Paper to be presented at
the DRUID16 20th Anniversary Conference
Copenhagen, June 13-15, 2016

# Second wind for innovation: strategies and intended innovation outcomes in a mature process industry


**Ksenia Onufrey**
**LinkÃ¶ping University**
**Management and Engineering**
**ksenia.onufrey@liu.se**

**Anna Bergek**
**Linköping University**
**Department of Management and Engineering**
**anna.bergek@liu.se**



**Abstract**

This paper challenges the established view of mature process industries as non-innovative by analysing the innovation strategies and their intended outcomes in companies in the Swedish pulp and paper industry, characterized by both challenges and opportunities for renewal. The paper is based on an embedded case study of 6 companies and 11 innovation initiatives in the pulp and paper industry and uses a multi-dimensional framework to investigate, on the one hand, the innovation strategies that are predominant in the industry and, on the other hand, the degree of newness of the intended outcomes of these strategies taking into account multiple steps in the value chain and relationship between product and process dimensions. The examination of companies' innovation strategies identifies several common patterns, most notably the dominance of exploitation strategies and a focus on product innovation. The analysis of the intended outcomes shows that there are new-to-the-company as well as new-to-the-industry innovative initiatives and that the degree of product newness is largely unsynchronized with the degree of process newness. In contrast to much of the previous research we find that the relationship between exploitation/exploration strategies and the degree of newness of product and process innovations is not at all straightforward, i.e. both product and process exploitation strategies are associated with new-to-the-company and new-to-the-industry products and processes. Taken together these results show that mature process industries in fact hold considerable innovation potential and that exploitation strategies can lead to more than incremental innovation outcomes.



Jelcodes:O33,-

# Second wind for innovation: strategies and intended innovation outcomes in a mature process industry

## 1. Introduction

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 (Barnett and Clark, 1998; Kurkkio, 2011), 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).

From the point of view of innovation, however, mature industries tend to be seen as rather uninteresting, due to the general perception that they are unwilling or unable to engage in anything but incremental innovation. For example, the industry lifecycle literature concludes that when an industry reaches the specific phase, it is associated with stable specialization patterns, standardized products and highly efficient and capital-intensive production processes and can – at best – achieve incremental product and process innovation (Abernathy and Utterback, 1978). Similarly, the literature on technological discontinuities argues that once a dominant design has emerged in an industry, innovation is limited to incremental changes within the dominant design and the collective of incumbent companies are described as locked-in and unable or unwilling to respond to radical innovation (Christensen and Rosenbloom, 1995; Henderson and Clark, 1990; Tushman and Anderson, 1986). In some cases, established firms in mature industries are even described as adversaries of technological change; when a new technology appears, they are said to work hard to increase the performance of their established technologies and products (i.e. "the sailing ship effect" (cf. Gilfillan, 1935)) or to oppose the new technologies, for example through lobbying (cf. Anderson and Tushman, 1990; Peltoniemi, 2011). In addition, although the possibility of process innovation in the mature phase is acknowledged it tends to be seen as "a second-order innovative activity, a rather dull and unchallenging cousin of the more glamorous product innovation (…) involving little of the great events that characterize product innovation." (Reichstein and Salter, 2006, pp. 653).

We see two main weaknesses with this view on mature industries. First, most of the research on lifecycles and discontinuities has focused on industries that manufacture assembled products (i.e. aircrafts, automobiles, personal computers, or mobile phones) (Peltoniemi, 2011). However, many mature industries are in fact process industries, i.e. industries that produce non-assembled products such as minerals and metals, pulp and paper, food and beverages, chemicals and petrochemicals, pharmaceuticals and textiles (Kurkkio, 2011; Lager and Blanco, 2010). There is little reason to believe that they would experience the same type of patterns of technological change as assembly industries; indeed, literature focusing on process industries argues that process industries are different and that their R&D and innovation processes need to be studied further (Barnett and Clark, 1998; Kurkkio, 2011; Lager et al., 2013).

Second, industrial innovation patterns tend to be described as homogenous within each type of industry. Most notably, mature industries are assumed to be characterized by incremental product innovation aimed at making small performance improvements and process industries are supposed to concentrate on improving production efficiency through process innovation, whereas potential for radical product innovations is suggested to be limited (Abernathy and Utterback, 1978; Linton and Walsh, 2008). However, there is empirical evidence that contradicts this: studies have shown that architectural and radical product innovations do occur in some mature industries, e.g. gas turbines and heavy vehicles (Bergek et al., 2013; Bergek et al., 2008; Berggren et al., 2015), and that process industries are increasingly engaging in product innovation in order to move forward in the value chain, from commodities to functional products (Lager and Blanco, 2010).

A case at hand is the pulp and paper industry. On the one hand, this industry has been described as locked-in to its established technological regime and characterized by incremental innovation (Kivimaa and Kautto, 2010; Novotny and Laestadius, 2014). On the other hand, it seems to perform on average or better compared with other process industries in terms of new-to-the-firm and new-to-the-world product and process innovation rates (Reichstein and Salter, 2006). In addition, new challenges and opportunities have increased the focus on innovation in the pulp and paper industry. 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). In parallel, such opportunities are emerging as other industries (e.g. the chemical and pharmaceutical industries) and sectors (e.g. energy and transports) are turning their attention to various biomass compounds in their search for replacements for fossil fuels (Novotny and Laestadius, 2014).[1] Recent research also suggests that several transformation strategies are available for pulp and paper companies: 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, it remains unclear what innovation ambitions the companies have, what innovation strategies they pursue and whether the innovation initiatives they participate in actually reach beyond the level of incremental improvements.

Against this background, the purpose of the paper is to challenge the established view of mature process industries as non-innovative by analysing the innovation strategies and their intended outcomes in companies in the Swedish pulp and paper industry, characterized by both challenges and opportunities for renewal.

[1] This is also at the core of the so-called “bioeconomy” (Scarlat et al., 2015).

## 2. Innovation strategies in mature process industries: theoretical framework

### 2.1 A dominant perspective on innovation strategies and their intended outcomes

A company's innovation strategy can be defined as its intentions with regard to what products and processes it should develop and commercialise, what resources it should utilise to do this and how much it should invest in innovation in relation to other parts of its business and compared with its competitors (cf. Bergek et al., 2009; Bergek et al., 2008). Some particularly important dimensions are (a) to what extent the company makes use of its own, internal resources for the development versus resources from outside the company, (b) its relative focus on product vs. process innovation (c) its innovation leadership ambitions, i.e. whether it aims at developing products and processes that are new to the industry or only to the company (cf. Zahra and Das, 1993). While there are many ways to describe and categorize innovation strategies (Zahra and Das, 1993), we have chosen to use a rather simple exploration – exploitation framework, building on the seminal work of March (1991).

March (1991) 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; Li et al., 2008). One way to describe it is that exploitation and exploration have different "precursors": exploitation is based on an "exploitable set of resources, assets, or capabilities under the control of the firm", whereas exploration is based on "the wish to discover something new" (Rothaermel and Deeds, 2004p. 203). From an innovation point of view, the essence of the distinction seems to be whether a company focuses on using its existing resources when searching for new technological opportunities (exploitation) or pursues initiatives that require new resources (exploration) (Benner and Tushman, 2002). This can also be described in terms of knowledge distance: exploitation involves "local" search, i.e. search for knowledge that is familiar or related to what the company already knows, whereas exploitation involves more distant search, i.e. search for knowledge that is unfamiliar or unrelated to the company's existing knowledge base (Li et al., 2008) in terms of product-, process- or marketing-related knowledge (Kazanjian and Drazin, 1987).[2] Exploitation can thus be described as a strategy that deepens a company's core knowledge base in any of these dimensions, while exploration broadens it (Guan and Liu, 2016).

It has been suggested that exploitation and exploration strategies need to be balanced for a company to be successful over time (March, 1991). At the same time, they are difficult to reconcile since they compete for scarce organizational resources, are self-reinforcing (and therefore lock each other out) and require different mind sets and routines (Gupta et al., 2006). Some authors therefore argue that exploration and exploitation are sequential in that exploration provides potentially valuable resources that can be exploited at a later stage

[2] In this paper, we focus on distance in terms of technological similarity/relatedness rather than geographical or temporal distance (cf. Li et al., 2008).

(Hollen et al., 2013; Rothaermel and Deeds, 2004). This is also in line with the technology and industry life cycle models, in which discontinuous variety creation, experimentation and product innovation dominate the early development stage of a technology or industry, while the subsequent stage is dominated by cumulative and incremental product refinements and process innovation (Anderson and Tushman, 1990; Malerba and Orsenigo, 1997; Utterback and Abernathy, 1975). With this kind of thinking, mature industries are clearly associated with exploitation. Indeed, it has even been suggested that companies in mature industries are more likely to succeed if they emphasize exploitation over exploration (Lumpkin and Dess, 2001).

A dominant belief in the exploitation – exploration literature also seems to be that exploration is primarily related to science and product development in the early stages of a largely linear innovation model, whereas exploitation is related to manufacturing process development and marketing in later stages (cf. Lavie et al., 2010; Li et al., 2008). This is again in agreement with technology and industry lifecycle models that attribute product innovation focus to the early development stages and process innovation focus to later ones (Klepper, 1997; Utterback and Abernathy, 1975).

Further, much of the extant literature associates exploitation with incremental improvements in existing products and exploration with radical innovation through the development of new products (Li et al., 2008). For example, Rosenkopf and Nerkar (2001) argue that invention is always related to exploration, Bauer and Leker (2013) define exploration as a firm’s ability to develop and introduce/implement new-to-the-company products or production processes and Wang and Hsu (2014) associate exploration with the development of completely new products and exploitation with small adaptations to existing products.

In sum, the existing literature provides rather distinct views on the two innovation strategies. Exploration requires new resources; it is associated with a product innovation focus, occur at the early stages of the industry or technology life cycle and results in radical product innovations. In contrast, exploitation builds on existing resources, has a process innovation focus, occurs at the mature stages of the industry or technology life cycle and results in incremental improvements of existing products.

However, these assumptions have been criticized by innovation research in general and studies of innovation in process industries in particular. First, the association of mature industries with a process innovation focus and low degrees of innovativeness has been questioned by multiple examples of radical product innovations generated by established companies in mature industries (Bergek et al., 2013; Berggren et al., 2015). Second, it has been argued that specific characteristics of process industries, such as complicated value chains consisting of multiple stages of material transformation and a high degree of interdependency between products and processes, require a special approach to studying innovation patterns (Hirsch-Kreinsen, 2008; Lager et al., 2013; Reichstein and Salter, 2006).

Therefore, the following section considers in more detail the dominating assumptions with regard to exploration and exploration and their applicability to process industries.

## 2.2 Towards a more nuanced understanding of innovation strategies and their intended outcomes in process industries

### 2.2.1 Strategy type and innovation focus

According to the dominant view on innovation strategies, established companies in mature industries tend to choose an exploitation strategy and focus on process innovation. However, several unresolved arguments in the literature suggest that this assumption needs to be revisited.

First, it has been argued that established companies in mature industries do not entirely build on existing resources in their innovation activities. For example, some incumbent actors choose to pursue “creative accumulation” (Bergek et al., 2013), which builds on existing competences but also involves search for new ones, i.e. has at least some elements of exploration. Therefore, the possibility of some companies in a mature process industry having an exploration strategy should not be excluded.

Second, even if an exploitation strategy is preferred, according to some studies it can be combined with a product innovation focus. Examples from the general innovation literature include series of incremental product improvements or competence-enhancing discontinuous product innovations (Anderson and Tushman, 1990). In a similar way, the association of an exploration strategy with a product innovation focus can also be questioned. For example, dealing with competence-destroying process discontinuities (Anderson and Tushman, 1990) requires exploration strategy with process innovation focus. Moreover, it has been argued that process industries differ from assembly ones and therefore require a specific consideration in innovation studies (Kurkkio, 2011; Lager et al., 2013). For example, there is empirical evidence that exploration in process industries can take the form of process design (Barnett and Clark, 1998), while exploitation can be combined with a focus on product innovation, for example, through forward integration in the value chain (Ford et al., 2014; Lager and Blanco, 2010). These examples show that generally accepted interdependencies between strategy type and innovation focus are not necessarily valid in process industries.

Therefore, taking into account disagreements that exist in general innovation literature and responding to a call for a better understanding of innovation patterns in process industries, we formulate our first research question as follows:

RQ1: How can the innovation strategies of companies in the Swedish pulp and paper industry be described in terms of exploration vs exploitation and product vs process innovation focus?

### 2.2.2 Innovativeness of the intended outcomes of innovation strategies

As discussed above, the dominant view on innovation strategies associates exploration with radical product innovations and exploitation with incremental ones. This assumption is challenged both in the general innovation literature and in studies of process industries.

First, general innovation studies provide evidence that both exploration and exploitation can result in outcomes of different degrees of newness. Second, the complex value chains in process industries make it necessary to consider multiple innovation outcomes of innovative initiatives. Third, the close relationship between product and process innovation in process industries requires consideration of both these dimensions when analysing outcomes of any innovation initiative in this type of industry. Therefore, this section takes a closer look at these three arguments and their implications.

a) Exploration and exploitation vs radical and incremental innovations

In spite of the established association of exploration strategies with radical innovation outcomes and exploitation strategies with incremental ones, there are plenty of conceptual examples that indicate that both exploitation and exploration can result in innovation with different degrees of newness. Thus, Anderson and Tushman (1990) discussed competence enhancing product and process discontinuities and Machani et al (2015) suggested 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. Both these examples show that the outcomes of exploitation strategy do not need to be limited to incremental innovation. There is also very little actual empirical evidence that an exploratory innovation strategy always results in radical innovations and an exploitative strategy always in incremental innovations (Enkel and Gassmann, 2010; Li et al., 2008). There therefore seem to be good reasons to question the established view of the innovation outcomes of different innovation strategies.

b) Value chains in process industries

The process industry literature has emphasized that 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 because of differences in the respective value chains.

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 then (gradually) transformed in a number of continuous, interconnected process stages. The transformation process tends to result in deliveries of several “intermediate” products (Storm et al., 2013). Some of these can be sold directly to end users, but most function as inputs 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). The final outcome of what can be called the primary process is a finished product (cf. "interface product" in Lager and Blanco, 2010), which is then further developed in a post-processing development stage to one or more end products aimed at particular applications (cf. Barnett and Clark, 1996; Frishammar et al., 2012; Lager, 2002; Lager and Blanco, 2010; Storm et al., 2013).[3]

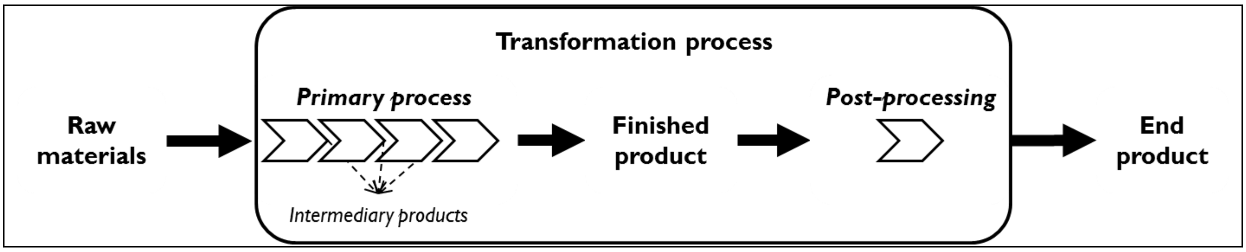


Figure 1: A simplified model of the material transformation process in process industries (adapted from Storm et al. (2013)).

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 end product but can also concern intermediate and finished products. Similarly, process innovation can involve technologies and equipment used either in the primary process or in the post-processing stage (or both). This implies that a study of innovation in process industries needs to take the entire transformation process into consideration, even if it involves several companies and is therefore the result of inter-organizational collaboration (Lager et al., 2013).

c) Relationship between product and process dimensions of innovation in process industries

There is an overall agreement in the literature that product and process innovations in the process industries are highly interrelated and complementary to each other (Barnett and Clark, 1996; Bauer and Leker, 2013; Lager, 2002; Lager et al., 2013). This close relationship implies that product and process development are often required in the same innovation projects and in order to manage innovation in process industries, both innovation dimensions have to be considered simultaneously (Kurkkio, 2011; Storm et al., 2013).

The influence from product on process innovation takes place as new product development often requires process innovation (Frishammar et al., 2012; Kurkkio, 2011). When it has been decided which application is in focus and what properties the end 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). The main development focus is therefore process design rather than product architecture design (as in assembly industries) (Barnett and Clark, 1998). Additionally, in

[3] In the case of the pulp and paper industry, raw materials can be forest products, which together with chemical ingredients are transformed to finished products such as pulp and end products such as different types of paper, packaging products etc.

some cases product innovations may open new opportunities for the production system (Storm et al., 2013).

The influence from process on product innovation is manifested not only in efficiency increases, time-to-market reduction and lower production costs (as in assembly industries) (Bauer and Leker, 2013), but process development also often results in changed features of final products (Frishammar et al., 2012; Linton and Walsh, 2008), which makes new product development dependent on process variables (Barnett and Clark, 1996). This dependency represents both constraints and opportunities for product innovation (Kurkkio, 2011). On the one hand, an established process is capital intensive and therefore inflexible and difficult to change. This implies that the extent to which an existing process can be modified limits the range of possible new product introductions, which is why many radically new products that are located outside this process window are either neglected or seriously challenged (Frishammar et al., 2012; Kurkkio, 2011). On the other hand, new processes can also open for new product concepts or applications that were previously impossible to implement (Kurkkio, 2011; Linton and Walsh, 2008).

However, it remains unclear from the literature whether the degrees of product and process innovations are interrelated too (i.e. if incremental process innovations are associated with incremental product innovations, while radical process innovations are associated with radical product innovations). Some literature suggests that even subtle process changes can change product properties in important ways from the perspective of the customers (Frishammar et al., 2012; Linton and Walsh, 2008).[4] On the contrary, other studies show that radical process innovations are associated with radical product innovations (Reichstein and Salter, 2006).

Such high interdependency between product and process dimensions of innovation significantly affects the intended outcomes of innovation strategies. Since product innovations are likely to affect production processes and vice versa, it is necessary to consider and compare the degree of change in both product and process in order to determine the extent to which a certain new technology is innovative.

To summarize all the three points discussed in this section, a general lack of conceptual clarity with regard to innovativeness of the intended outcomes of different innovation strategies calls for a continued empirical research in this subject. At the same time, the specific characteristics of innovation in process industries provide certain guidelines for studying innovation strategies and their intended outcomes in this type of industries. First, the characteristics of the value chain make it necessary to explicitly include different stages of material transformation process into the analysis. Second, interdependencies between product and process dimensions of innovation require a simultaneous consideration of both these dimensions. Against that background, the second research question of this study is the following:

[4] This also applies in the scaling up of the production process from pilot and demonstration scale to commercial scale (Linton and Walsh, 2008).

RQ2: How can the intended outcomes of the innovation strategies of companies in the Swedish pulp and paper industry be described in terms of the degree of newness, considering: (a) multiples steps in the value chain and (b) relationship between product and process dimensions?

# 3. Research design

## 3.1 Case selection

The paper is based on an embedded case study of innovation strategies of six companies in the Swedish pulp and paper industry and 11 examples of innovation initiatives, which reflect the intended innovation outcomes of these companies. Case selection was performed at three 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) Intermediate cases of six pulp and paper companies (in the rest of the paper referred to as Companies A-F) were selected based on the presence of innovation activities outside traditional business areas, as described in annual reports and other publicly available company information.
3) Innovation initiatives were selected based on overall company interviews. 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 3.3) were selected for further research and those with enough publicly available information were included in the study (11 projects).[5] Although this is probably a subset of all innovation initiatives in the pulp and paper industry, we expect that the initiatives that are made public are not the most innovative of the companies' projects, which implies that we are most likely not in danger of over-estimating the innovativeness of this industry.

## 3.2 Data sources

The study builds on (a) secondary data in the form of annual reports and other published company information and (b) primary data in the form of twenty semi-structured interviews with six key pulp and paper producers and three forest industry research institutes in Sweden (see Table 1). 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. Most of the interviews were conducted in person, the remaining ones conducted by telephone. All but two telephone interviews were recorded and all interviews were transcribed. In addition to the 20 main interviews, three

[5] We chose to include both completed and ongoing projects both because there are very few completed diversification projects in the industry so far and because these projects reflect the intended innovation outcomes of the studied companies in terms of high degrees of potential product and process newness.

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 in the data analysis process. More details on what topics the interviews covered and how they were used in the analysis are provided below, divided per research question.

**Table 1**. 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) |

## 3.3 Operationalisation, data collection and analysis

### 3.3.1 Innovation strategies

In order to understand and categorise companies' innovation strategies, 11 overall interviews were used as a starting point.[6] These aimed at understanding the company's approach to new business development and diversification to new product markets. The questions asked thus concerned strategies, challenges and success factors with regard to new product development initiatives outside companies' traditional business areas.

[6] Two of the overall interviews were conducted with Research Institutes. They contributed to a better understanding of the industrial context as well as the level of technological knowledge development in the industry, but were not a foundation of interpreting companies' strategies. Therefore, these interviews were not counted in the total of 11 overall interviews mentioned above.

In addition to the interviews, annual reports of involved companies from 2010 to 2014 were studied, focusing on statements concerning companies' overall innovation strategies. In particular, the sections devoted to R&D and innovation were most closely studied. Company B is a part of a multi-national and multi-business giant, which is why no detailed information could be found in the annual reports. Therefore, the strategy of Company B was assessed based on three interviews, information on the homepage as well as secondary data (reports and previous company studies).

The analysis was performed as follows. First, we gathered statements with regard to process and product development as well as companies' aimed-for position in the future. Then, the selected statements were characterised as either exploitative (e.g. formulated as build on, maintain connection with) or explorative (e.g. discussion of major changes, expansion, new business development). We also noted what kind of resources companies described as the basis for their innovation strategy. Focus on product versus process innovation was assessed based on whether innovation ambitions were described in terms of new product/material introduction vs new process development.

### 3.3.2 Intended innovation outcomes

The study of the companies' intended innovation outcomes is based primarily on seven project-specific interviews and three follow-up interviews. The questions asked in these interviews concerned background, development and key decisions in relation to particular innovation initiatives as well as what kind of changes (process and product) 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' homes pages, articles devoted to specific new materials and technologies and projects' dedicated websites were also included in the data collection.

The analysis of the initiatives focused on determining their newness, including both product and process dimensions. In the innovation literature, there are several established ways to describe the degree of newness (or radicalness) of product innovations (cf. Ehrnberg, 1995; Gatignon et al., 2002). However, these tend to be based on studies of assembled products and focus on, e.g., changes in product performance improvement rates or changes in product hierarchies and product architectures (Christensen and Rosenbloom, 1995; Clark, 1985; Henderson and Clark, 1990), which are not so relevant for non-assembled products, which cannot be decomposed into components and sub-systems and for which technological progress tends to concern several performance attributes at the same time (Barnett and Clark, 1996).

We therefore build further on frameworks found in the process industry literature, which distinguish between innovation initiatives that add new products to the product portfolio (often aimed at new markets) and initiatives that imply changes in existing products (cf. Bauer and Leker, 2013). Within the latter category, 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. Aylen, 2013; Lager, 2002; Reichstein and Salter, 2006).

In order to capture the complexities of the process industry value chain (as described above), we include two different product categories: the finished product and the end product. The finished product is the final product delivered by the focal company to the next step in the value chain and the end product the final outcome of the entire transformation process and is delivered to a group of end users. If the focal company is located far downstream, the finished product is also the end product.

In addition, we follow the recommendations in the Oslo manual (OECD/Eurostat, 2005) and distinguish between products that are new to the company and products that are new to "the world", which in a process industry value chain context can be conceptualized in two ways: new to the industry and new to the market in which the end product is used (c.f. Lager, 2002; Reichstein and Salter, 2006). The same sub-categories apply: the expected outcome of an innovation initiative ranges from unchanged products (where the product does not differ in any important way from products already available in the industry or market), over modified products (where the product has some kind of distinctive properties or performance attributes in comparison with products already available in the industry or market) to entirely new product for the industry or market.

With regard to process innovations, process design changes may 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, 1996, 1998; 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 requires changes to it (e.g. investments in new equipment) (Aylen, 2013; Bauer and Leker, 2013; Lager, 2002).[7] Three levels can be distinguished: innovation initiatives that leave the existing process design largely unchanged (i.e. that are in the "process window"), initiatives that require some modification or addition to the existing design and initiatives that require an entirely new process design (Lager, 2002).[8]

[7] This is similar to the hierarchy/architecture-based categorizations of product innovations.
[8] Aylen 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" (p. 272). (2013).

In order to capture the complexity of the process industry value chain, we consider two main parts of the transformation process: the primary process of a focal company (resulting in a specific finished product) and the company-internal or external post-processing (resulting in a specific end product).

As for product innovations, we also add the distinction between process innovations that are new to the company and those that are new to the world, which in this case is conceptualised as new to the industry, i.e. that are not already used by other companies in the industry (cf. Lager, 2002; Reichstein and Salter, 2006).

To sum up this discussion, our framework for analysing the newness of the intended outcomes of the companies' innovation initiatives considers product and process dimensions of innovation in different parts of the value chain (finished and end products (product dimension) and primary process and post-processing (process dimensions)) (see Table 2). Within each of the resulting dimensions, the framework considers different degrees of newness, ranging from unchanged, over modified to new for the company, industry or market.[9] This framework thus acknowledges that an innovation initiative can innovative in one dimension, but not in others and also has the potential to provide insight into the relationship between different dimensions (e.g. if high degrees of product newness is associated with high degrees of process newness).

**Table 2**: Combined framework for categorization of innovation initiatives according to product and process dimensions.

| | **Product dimensions** | | | | **Process dimensions** | | |
|---|---|---|---|---|---|---|---|
| **Part of value chain** | Finished product | | End product | | Primary process | | Post-processing |
| **Unit of analysis** | Company | Industry | Industry | Market | Company | Industry | Industry |
| **Degree of newness** | ▪ Unchanged<br>▪ Modified<br>▪ New product | | ▪ Unchanged<br>▪ Modified<br>▪ New product | | ▪ Unchanged<br>▪ Modified<br>▪ New process | | ▪ Unchanged<br>▪ Modified<br>▪ New process |

Categorization with respect to the three adopted degrees of newness was performed in accordance with descriptions presented in the theoretical section. One possible limitation of the chosen approach is that this categorization was to some extent based on subjective assessments of initiative's newness by companies' representatives. We tried to handle this limitation by triangulating data sources (i.e. asking several involved parties about the same project and studying secondary data sources) and by performing web search of innovation initiatives similar to the ones discussed in the interviews.

[9] We have omitted two possible aspects of innovativeness in our framework, i.e. end product innovativeness for the value chain and post-processing innovativeness for the value chain. Although both these aspects are theoretically relevant, for all initiatives included in our study where end product development and post-processing took place, a particular value chain was composed specifically in relation to this initiative, which implies that any end product or post-processing would be categorized as new.

Since many innovation initiatives in the pulp and paper industry are still ongoing (i.e. the results are not yet commercialized), the resulting products or processes might still be under development, which means that the future degree of newness might be higher (or lower) than our analysis at this point in time shows.

# 4. Empirical findings and analysis

## 4.1 Innovation strategies in the paper and pulp industry: strategy types and innovation focus

A first observation from the analysis of annual reports of the companies is that they all make largely the same interpretation of contemporary industry conditions and share a basic rationale for making strategic priorities. In particular, all manufacturers describe the same external threats (e.g. competition from Latin America) and pressures (e.g. the transition to a biobased economy) and seem to agree that their existing wood fibre competence is a central resource in handling these threats and pressures.

Furthermore, despite the fact that the pulp and paper industry is conservative and has had historical difficulties with developing and adopting new technologies (Novotny and Laestadius, 2014), the companies now seem to be in consensus that innovation and new product development are strategically important for the industry's further prosperity. Innovation is a keyword in strategic statements of all six companies and five of the six companies have established or considerably expanded separate divisions for new product development over the past decade.

At an overall level, it also seems as if their strategic priorities with respect to innovation are similar. They all describe existing businesses as important and articulate the ambition to prioritize and develop them further and while five of the six companies also highlight the importance of developing new business areas, they also agree that potential new businesses need to be based on and connected to existing ones. It would, thus, not be surprising to find a homogeneous set of innovation strategies characteristic of the archetypical mature industry, i.e. focused on exploitation of existing assets and a limited set of core competences.

However, a closer look at each company's strategy provides a more nuanced picture and reveals a variety of distinct strategic approaches, thus questioning the idea of a common strategic pattern. Table 3 contains a summary of the main characteristics of each company's innovation strategy. In line with the theoretical framework of the paper, we have categorized each company's innovation strategy as predominantly exploitative or explorative as well as predominantly product- or process-focused. We have also indicated whether the companies primarily aim at exploiting/exploring product- or process-related resources.

Several observations can be made from this summary. First, with respect to exploitation vs exploration, with the exception of Company F, all companies have chosen an exploitative innovation strategy, which corresponds well with the established view on innovation patterns in mature industries. However, whereas Companies B and E underline the value of existing processes for future strategic development (process exploitation), Companies A, C and D state that they want to make further use of their material and product-related knowledge (product exploitation). This indicates an absence of a single, common-to-all strategic pattern.

Second, all companies have product innovation focus, i.e. even those companies that exploit their processes discuss their innovation ambitions in terms of new product introductions rather than design and development of new processes. In addition to that, most of the companies (except from Company D) have a high ambition level with regard to the level of product newness, as they aim for new for the company and/or for the industry products, markets and businesses.

**Table 3.** Summary of the strategies of pulp and paper companies.

| Company | Overall competitive strategy | Innovation strategy | Exploitation vs exploration | Innovation focus |
|---|---|---|---|---|
| Company A | Provide wood-based commercializable products | Develop new products and markets based on wood fibers, but not diversify endlessly (keep focus).Focus on commercialization (market potential) rather than only innovation. | Product exploitation | Product (at least new to the company) |
| Company B | Biorefinery rather than pulp and paper company. | Take advantage of by-products of the dissolving cellulose production process, while taking into account market conditions. | Process exploitation | Product (improvement of existing products and new product introductions) |
| Company C | Compete within the strictly defined packaging segment of the market. | Lead and drive innovation within packaging materials, i.e. develop and introduce radically new products, materials, applications. | Product exploitation | Product (radically new products in packaging) |
| Company D | Vertically integrated business in packaging segment (from raw materials to functional end products) | Production oriented. For new product to be considered, ready-made product technology and short-term investment are required. | Product exploitation | Product (improvements of existing products) |
| Company E | Wood-based materials supplier in the B2B segment in accordance with existing resources | Identify and develop new business areas, i.e. completely new materials and products, while taking advantage of by-products of existing production processes and maintaining linkage with existing facilities. | Process exploitation | Product (search for a new business) |
| Company F | Renewable materials producer in accordance with market needs. Shift from product-driven to market-driven strategy. | Find fit between technology push and market pull. Expand to new industries and serve a more diverse range of applications (avoiding bulk products). | Product exploration | Product (at least new to the company) |

## 4.2 Intended innovation outcomes: degree of newness of current innovation initiatives

All companies are involved in innovation initiatives outside their traditional business product portfolio. In this section, 11 selected initiatives are considered in more detail.

As can be seen in Appendix A, some innovation initiatives unite several companies. In those cases, the new products are either based on already existing technologies (e.g. dissolving cellulose) or the companies supply existing or modified raw materials without actively participating in the innovation process (e.g. tall oil). However, most of the considered initiatives are company-specific, which can be explained by the fact that such projects as a rule require high managerial commitment, large investments, access to key expertise and partners and a general alignment with the company strategy.

As a basis for the following analysis, all the studied initiatives have been categorized using the typology developed earlier in this paper. Categorization results are summarized in Table 4.

**Table 4**. Categorization of new product development initiatives in the pulp and paper industry

| Innovation initiatives | Finished product for company | Finished product for industry | End product for industry | End product for market | Primary process for company | Primary process for industry | Post-processing for industry[a] |
|---|---|---|---|---|---|---|---|
| Composite Material | New | New | New | Modified | Modified | Modified | New |
| Insulation Material | Unchanged | Unchanged | New | Modified | Modified | Unassigned | 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 |

[a] N.A. = Not Applicable.

### 4.2.1 Main findings with regard to product innovation

As could be expected, the degree of product innovativeness decreases from company- to industry-level: the share of new products decreases, while the share of unchanged or modified products grows. That implies that a product that is new for a particular company (or a value chain) is not necessarily new for the whole industry (see Figure 2), i.e. the same products existed before in other companies or in other value chains. For example, three studied companies have recently added dissolving cellulose to their portfolios, and by doing that joined an already existing market. In order to start producing dissolving cellulose, the companies had to either adopt an existing production technology, or even reuse their own experience with this product (e.g. dissolving cellulose was produced at Company B several decennia ago, but was abandoned for environmental reasons and recently restarted after a long timeout). In a similar way, Company B joined the already existing lignosulfonates market, and Company F became the second company in the world to implement the Lignin Technology to produce high quality lignin. Therefore, we categorized these initiatives as new products to the respective companies, but existing products for the industry.

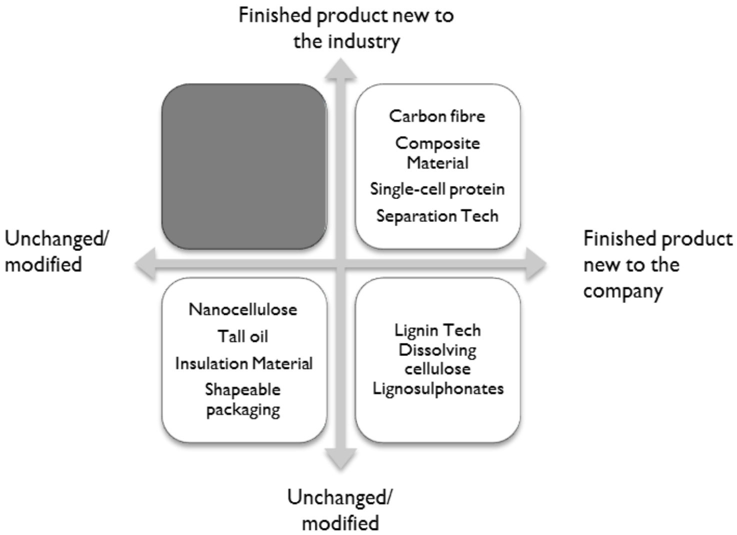


Figure 2. The degrees of new product innovativeness compared between company and industry levels and between value chain and industry levels.

Further, none of the products that are new for the industry (i.e. that have not been produced by any other pulp and paper company or value chain before) are new from the point of view of the end market (see Figure 3). For example, single-cell protein is a completely new product for the industry, but in the end market it only substitutes other sources of fish feed (the predominant fish meal alternative is clearly an unsustainable option and the need for an alternative solution is explicitly pronounced). Similarly, development of lignin-based carbon fibre is a potentially new product and a major technological achievement for the pulp and paper industry. However, carbon fibre already exists at the market, but it is currently produced from fossil-based raw materials.

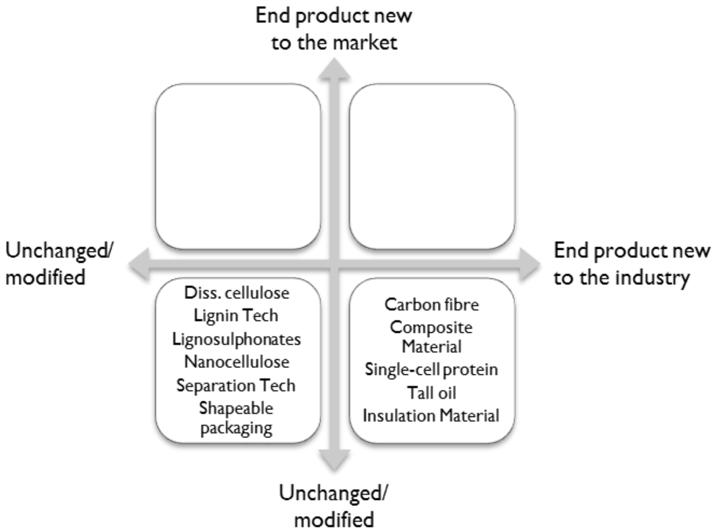


Figure 3. The degrees of new product innovativeness compared between industry and end market levels.[10]

Since no new-to-the world product introductions have been developed so far, pulp and paper industry can be perceived as non-innovative from the outside. However, the degree of innovativeness of the discussed above products for the pulp and paper industry shows that this perception is wrong. Development of these products 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, new product development also required entering new markets and developing new business models which is in itself a great challenge for a mature industry.

Moreover, as long as the pulp and paper industry delivers modified products to the end markets, the modification takes place in very important aspects. Sometimes new characteristics are added (e.g. Composite Material combines characteristics of paper and plastics), and in most cases wood fibre-based products provide alternative (and, importantly, more sustainable) raw materials for existing applications. Apart from single-cell protein and carbon fibre discussed above, Insulation Material aims at replacing polyurethane-based insulation foams and tall oil is used to produce a more sustainable transportation fuel.

### 4.2.2 Main findings with regard to process innovation

In general, the degree of primary process newness to the company was lower than the level of finished product newness in the studied initiatives, which is an indirect indication of a possibility to develop new products based on existing processes. However, when either the primary process or the post-processing was new it also tended to be new for the entire industry rather than only for a particular company or a value chain (see Figure 4).

[10] For Single-Cell Protein, a finished product (produced at a pulp and paper facility) can without further processing be used in the end market. No separate end product exists (i.e. finished and end products are the same), which is why Figure 3 shows the newness of the finished product to the industry in this case.

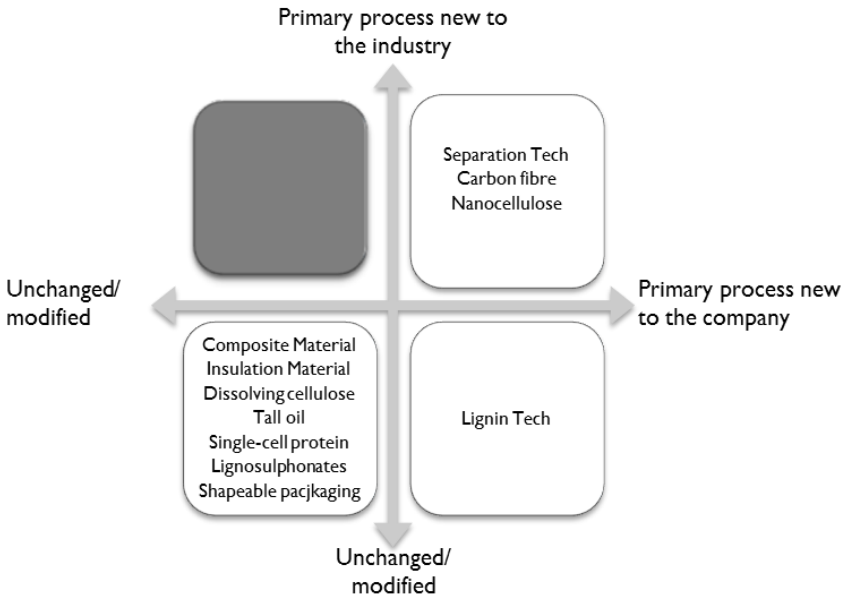


Figure 4. Degree of innovativeness of of studied projects with regard to primary process

Interestingly, post-processing was more often new than primary processes (5 out of 11 vs 3 out of 11 cases), i.e. while no or incremental process changes took place in the interviewed companies, new processes were still developed within the value chain. As a consequence, a similar pattern can be observed with regard to products: unchanged or modified finished products (those based on unchanged or modified primary processes) could be used as raw materials for development of new end products (those based on new post-processing). For example, several companies sell an unchanged by-product of their production process (i.e. tall oil) to a biofuel producer that transforms it in a specialized unique facility into a tall diesel and further into a second generation diesel fuel.

### 4.2.3 Main findings with regard to product-process innovation interconnections

With regard to interconnection between product and process innovation no single pattern could be seen in the results[11] (see Figure 5). In some cases, the levels of product and process innovativeness seemed to be synchronized. For example, the development of carbon fibre, a new product for the company (and the industry), requires the development of a new process. Similarly, adoption of the Lignin technology and the Separation technology is associated with new to the company products.

However, in many cases we can see no clear relationship between the degree of newness of products and processes. In some cases a completely new process was developed as an alternative way to produce an already existing product. For example, nanocellulose requires development of new processes, but is planned to be applied, at least initially, for already existing products. Similarly, Shapeable Packaging initiative has resulted in production of modified end products (i.e. cylindrical paper-based bottles), but it also has required the development of a new post-processing equipment. In other cases small process changes could

[11] Here, we are talking about interconnections between finished product and primary process and between end product and post-processing, respectively.

result in new product introductions. For example, dissolving cellulose became a new finished product in the portfolios of three interviewed companies, which required not more than modifications of already existing primary processes. Other similar examples are lignosulfonate, single-cell protein and composite material.

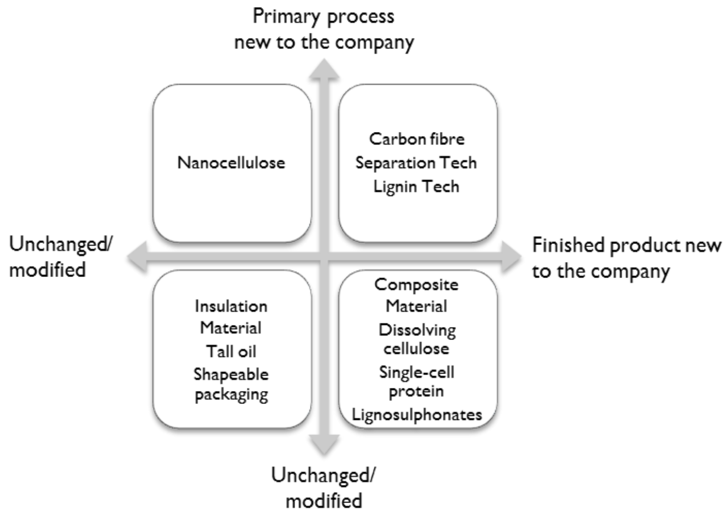


Figure 5. Interconnection between finished product and primary process innovativeness at the company level.

The above findings raise a question of whether product innovations are a result of or, to the contrary, enable process innovations. The industry lifecycle literature suggests that the development stage of incremental process improvements follows after the stage of radical new product introductions. However, among the studied projects several different logics can be seen:

- An ambition to introduce a certain product required process changes. For example, in order to produce Composite Material, new post-processing techniques had to be adopted.

- Process innovation enables product innovation. For example, Company F's investment in the Lignin Technology resulted directly in the possibility to deliver high quality lignin, a new product that the company sells. Further, ongoing development of lignin-based carbon fibre requires access to high-quality lignin. Although carbon fibre was not considered among the potential results when the technology was initially developed, the Lignin Technology provides access to lignin of required quality.

- Product innovation opens up for further new product introductions. For example, at Company B, the strategic decision to shift from paper pulp to dissolving cellulose not only led to small process changes, but also opened for further new product introductions (e.g. increased side streams led to the decision to reposition lignosulfonates from an energy source into a separate business area).

### 4.2.4 Initiatives from the point of view of exploration/exploitation strategies

This section integrates the findings made in relation to innovation strategies with the intended innovation outcomes. Figure 6 presents a combination of the strategy type (exploration vs exploitation) with the degree of product and process newness of the innovation initiatives pursued by each company. This creates a rather heterogeneous picture. The only company that has adopted a product exploration strategy (Company F) is involved in innovation initiatives aiming at introducing new to the company/industry product and process innovations, which is in line with expectations in previous literature. However, product exploitation can be associated with a low degree of both product and process newness (Company D), a high degree of both product and process newness (Company A) or a low degree of product newness and a high degree of process newness (Company C), which is less self-evident. Moreover, process exploitation seems to be associated both with product innovation (Company B) and a general low degree of innovation (Company E). All of that indicates that there is no straightforward relation between exploration/exploitation and product/process innovation outcomes.

Moreover, the innovation foci of the companies (see Table 3) correspond well with the intended outcomes of the innovation initiatives. Companies A, B and F all participate in innovation initiatives that match their intentions to introduce new to the company and industry products and Company D's absence of highly innovative initiatives is also in line with their strategy to focus on making improvements of its existing products. Company C' engagement in the development of a new process may seem to be in disagreement with their strategy, but considering that in process industries new products often require development of new processes (which is also supported by the evidence of new process development initiatives by Companies A and F), this can be interpreted as a first step in implementing its strategy. So far, only Company E has shown no evidence of implementing their innovation strategy, but in that case more time is needed before conclusions can be made as most of the innovation initiatives it is participating in are still ongoing and coming years may reveal new results.

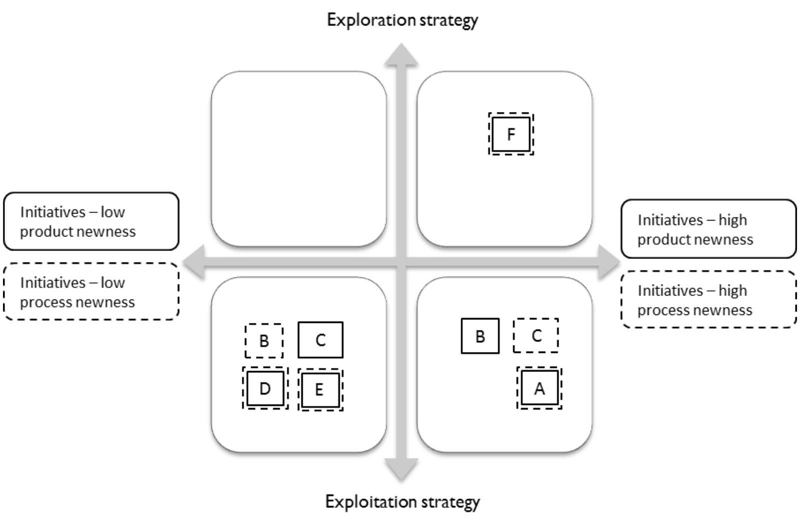


Figure 6: *Companies' innovation strategies vs* outcomes (Note: only the most innovative initiatives are considered in the figure.)

Taken together, the above observations imply that exploitation is not necessarily related to incremental process innovation (or lack of innovation) as evidenced by the examples of new products and processes delivered by companies adopting product and process exploitation strategies. That also adds to an overall conclusion that the relationship between innovation strategies and innovation outcomes is far more complex than what has been described in the previous literature.

## 5. Conclusions and further research

The purpose of this paper was to challenge the established view of mature process industries as non-innovative by analysing the innovation strategies and their intended outcomes in companies in the Swedish pulp and paper industry.

Our first research question was how the innovation strategies of companies in the Swedish paper and pulp industry could be described in terms of exploration vs. exploration and product vs. process innovation focus. Our analysis of the companies' strategies revealed that most of them apply an exploitation strategy, which is well in line with previous literature (cf. Lavie et al., 2010; Li et al., 2008). However, companies differ with regard to whether they aim primarily at exploiting product- or process-related resources, which confirms the suggestion by some diversification literature that existing resources related to product technology, process technology and marketing all have a potential to be exploited (cf. Kazanjian and Drazin, 1987). Moreover, in contrast to what could be expected of a process industry in the mature phase judging from the technology and industry life cycle literature (Klepper, 1997; Utterback and Abernathy, 1975), all companies discussed their innovation focus in terms of new products rather than new processes.

Our second research question concerned the intended outcomes of the innovation strategies and how they could be described in terms of the degree of newness, considering (a) multiple steps in the value chain and (b) relationships between product and process dimensions of innovation.

Overall, we observed a high heterogeneity of the reviewed initiatives. Regarding different steps in the value chain, the results showed that in different projects either finished or end products as well as either primary processes or post-processing could be new, while in only few projects both steps along the value chain were new. This confirmed that failing to include different steps of the value chain may lead to an underestimation of the overall innovativeness of an industry.

With respect to product dimensions, the main finding was a decreasing degree of initiative newness from company to industry and from industry to market. While the former can be explained by the fact that companies adopt technologies and solutions that already exist in the industry, the latter is rooted in the nature of the industry's products, i.e. materials; new-to-the-industry materials substitute existing ones delivered by other industries (e.g. plastics), which is why they are not considered as new in the market. However, since this study demonstrated innovation initiatives behind these materials and since market substitution in most of the cases is encouraged by societal needs (shift to the bio-based economy), we would still call for not underestimating the innovation potential of mature process industries (cf. Ford et al., 2014; Frishammar et al., 2012).

With regard to process dimensions, it was found that post-processing is more often new than primary processes, i.e. unchanged or modified finished products can be used to produce new end products. This raises a number of questions in relation to the complex nature of innovation in the process industry. For example, at what development step does innovation take place? Is focus on post-processing more beneficial than development of new raw materials? Further, one might also wonder who (i.e. what type of actors) are the innovators in the process industry. Is this role fulfilled by some individual actor (research institute, producer of raw materials or of end products, potential customer) or should we speak about open innovation dynamics as this role is distributed throughout the whole collaborative network (value chain)? These are examples of questions to be explored deeper in further research.

With regard to the relationship between product and process dimensions of innovation, only a part of the initiatives showed signs of synchronization between the levels of newness of products and processes. In some cases, a new process could be developed to deliver previously existing products or an existing/slightly modified process could serve to develop entirely new products. This shows that the interconnection can take different forms and further research is needed to understand under what conditions and why products versus processes enable further changes in a product-process system.

All the above results lead to an overall conclusion that new product development initiatives in the pulp and paper industry were highly heterogeneous. Various degrees of innovativeness of finished and end products as well as of primary processes and post-processing were found in different combinations across the studied projects. This is rather different from how the existing literature represents innovation activities in mature process industries, i.e. a homogenous pattern of small incremental improvements. Taken together with the previous finding that most of the companies had exploitation strategies, this showed that exploitation was not associated primarily with (incremental) process innovation, but also with new-to-the-company/industry product and process innovations. Therefore, the results of this study question the established view that associates exploitation primarily with incremental product improvements and process changes (cf. Bauer and Leker, 2013; Wang and Hsu, 2014).

To return to the purpose of this paper, the above conclusions show that considering both product and process dimensions of innovation strategies and outcomes throughout the whole value chain provides a more complete understanding of the innovativeness of mature process industries, as also suggested in some of the recent process industry literature (Storm et al, 2013). By adopting a multi-dimensional product-process framework, we have shown that the Swedish pulp and paper industry does not only pursue incremental innovation and process development, but also innovation initiatives characterized by high degrees of product and process newness, thereby challenging the established view of mature process industries as largely non-innovative.

## References


Abernathy, W.J., Utterback, J.M., 1978. Patterns of industrial innovation. Technology Review 80, 40-47.

Anderson, P., Tushman, M.L., 1990. Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change. Administrative Science Quarterly 35, 604-633.

Aylen, J., 2013. Stretch: how innovation continues once investment is made. R&D Management 43, 271-287.

Barnett, B.D., Clark, K.B., 1996. Technological newness: An empirical study in the process industries. Journal of Engineering and Technology Management 13, 263-282.

Barnett, B.D., Clark, K.B., 1998. Problem solving in product development: a model for the advanced materials industries. International Journal of Technology Management 15, 805-820.

Bauer, M., Leker, J., 2013. Exploration and exploitation in product and process innovation in the chemical industry. R&D Management 43, 196-212.

Benner, M.J., Tushman, M., 2002. Process Management and Technological Innovation: A Longitudinal Study of the Photography and Paint Industries. Administrative Science Quarterly 47, 676-707.

Bergek, A., Berggren, C., Magnusson, T., Hobday, M., 2013. Technological discontinuities and the challenge for incumbent firms: Destruction, disruption or creative accumulation? Research Policy 42, 1210-1224.

Bergek, A., Berggren, C., Tell, F., 2009. Do technology strategies matter? A comparison of two electrical engineering corporations, 1988-1998. Technology Analysis and Strategic Management 21, 445-470.

Bergek, A., Tell, F., Berggren, C., Watson, J., 2008. Technological capabilities and late shakeouts: industrial dynamics in the advanced gas turbine industry, 1987–2002. Industrial and Corporate Change 17, 335-392.

Berggren, C., Magnusson, T., Sushandoyo, D., 2015. Transition pathways revisited: Established firms as multi-level actors in the heavy vehicle industry. Research Policy 44, 1017-1028.

Castaldi, C., Sapio, S., 2006. The Properties of Sectoral Growth: Evidence from Four Large European Economies, Research Memorandum GD-88. Groningen Growth and Development Centre, University of Groningen, Groningen.

Christensen, C.M., Rosenbloom, R.S., 1995. Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. Research Policy 24, 233-257.

Clark, K.B., 1985. The interaction of design hierarchies and market concepts in technological evolution. Research Policy 14, 235-251.

Ehrnberg, E., 1995. On the definition and measurement of technological discontinuities. Technovation 15, 437-452.

Enkel, E., Gassmann, O., 2010. Creative imitation: exploring the case of cross-industry innovation. R&D Management 40, 256-270.

Ford, N., Trott, P., Simms, C., Hartmann, D., 2014. Case Analysis Of Innovation In The Packaging Industry Using The Cyclic Innovation Model. International Journal of Innovation Management 18, 1450033.

Frishammar, J., Lichtenthaler, U., Kurkkio, M., 2012. The front end in non-assembled product development: A multiple case study of mineral- and metal firms. Journal of Engineering and Technology Management 29, 468-488.
Gatignon, H., Tushman, M.L., Smith, W., Anderson, P., 2002. A Structural Approach to Assessing Innovation: Construct Development of Innovation Locus, Type, and Characteristics. Management Science 48, 1103-1122.
Gilfillan, S.C., 1935. Inventing the Ship. Follett Publishing Co, Chicago.
Guan, J., Liu, N., 2016. Exploitative and exploratory innovations in knowledge network and collaboration network: A patent analysis in the technological field of nano-energy. Research Policy 45, 97-112.
Gupta, A.K., Smith, K.G., Shalley, C.E., 2006. The Interplay between Exploration and Exploitation. The Academy of Management Journal 49, 693-706.
Henderson, R.M., Clark, K.B., 1990. Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. Administrative Science Quarterly 35, 9-30.
Hirsch-Kreinsen, H., 2008. “Low-Tech” Innovations. Industry and Innovation 15, 19-43.
Hollen, R.M.A., Van Den Bosch, F.A.J., Volberda, H.W., 2013. The Role of Management Innovation in Enabling Technological Process Innovation: An Inter-Organizational Perspective. European Management Review 10, 35-50.
Kazanjian, R.K., Drazin, R., 1987. Implementing Internal Diversification: Contingency Factors for Organization Design Choices. Academy of Management Review 12, 342-354.
Kivimaa, P., Kautto, P., 2010. Making or breaking environmental innovation?: Technological change and innovation markets in the pulp and paper industry. Management Research Review 33, 289-305.
Klepper, S., 1997. Industry Life Cycles. Industrial and Corporate Change 6, 145-181.
Kurkkio, M., 2011. Managing the fuzzy front-end: insights from process firms. European Journal of Innovation Management 14, 252-269.
Lager, T., 2002. A structural analysis of process development in process industry: A new classification system for strategic project selection and portfolio balancing. R&D Management 32, 87-95.
Lager, T., Blanco, S., 2010. The Commodity Battle: a product-market perspective on innovation resource allocation in the Process Industries. International Journal of Technology Intelligence and Planning 6, 128-150.
Lager, T., Blanco, S., Frishammar, J., 2013. Managing R&D and innovation in the process industries. R&D Management 43, 189-195.
Lavie, D., Stettner, U., Tushman, M.L., 2010. Exploration and Exploitation Within and Across Organizations. The Academy of Management Annals 4, 109-155.
Li, Y., Vanhaverbeke, W., Schoenmakers, W., 2008. Exploration and Exploitation in Innovation: Reframing the Interpretation. Creativity and Innovation Management 17, 107-126.
Linton, J.D., Walsh, S.T., 2008. A theory of innovation for process-based innovations such as nanotechnology. Technological Forecasting and Social Change 75, 583-594.
Lumpkin, G.T., Dess, G.G., 2001. Linking two dimensions of entrepreneurial orientation to firm performance: The moderating role of environment and industry life cycle. Journal of Business Venturing 16, 429-451.
Machani, M., Nourelfath, M., D’Amours, S., 2015. A scenario-based modelling approach to identify robust transformation strategies for pulp and paper companies. International Journal of Production Economics 168, 41-63.
Malerba, F., Orsenigo, L., 1997. Technological Regimes and Sectoral Patterns fo Innovative Activities. Industrial and Corporate Change 6, 83-117.

March, J.G., 1991. Exploration and Exploitation in Organizational Learning. Organization Science 2, 71-87.
Novotny, M., Laestadius, S., 2014. Beyond papermaking: technology and market shifts for wood-based biomass industries – management implications for large-scale industries. Technology Analysis & Strategic Management 26, 875-891.
OECD/Eurostat, 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data (3rd Ed.). OECD Publishing, Paris.
Peltoniemi, M., 2011. Reviewing industry life-cycle theory: Avenues for future research. International Journal of Management Reviews 13, 349-375.
Reichstein, T., Salter, A., 2006. Investigating the sources of process innovation among UK manufacturing firms. Industrial and Corporate Change 15, 653-682.
Rosenkopf, L., Nerkar, A., 2001. Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry. Strategic Management Journal 22, 287-306.
Rothaermel, F.T., Deeds, D.L., 2004. Exploration and exploitation alliances in biotechnology: a system of new product development. Strategic Management Journal 25, 201-221.
Scarlat, N., Dallemand, J.-F., Monforti-Ferrario, F., Nita, V., 2015. The role of biomass and bioenergy in a future bioeconomy: Policies and facts. Environmental Development 15, 3-34.
Storm, P., Lager, T., Samuelsson, P., 2013. Managing the manufacturing–R&D interface in the process industries. R&D Management 43, 252-270.
Tushman, M., Anderson, P., 1986. Technological Discontinuities and Organizational Environments. Administrative Science Quarterly 31, 439-465.
Utterback, J.M., Abernathy, W.J., 1975. A Dynamic Model of Process and Product Innovation. OMEGA, the Int. Jl of Mgmt Sci. 3, 639-656.
Wang, C.-H., Hsu, L.-C., 2014. Building exploration and exploitation in the high-tech industry: The role of relationship learning. Technological Forecasting and Social Change 81, 331-340.
Zahra, S.A., Das, S.R., 1993. Innovation strategy and financial performance in manufacturing companies: an empirical study. Production and Operations Management 2, 15-37.

**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. | Research project 2002 – 2007. Collaborative knowledge development project about fibers, including how they react to different conditions and treatments.<br>Applications/business development project (2007 – present). 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. | Development of new conversion (post-processing) 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 (2015 – present). | First step: Research Institute 2 + several P&P<br>Second step: Company A + Research Institute 2 and the converter company. |
| Insulation material | Wood-based thermal insulation foam. Advantage: low environmental impact in comparison with traditional materials (e.g. fossil oil-based polyurethane foam). | 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).<br>Evaluation of fire, water and microbe resistance (to ensure performance on par with existing insulation products). | 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. | Available already in the beginning of the 20th century (when it was not used because of environmental and economic reasons); new for individual companies.<br>New market for P&P companies; adaptation to new customers needed. | 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 |

| | | | | |
|---|---|---|---|---|
| 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 will require 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.<br>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.<br>New primary processes and post-processing technologies 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 mircofibrillated 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 end 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 post-processing, a specialized production facility was built that pioneered the renewable diesel process technology. | Company A,<br>Company D,<br>Company E |

| | | | | |
|---|---|---|---|---|
| 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 post-processing techniques, but can also be further processed in a specially developed post-processing 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.<br>Importantly, the business model implies sales of both the material and the post-processing machinery to producers of branded materials. | A new post-processing technology 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 post-processing equipment producer |