final process), while still unchanged or modified with regard to the other three. Second, the dimensions that were unchanged or only slightly modified in the studied initiatives appeared to have an enabling role in the innovation process. The detailed examples discussed in Case Boxes 1-5 show that existing products and processes held an exploitation potential that drove the development of new products and processes. Together, these two insights show that the exploitation of existing resources was a precursor of several innovation initiatives in the pulp and paper industry and, thus, that it is possible for an exploitation logic to result in the development of product and process innovations characterised by a high degree of newness.

However, the analysis also showed that there was an absence of new to the market innovations. This might be one reason why the pulp and paper industry is perceived as non-innovative from the outside (cf. Kivimaa and Kautto, 2010, Novotny and Laestadius, 2014). It could also raise the question of whether the studied initiatives brought any value to the companies and end users and whether a possible lack of value was caused by a lack of market-related innovation precursors, i.e. market orientation (Narver and Slater, 1990). However, the initiatives did bring value to the companies. By 2018, six of the eleven initiatives had been commercialized (composite material, dissolving cellulose, tall oil, lignin

technology, lignosulfonates, shapeable packaging) and one more awaited the beginning of commercial deliveries in 2018 (separation technology). Although no exact sales numbers were available at the time this paper was written, the new markets showed in general positive dynamics (e.g. the demand for lignosulfonate has in recent years been growing at 1.4% rate, and the global market for dissolving cellulose has almost tripled since 2001) (ResearchAndMarkets, 2016, OrbisResearch, 2017). Moreover, as discussed above, a majority of both the commercialized and non-commercialized initiatives add value by providing more sustainable alternatives to existing products which is highly valued in the eyes of customers given current environmental pressures (Konar and Cohen, 2001).

Moreover, the existence of an exploitation logic does not imply that market potential and customer value were not taken into account. Well in line with the research pointing at the importance of market orientation for business performance and innovativeness (Hult et al., 2004), the respondents highlighted that a perception of a promising market potential was an important criterion for engaging in the innovation initiatives. Since most of the initiatives implied entering a new market, market competence was not one of the existing resources that could be exploited. However, companies were able to gain an understanding of the needs and requirements of the new markets by collaborating with potential customers and including them as partners in the new product and process development projects – just as the proponents of market orientation and a service-dominant logic to innovation advocate (cf., e.g., Han and Hansen, 2017, Hansen, 2010, Slater and Narver, 1994). While this was not the focus of the study, this might indicate that the studied initiatives were not purely exploitative, but might also have contained some element of exploration from the point of view of the pulp and paper industry. However, this does not contradict the main findings of the study, i.e. that the studied innovation initiatives were characterised by an exploitation logic and that this resulted in high levels of newness in other parts of the value chain. Moreover, the study did not cover the innovation strategy of downstream actors (e.g. customers) in these cases. Considering that the products were not new to the receiving markets, it is likely that they involved in at least some degree of exploitation as well (although the precursor of their engagement has not been studied here).

5.1 Implications for theory

The paper contributes to theory in several ways. First and most important, by demonstrating how exploitation can contribute to innovations characterised by a high degree of newness, the results of this study challenge the traditional association of exploitation with incremental product improvements and process changes (cf. Bauer and Leker, 2013; Wang and Hsu, 2014). In doing so, the paper also contributes to the ongoing discussion on the importance of existing resources for developing major innovations (cf. Bergek et al., 2013a, Geels, 2006).

Second, this paper contributes to the previous literature by emphasising the importance of simultaneously considering not only product and process dimensions, as highlighted in previous studies (Bauer and Leker, 2013), but also different steps in the value chain. The possibility to combine new and existing dimensions creates a much wider range of innovation

opportunities than normally considered. It should also be noted that although the value chain was divided into two steps for the purpose of this study, it is possible to distinguish more and smaller steps in the value chain, for example by including intermediate products (cf. Storm et al., 2013), which further enlarges the range of innovation opportunities available to companies.

Third, with respect to the interaction between product and process innovation, the results of the study shed further light on the interrelation between product and process innovations. The observed patterns only partially correspond with the theory-based expectation that product and process changes need to be aligned (Lager et al., 2013, cf. Frishammar et al., 2012). In particular, the identified possibility that unchanged/modified products and processes could have an enabling influence on new ones has not been discussed in previous literature.

5.2 Implications for practice

In terms of managerial implications, the results of this study suggest that existing resources do not need to be abandoned in order to retain innovativeness, as is the general advice to managers of companies in mature industries facing transformation challenges. Instead, managers in established companies need to carefully select resources (within product or process dimensions and within the primary or final step in the value chain) for further exploitation. They can then identify resource interdependencies in order to develop complementary new resources in other dimensions.

5.3 Implications for policy

This paper provides new insights for policy makers with regard to addressing radical innovations in mature industries. Recent literature on transformative innovation policy, highlights the need for destabilization policies, i.e. policy instruments that open up established sociotechnical regimes and create a window of opportunity for new niche innovations to break into and change existing sociotechnical systems (cf. Kivimaa and Kern, 2016). However, this study shows that radical innovation does not necessarily require total creative destruction. In order to speed up transition processes and also reduce the total level of investments needed, policy makers should strive to actively search for synergies with existing business areas and encourage incumbent actors to reuse parts of their existing resource bases when diversifying into new product markets. The study also shows that efforts to encourage radical innovations in mature industries should be made at the level of value chains rather than individual companies, in order to include potential synergies across different steps in the value chain.

5.4 Limitations and suggestions for further research

The study has some *limitations* due to the fact that not all of the investigated innovation initiatives have been commercialized. This implies that the future degree of newness of these initiatives might be higher or lower than the present analysis shows. Nevertheless, it was

important to include those initiatives in the study in order to provide a more complete range of exploitation-driven product and process development activities.

Two main suggestions for *further research* can be identified. First, as discussed in the analysis and shown in Appendix A most of the studied initiatives were conducted in collaboration with external partners. The role of such collaborations for companies' innovation strategies is an important avenue for further research. One possible line of investigation could consider the division of labour between different actors in the value chain with respect to exploration/exploitation, i.e. the possibility to combine exploitation by some actors with exploration by others and the overall logic behind such development processes. Second, while this study included a number of innovation initiatives developed by pulp and paper companies in Sweden, recent research has suggested that the value of existing resources and assets might differ between institutional contexts (cf. Fuentelsaz et al., 2015). Comparing the results of this study with results of the same industry in other countries (different political contexts) or other industries in Sweden (different economic contexts) could therefore be of interest.

6. Conclusions

The purpose of this paper was to investigate to what extent and how an exploitation logic is consistent with the successful development of innovations characterized by a high degree of newness and, more precisely, how an exploitation logic can enable new-to-the-company/industry innovation, considering (a) both product and process dimensions and (b) multiple stages in the value chain.

The results of the analysis of a number of innovation initiatives in the Swedish pulp and paper industry showed that an exploitation logic can indeed lead to innovations characterised by high levels of newness. High innovativeness was demonstrated with examples of products and processes that were new-to-the-company or new-to-the-industry or both. This paper thereby contributes to theory by challenging the traditional association of exploitation with incremental improvements and demonstrating how exploitation can result in major product and process innovations in complex value chains.

The existence of an exploitation logic behind the studied innovations was demonstrated through an analysis of interdependencies between product and process innovations as well as between different steps in the value chain. First, in some cases decisions to exploit existing product resources drove the development of new processes and vice versa. Second, in some cases the exploitation of one step of the value chain facilitated novelty generation in the other step. Together, the possibility to innovate in product or process and in different steps of the value chain created a large range of innovation opportunities, where the pursuit of novelty generation in one of several available dimensions (primary process, primary product, final process or final product) could build on the exploitation of existing resources in all or some of the other dimensions.

In summary, by adopting a multi-dimensional framework that took into account both product and process innovation dimensions as well as the complexity of the innovation value chain, the paper has shown that the Swedish pulp and paper industry does not only deliver incremental innovation, but also pursues innovation initiatives characterized by high degrees of newness, while not abandoning an exploitation innovation logic.

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Appendix A. Innovation initiatives in the pulp and paper industry

| Example | Description | Product development needs and activities | Process development needs and activities | Company |
|----------------------|---|--|--|---|
| Composite material | Biobased and biodegradable composite material. By mixing paper pulp with an environmentally friendly plastics material, the tactile and environmental qualities of paper are combined with the strength and mouldability of plastics. | <p><i>Research project 2002 – 2007.</i> Collaborative knowledge development project about fibers, including how they react to different conditions and treatments.</p> <p><i>Applications/business development project (since 2007).</i> Applications development by Company A, e.g. demonstration of what the material could be used for (a chair was produced, which won first prize at the 2009 Milan exhibition). Business model development and marketing to attract customers.</p> | Development of new conversion technology (final process) required to activate the material and make it strong, water-resistant and mouldable. Close cooperation between Company A and a converter company. Pilot plant launched in 2015. Further development of dry production process (since 2015). | <p>First step: Research Institute 2 + several P&P</p> <p>Second step: Company A + Research Institute 2 and the converter company.</p> |
| Insulation material | Wood-based thermal insulation foam. Advantage: low environmental impact in comparison with traditional materials (e.g. fossil oil-based polyurethane foam). | <p>Materials and product development. The idea is to use foam forming technology (a wet forming technique that does not use synthetic binders) to produce new, cellulosic foam products (specifically a spray-on thermal insulation foam based on nanocellulose).</p> <p>Evaluation of fire, water and microbe resistance (to ensure performance on par with existing insulation products).</p> | The possibilities of process scale-up are to be explored as well as the ways to produce fibre-based spray-on insulation foam material. | Companies across the value chain (incl. Company E) and research institutes from three European countries. |
| Dissolving cellulose | Refined wood pulp (lignin and hemicellulose are filtered away), which is used in the textile, pharmaceutical and hygiene industries. | <p>Available already in the beginning of the 20th century (when it was not used because of environmental and economic reasons); new for individual companies.</p> <p>New market for P&P companies; adaptation to new customers needed.</p> | Similar primary process as paper pulp, but with modified cooking times and management of side streams. Technology is commercially available. | Company B (main focus), Company F (one line since 2012), Company A (one small line since 2012) |
| Ligno-sulfonates | Byproduct from the sulphite pulping process, which is used as a plasticizer in concrete production (to reduce the amount of water needed and, thus, concrete weight). | Traditional byproduct, but new as a commercial product (used to be burned and used for energy) and aimed at a new market. | Two drier machines were bought and installed in order to enable production of powder-form lignosulfonates (optimal for transportation compared to liquid form). | Company B |

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|-----------------------|---|--|--|---|
| Single- cell protein | Cultivation of bacteria which are rich in protein in the organic residues of a biorefinery process. The protein can be used as fishmeal in fish feed, thereby replacing the non-environmental friendly use of young fish. | Product developed in a research project aimed at improved use of Company B's rest streams. The research project was led by one of the company B's partners having biochemistry expertise. The product has been tested in fish feeding trials. A new business model still needs to be developed. | The harvesting of bacteria requires some modification of the primary process, but technology is available and pilot and demonstration trials have been successful. Full scale production requires large investments in a known process technology. | Several partners including Company B |
| Carbon fibre | Carbon fiber based on lignin from wood (instead of fossil oil). | Idea not new, but the development of high-quality fibers is. Development and tailoring of carbon fibers to be used in carbon fiber-reinforced plastic composite components for the automotive industry (large-scale EU research project). | The lignin technology paved the way by making it possible to separate pure lignin. New primary and final processes needed to produce fibers and tailor their characteristics to intended applications. | Several partners incl. Company A; coordinated by Research Institute 2 |
| Nano-cellulose | Extremely strong material derived from wood fibers, which can substitute for similar materials based on fossil fuels in e.g. packaging (barrier materials) and potentially new to the industry applications such as food, cosmetics and electronics. | Development of packaging materials strengthened with microfibrillated cellulose (MFC) which will result in considerably improved product properties (e.g. strength, water-resistance). This is a middle option between developing small changes in packaging materials with the help of MFC and extracting MFC as a separated primary product. | Development of mechanical decomposition process technology is required before product commercialization. Company C collaborates with research partners with regard to process development. | Company C, research institutes and universities. |
| Separation technology | New process technology that transforms biomass into lignin and five and six carbon sugars, e.g. xylose, five-carbon sugar derived from wood raw materials; can be converted to final products such as Xylitol (natural sweetener). | Among several products that can be extracted in the new separation process, the first focus is made on high-quality pure xylose, which will be a new primary product for the industry. At present, lower volumes of xylose-containing biomass can be available as a rest-stream of other processes. | Development and construction of a demonstration plant to validate the technology (developed earlier by acquired firm). | Company F |
| Tall oil | Tall oil, a bi-product from the pulp and paper production, is supplied by several companies to a producer of second generation renewable fuel. Tall oil has no competition with food raw materials, unlike other existing sources of biodiesel (e.g. raps oil). | Tall-oil is traditional bi-product from the pulp and paper industry. Used as a raw material to produce, primarily, biodiesel (tall oil -> tall diesel -> high quality diesel fuel), but also rosin (raw material for manufacturing products) and bio oil (bi-product of diesel production, energy raw material). | No changes in primary processes to produce tall oil. For final processes, a specialized production facility was built that pioneered the renewable diesel process technology. | Company A, Company D, Company E |

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|---------------------|--|---|--|--|
| Lignin technology | Technology for extracting high quality lignin developed by Research Institute 2 in cooperation with other partners. Company F has invested in the technology to be integrated into one of their facilities in Finland (lignin production started in 2015). | High quality lignin can be used as a fuel at a pulp mill that substitutes natural gas, or as a raw material for other products, potentially including, biodegradable plastics or carbon fibre. At the Company F facility, dried lignin has replaced natural gas and is sold externally (for phenols substitution in cement production). | Lignin extraction technology has been integrated with the pulp production facility to enable collection and separation of lignin that is further dried into a powder. The facility has become the second case of that technology at commercial scale in the world. | Company F |
| Shapeable packaging | Company C has developed a stretchable packaging material that is compatible with conventional final processes, but can also be further processed in a specially developed machinery to produce cylindrical paper-based bottles. | Paper material with new mechanical properties has been developed ta Company C: material stretchability is 10-15 times higher than usual paper. This paper material is further processed to produce cylindrical paper-based bottles. Importantly, the business model implies sales of both the material and the final process machinery to producers of branded materials. | A new final process equipment has been developed in collaboration with the Company C's partner to shape the improved paper material into cylindrical bottles. | Company C in a joint venture with the final process equipment producer |
