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An overview of factors for the adoption of energy efficient eco-innovation: The cases of the Dutch brewing and paper industry

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ABSTRACT

This study develops a framework of internal and external factors that influence the adoption of eco-innovation. We studied 80 adoption processes in the Dutch brewing industry and the Dutch paper industry and analysed the relative importance of different factors. We find that internal factors were more important than external factors. The analysis also shows differences between the industries. The financial advantage was important for both industries, but especially for the paper industry. For the brewing industry, ethical responsibility and stakeholders played a more important role in the adoption. The analysis also revealed differences for small and large firms. Ethical responsibility and stakeholders are relatively more often mentioned by small firms, whereas clear objectives and regulations were mentioned more by large firms.

Our study highlights that the adoption of eco-innovation is a complex process and the position in the supply chain as well as the size of a firm influence what is important in the adoption of eco-innovation.
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1. Introduction

Anthropogenic emissions of carbon dioxide (CO_2) and other greenhouse gases at or above current rates cause significant changes in the global climate system (IPCC, 2007). Organisations are not only a major contributor to the problems, but they are also crucial for the development of solutions (Wright and Nyberg, 2017). More and more organisations are being pressured by stakeholders (e.g. shareholders and customers) to decrease these detrimental practices (Chappin et al., 2015; Jeswani et al., 2008) and firms have started responding to these "greening" pressures (Wiengarten et al., 2013).

Eco-innovation plays an important role in the realm of these societal problems that we are facing. It has potential for organisations to achieve environmental improvements (Horbach et al., 2012; Jänicke, 2008). These improvements can be diverse. It can be about the reduction of pollution, such as the reduction of water pollution or air pollution, or the reduction of material use (Horbach et al., 2012). Being more energy efficient is also one of the options to reduce global carbon emissions (Cullen and Allwood, 2010). Energy efficient eco-innovations are important in the overall reduction of CO_2 emissions of businesses (Carrillo-Hermosilla et al., 2009; Ragsdell, 2000). Eco-innovation stimulates the progress towards the goal of sustainable development, through reducing impacts on the environment (CO_2 emissions) or achieving a more efficient and responsible use of natural resources (Carrillo-Hermosilla et al., 2009). Innovation does not always require in-house investments in R&D, because innovation can also be adopted from other organisations that have developed the innovation. This is especially relevant in the context of eco-innovation, as sustainability and eco-innovations are not part of the primary process of the organisation (Chappin, 2008). It is therefore important to understand the adoption of eco-innovation and gain insight into what motivates organisations to adopt eco-innovation.

Conditions inside (internal factors) as well as outside (external factors) the organisation can influence the organisation towards the adoption of innovation (Damanpour and Schneider, 2006). Different scholars have already identified several internal as well as external factors that influence the adoption of innovation and some also specifically for eco-innovation (Bossle, 2016). Some studies (e.g. Cogan, 2006; Epstein and Roy, 2001) focus mainly on internal factors that influence the adoption of eco-innovation, whereas others (Jamali et al., 2008; Bansal, 2005) focus mainly on external

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factors. There are also some studies in which internal as well as external factors are included (e.g. Chappin et al., 2009). But these studies often focus on one technology and/or one industry. Whereas it is likely that adoption processes will be different in different industries and for firms of different sizes. In sum, a broad set of different types of factors that influence the adoption of eco-innovation has been identified in the literature on sustainable businesses, eco-innovation and sustainability. A systematic overview of factors, however, is missing. Moreover, insights into how the influence of the factors is different for different industries and firm sizes is also lacking, and scholars so far hardly studied the relative importance of different factors. Therefore, the aim of this paper is to develop and test a framework of factors and analyse their relative importance as well as interactions among factors. Our research question is *What are the internal and external factors that influence the adoption of energy efficient eco-innovations in small and large firms in the Dutch brewing and the Dutch paper industry, and how do they influence the adoption*?

There are several reasons to select these industries. First, both industries are typical industries that are polluting and energy intensive. In the EU, the pulp and paper industry is the 4th largest industrial energy user (Moya and Pavel, 2018). The Dutch paper industry focusses on the production of packaging, but also graphical paper and hygienic paper (VNP, 2019). In 2018, the primary energy use of the Dutch paper industry was 24.968 TJ (RVO, 2019).

The consumption of food and beverages, such as beer, also has large environmental impacts (Notarnicola et al., 2017). The Dutch brewing industry focusses on the production of different types of beer (Nederlandse Brouwers, 2020). In 2018, the primary energy use of the Dutch brewing industry was 3.220 TJ (RVO, 2019). So, both industries are responsible for a relative high amount of CO_2 emissions, but firms in both industries have been active in adopting eco-innovations. Both industries participate in the covenant "Meerjarenafspraken energie-efficiëntie" (long term agreement energy efficiency) and realised the highest process efficiency improvements in the period 2009–2018: The paper industry 17.5% and the brewing industry 16.0% (RVO, 2019).

In addition, both industries are comparable in the sense that the number of organisations is limited. The Dutch industry association for the paper industry (Koninklijke Vereniging van Nederlandse Papier-en Kartonfabrieken) has 17 members (the whole sector) (VNP, 2019). Dutch breweries also united themselves: ten organisations that are responsible for over 95% of the production are part of the Vereniging Nederlandse Brouwers, whereas most other Dutch breweries have united themselves in CRAFT Independent Breweries Netherlands (Nederlandse Brouwers, 2020).

The final reason is that the industries have a different position in the supply chain as the paper industry supplies to other business, whereas the brewing industry is closer to the end-consumer. Such differences influence motivations for firms to conduct environmental friendly behavior (Chappin et al., 2015). Based on the reasons above studying these two industries is relevant to answer our research question.

The paper contributes to the literature by combining earlier insights into a framework that allows for a systematic comparison also across industries and by gaining an in-depth understanding of the relative importance of different factors and their interactions. The results are relevant for policy makers and stakeholders as the study will reveal in what way they can impact these adoption processes. A further reduction of CO_2 emissions in those industries can play a big role in Europe's transition to a low carbon industry. Insight into the specific factors that influence the adoption of eco-innovation can accelerate the reduction of energy consumption and emissions of those industries.

2. Theory

Adoption of innovation refers to the decision of an organisation to make use of a specific innovation (Rogers, 1995). In this study we focus on the adoption of eco-innovation. Eco-innovation can be broadly defined as: "… new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harms" (Beise and Rennings, 2005:6). More specifically, we study energy efficient eco-innovations.

Our focus is on the set of factors that influenced the decisions to adopt energy efficient eco-innovations. There is a large body of literature on the adoption of innovation and many different factors have been identified that influence adoption. These factors can be generally grouped in three groups: innovation characteristics, innovator characteristics and finally context characteristics (Wejnert, 2002). In his seminal work Rogers (1995) has identified five perceived attributes of innovation (innovation characteristics) which determine the rate of adoption: relative advantage, complexity, compatibility, trialability, and observability. The second group contains factors such as the network position (Frambach and Schillewaert, 2002; Wejnert, 2002), the availability of financial resources (Waarts et al., 2002), or the familiarity with the innovation (Wejnert, 2002). The context characteristics are diverse and encompass factors like competition (Waarts et al., 2002) or political conditions (Frambach and Schillewaert, 2002; Wejnert, 2002). These factors have been identified in the context of general innovation adoption, whereas our focus is on the adoption of eco-innovation. Although this body of literature is more recent, still a large number of factors has been mentioned (and some are similar to factors observed for general innovation). Since we want to understand what motivates organisation to adopt eco-innovation, factors that relate to the characteristics of the innovating firms as well as of the context are most relevant. We label these internal and external factors, respectively. Internal factors are conditions located inside the organisation, whereas external factors are conditions that are located in the organisational environment.

In order to develop the framework for this study we reviewed the literature in the context of sustainability, corporate sustainability and eco-innovation, and identified relevant internal and external factors. We mainly made use of snowballing to search the literature. Different scholars sometimes have different labels or names for factors that are similar content wise. We have clustered such factors into one factor and included the factor when it has been mentioned by at least four different scholars. In the end, this resulted in a framework of twelve factors, six internal and six external factors (see Table 1). The different factors including the effect on adoption will now be briefly explained.

2.1. Awareness of the high CO_2 emissions by constantly reporting (Int1)

Reporting or public disclosure describes a situation in which organisations make information publicly available by publishing annual or sustainability reports (Cogan, 2006; Lozano and Huisingh, 2011). A sustainability report provides the economic, environmental and social impacts (non-financial) resulting from the everyday activities of a company or organisation (Global Reporting Initiative, 2017; Hayatun et al., 2012). The report not only helps the organisation to measure, understand, and communicate their performance, but also to set goals and manage change more effectively (Global Reporting Initiative, 2017). Widespread sustainability reporting practices can help to create transparency and help markets to function more efficiently (Global Reporting Initiative, 2014). Therefore, by continuous reporting organisations are aware of and triggered by their high CO_2 emissions, which can

Table 1
Overview of the internal and external factors.

Code	Factor	Example literature where the factor (or a similar concept) has been identified
Internal factors		
Int1	Awareness of the high CO_2 emissions by constantly reporting	Bansal (2005); Calabrese et al. (2016); Cogan (2006); Gladwin and Kennelly (1995); Guthrie et al. (2008); Lozano and Huisingh (2011); Siew (2016); Stubs and Cocklin (2006)
Int2	High resources and production costs (financial advantage)	Azapagic (2003); Chappin et al. (2009); Cogan (2006); Daily and Huang (2001); Demirel and Kesidou (2011); DeSimone and Popoff (2000); Green et al. (1994); Hoffman (2007); Horbach (2008); Horbach et al., 2012; Quazi et al. (2001); Robbert et al. (2002)
Int3	Ethical (social) responsibility	Paine (1997); Sinclair (1993); Kaptein (2008); Treviño and Weaver (2003); Carroll (1991); Solomon (2004); Crane and Matten (2007); Victor and Cullen (1988); Riivari et al. (2012)
Int4	Management promoting CO_2 reduction initiatives	Cogan (2006); Crews (2010); Doppelt (2009); Epstein and Roy (2001); Hoffman (2007); Lueneburger and Goleman (2010); Reid and Miedzinski (2008); Stubs and Cocklin (2006)
Int5	Corporate culture encouraging initiatives from employees	Epstein et al. (2010); Griffiths and Petrick (2001); Hoffman (2007); Lozano (2015)
Int6	Clear objectives and plans in terms of CO_2 reductions	Cogan (2006); Epstein and Roy (2001); Lozano (2012); Stubs and Cocklin (2006)
External factors		
Ext1	Regulatory pressure on CO_2 emissions	Benn et al. (2006); Chappin et al. (2009); Cleff and Rennings (1999); Dewick and Miozzo (2002); Frondel et al. (2008); Green et al. (1994); Moon (2004); Reid and Miedzinski (2008); Smith and Crotty (2006)
Ext2	Threat of new regulation on CO_2 emissions	Chappin et al. (2009); Green et al. (1994); Horbach et al. (2012); Jaffe and Palmer (1997); Jamali et al. (2008); Triguero et al. (2013)
Ext3	Subsidies on CO_2 reductions	Chappin et al. (2009); Del Rio et al. (2010); Moon (2004); Jelsma (2003); Reid and Miedzinski (2008); Vollenbroek (2002)
Ext4	Stakeholders' expectations	Azapagic (2003); Doh et al. (2010); Benn et al. (2014); Dyllick and Hockerts (2002); Garvare and Johansson (2010); Lozano (2015); Quazi et al. (2001); Vermeulen and Witjes (2016)
Ext5	Business opportunities	Bansal (2005); Green et al. (1994); Grubb and Ulph (2002); Kesidou and Demirel (2012); Stern (2006)
Ext6	Competitive advantage	Carrillo-Hermosilla et al. (2009); Cogan (2006); Hart and Ahuja (1996); Lieberman and Montgomery (1988); Quazi et al. (2001); Markusson (2001)

result in the adoption of eco-innovations in order to reduce the CO_2 emissions of the organisation. Based on the literature we state that organisations can be motivated to adopt eco-innovations by the awareness of their (too) high CO_2 emissions.

2.2. Financial advantage (high resources and production costs) (Int2)

Research shows that energy efficiency and therefore CO_2 reductions can enhance the operating and financial performance of firms with high emission levels (Hart and Ahuja, 1996). Organisations seek opportunities to reduce costs, in order to increase their profitability (Cogan, 2006). A promising solution is increased energy efficiency as this can reduce costs (Galitsky and Worrell, 2008). The decision to spend money in order to reduce energy expenditures will depend on the expected savings and decision makers weigh the expected savings with several other issues (Kissock and Eger, 2008). Cost savings resulting from eco-innovations have been found to be an important motivation for the adoption of these eco-innovations (Chappin et al., 2009; Demirel and Kesidou, 2011; Green et al., 1994; Horbach, 2008; Horbach et al., 2012). For that reason, in order to reduce high production costs organisations are likely to decide to adopt eco-innovations that will result in a financial advantage.

2.3. Ethical (social) responsibility (Int3)

Ethical responsibility encourages organisations to operate in a sustainable way, which means that organisations are doing right, are admirable and have fair values and practices (Kaptein, 2008; Paine, 1997; Sinclair, 1993; Treviño and Weaver, 2003). More and more organisations recognise that ethics, along with the demand for innovativeness, are crucial for their sustainability performance (Carroll, 1991; Crane and Matten, 2007; Paine, 1997; Solomon, 2004). Research on ethics focus mainly on two constructs, namely ethical climate and ethical culture (Kaptein, 2008; Treviño and Weaver, 2003). Ethical climate focuses on the perceptions and aspects that determine what constitutes ethical conduct, whereas ethical culture is defined as those aspects that stimulate ethical conduct (Kaptein, 2008; Treviño and Weaver, 2003). Organisations with ethical (social) responsibility are aware of their risks and opportunities which will result in a more sustainable business. The organisations that are able to deal with risk are the most innovative in the long run (Riivari et al., 2012). Organisations that experience an urgency because of their ethical responsibility are likely to decide to adopt eco-innovations in order to do 'right'.

2.4. Management promoting CO_2 reduction initiatives (Int4)

Boards can change the course and strategy of an organisation, and therefore the board can stimulate an organisation towards a more sustainable business (Cogan, 2006; Weymes, 2002). High costs of innovation activity, the lack of an appropriate source of finance, and perceived excessive economic risks are seen as barriers for eco-innovation (Reid and Miedzinski, 2008). This lack of an appropriate source of finance can be resolved when top management shows their vision on energy savings and makes money and time available in order to adopt eco-innovation. Therefore, top management needs to articulate a clear company view on energy savings and greenhouse gas (GHG) control measures in order to stimulate the adoption of eco-innovation (Cogan, 2006; Crews, 2010; Doppelt, 2009; Epstein and Roy, 2001; Hoffman, 2007; Lueneburger and Goleman, 2010; Stubs and Cocklin, 2006). To sum up, top management can influence the adoption of eco-innovation by promoting CO_2 reductions and energy savings initiatives.

2.5. Organisational culture encourages initiatives from employees (Int5)

The adoption of eco-innovation requires an organisational culture that is open towards change and is aware of the impact of CO_2 emissions. Lozano (2015) shows that the organisational culture is

an important driver for corporate sustainability. Organisational or management support for idea development and tolerance for risk taking are found to have positive influence on the innovative performance of organisations (Alpkan et al., 2010). On the one hand top management (upper-level) can promote initiatives for the adoption of eco-innovation, on the other hand the adoption of eco-innovation can also be initiated by the lower-levels of the organisation. Employees can influence the adoption of eco-innovation when they discover new types of eco-innovations in the market and promote them internally. However this requires such an organisational culture in which initiatives from employees are being encouraged in order to stimulate the adoption of eco-innovations from a bottom-up perspective.

2.6. Clear objectives and plans in terms of CO_2 reductions (Int6)

Senior managers recognise the importance of formulating a strategy on corporate sustainability, e.g. CO_2 reductions strategies (Epstein and Roy, 2001). However managers often struggle with how to translate the strategy into action (Epstein and Roy, 2001; Stubs and Cocklin, 2006). In order to overcome this, organisations can develop and implement goals and action plans to manage climate risks and seize market opportunities (Cogan, 2006). For example, the board can formulate a corporate CO_2 reduction strategy that includes the company's values, commitment, and goals with respect to the reduction of CO_2 emissions (or energy consumption) (Epstein and Roy, 2001). Based on the literature we expect that organisations with clear objectives and plans will be motivated to adopt eco-innovations.

2.7. Regulatory pressure on CO_2 emissions (Ext1)

State, national, and international regulators are putting increasing pressure on companies with emissions from operations or products to invest for instance in emissions controls (Reid and Miedzinski, 2008). The literature shows that organisations will adopt sustainability practices when regulations require these practices (Chappin et al., 2009; Dewick and Miozzo, 2002; Smith and Crotty, 2006) and empirical firm-level studies suggest that stricter environmental regulations can boost eco-innovations (Cleff and Rennings, 1999; Frondel et al., 2008; Green et al., 1994). As a result, regulatory pressures have an influence on the adoption of eco-innovations.

2.8. Threat of new regulation on CO_2 emissions (Ext2)

Green et al. (1994) suggest that organisations implement eco-innovations in order to comply with anticipated regulation. Also Horbach et al. (2012) suggest that expected future regulation influence the adoption of eco-innovation. New and more stringent environmental regulations (e.g. regulation on CO_2 emissions) can provide an incentive for firms to innovate (Jaffe and Palmer, 1997). So, the threat of the implementation of new regulation on CO_2 emissions can motivate organisations to adopt eco-innovations (Chappin et al., 2009; Jaffe and Palmer, 1997; Jamali et al., 2008; Triguero et al., 2013).

2.9. Subsidies on CO_2 reductions (Ext3)

Higher price (and not lower quality or less reliability) of environmental products seems to be a major barrier for market penetration (Reid and Miedzinski, 2008). Investment subsidies might help when investment costs are high and form a barrier (Del Rio et al., 2010). In many countries subsidies are used as a positive impulse for businesses to adopt corporate sustainability practices, which includes the adoption of eco-innovations (Chappin et al., 2009; Jelsma, 2003; Moon, 2004; Vollenbroek, 2002).

2.10. Stakeholder's expectations (Ext4)

Stakeholders are actors that can affect or who are affected by a company (Freeman, 1984). Given that we focus here on external conditions, it concerns only the stakeholders external to the organisation. Since support of stakeholders can be crucial, the management of stakeholders is important. If stakeholders withdraw their support when expectations are not being met, this can negatively impact the company (Garvare and Johansson, 2010). According to literature, organisations adopt specific behaviours (e.g. CO_2 reductions) to obtain the support by critical stakeholders (Doh et al., 2010). Therefore, we expect that stakeholder's expectations can also be a motivation to adopt eco-innovation.

2.11. Business opportunities (Ext5)

Organisations enter new markets in order to get access to resources and new customers' segments (Bansal, 2005; Suchman, 1995). The adoption of an eco-innovation can also be linked to entering new markets or seeing new business opportunities, especially when it concerns the adoption of product innovation. Therefore we expect that when organisations perceive business opportunities resulting from an eco-innovation, they are more likely to adopt.

2.12. Competitive advantage (Ext6)

Competitors are also part of the organisational environment. In general, companies are aiming for a competitive advantage. Through pollution prevention companies can realise significant savings resulting in a cost advantage relative to competitors (Hart and Ahuja, 1996). Competitive advantage can be protected through competitive pre-emption (Lieberman and Montgomery, 1988). We therefore argue that organisations are reducing their CO_2 emissions in order to obtain and sustain their competitive advantage by adopting different types of eco-innovations.

These factors can have an independent effect on the adoption of energy efficient eco-innovation. Some factors, however, might be dependent on each other. Subsidies, for instance, can have a positive impact on the financial advantage. In order to account for this we also look at the interactions among these twelve factors.

3. Methods

3.1. Design and case selection

This study adopts a multiple and embedded case study design. Within multiple organisations (twenty) we studied multiple adoption processes of energy efficient eco-innovations (eighty in total). For both the paper industry as well as the brewing industry ten organisations were analysed. Since both industries consist of a few large players in The Netherlands, we have a quite good coverage of both industries. All selected and approached organisations in the paper industry were willing to cooperate in the research. For the brewing industry ten out of twelve organisations that were approached were willing to cooperate. Organisations in both industries were selected based on the following criteria: 1) the organisation is part of one of the two industries, 2) the organisations are known by the respective industry associations (Koninklijke VNP or Nederlandse Brouwers); and 3) the organisations have a production plant in The Netherlands. For each of the selected organisations four eco-innovations adopted during the period 2005

to 2017, were selected and analysed. The selection of the innovations was based on their reduction of CO_2 emissions. The four innovations with the highest reduction in CO_2 emissions were selected. This resulted in a total of eighty adoption processes.

3.2. Data collection and analysis

Data were collected by means of desk research and semi-structured interviews. The desk research consisted of the analysis of the annual and sustainability reports and the websites of the selected organisations. The reason for the analysis of the documents and website was twofold. First, it was used to identify important eco-innovation that were adopted. This information served as input for the semi-structured interviews. Second, the analysis was used to identify possible activities and factors that were described in the reports that influenced the adoption of the eco-innovations. This enabled us to see if factors were missing in our theoretical model. The desk research did not result in the addition of factors.

The semi-structured interviews were crucial in order to reconstruct the adoption processes. Before the actual interviews took place, the interview guide and scheme were tested. Pilot interviews were conducted with an intern (Deloitte), a consultant (Deloitte), a scientist (Utrecht University) and a small organisation (brewing industry).

The interviews were conducted with decision-makers that were responsible for the adoption of eco-innovations, in order to assess their opinion on which of the factors influenced the adoption of the eco-innovations. The interviews were conducted at the location of the interviewee and often after the interview a factory tour took place. The interviews lasted between 1 and 2 h.

In the first part of the interviews the four most important eco-innovations (in terms of CO_2 emission reduction) were identified. The second part of the interview focused on the identification of factors that influenced the adoption of each of the four innovation. Respondents were first asked to mention factors that influenced the specific adoption decisions. The factors that were mentioned, were very similar to the factors that we had already identified beforehand. There was only one factor, replacement investments, that was mentioned by some respondents of the paper industry in response to the open question. This factor was not part of our framework. Chappin et al. (2009) did identify this as a relevant reason for adoption of eco-innovation in that industry. It was however not prominent in many other papers, which explains why it is not part of our framework. Moreover, it is a slightly different type of reason compared to the factors identified in our framework. In order to be able to compare the results among the cases, we then provided them with our list of factors and asked them which of these influenced their decision and how.

In the final part interviewees were asked to rank the factors from most influential to least influential. The majority of the respondents were able to rank the different factors, but for two interviewees from the brewing industry and two from the paper industry it was not possible or relevant to distinguish between the four adoption processes. They explained that the same factors play a similar role in these different adoption processes.

In addition to these factors that motivated the adoptions, respondents were asked to list and explain possible barriers as well as measures that could stimulate the adoption.

The interviews were recorded in order to transcribe the interviews.[1] The transcripts enabled us to understand and support the different findings. The data for the different adoption processes were first entered in tables. The two industries have been entered and analysed separately. These tables enabled us to analyse the data: 1) the first analysis was a count of how often each factor was mentioned as an influence on the adoption process; 2) the second step in the analysis was to include the level of influence. Since the respondents were asked to also rank the factors, we were able to calculate the average rank of each factor; 3) the third step was to explore the interactions between different factors. For each industry we analysed how often each combination of two factors appeared. Given that we have 12 factors, 66 combinations were analysed. In order to be able to also compare industries we also ranked the combinations from most often observed to least often observed; 4) the fourth step was to look for patterns between large and small organisations (firms are considered to be large if the number of FTE is 150 or more); 5) the final step was a comparison of the two industries.

4. Results

4.1. Brewing industry

The 40 eco-innovations were adopted between 2005 and 2017. The highest number of adoptions are observed in the years 2006, 2010, and 2013 and the majority were adopted between 2012 and 2017.

All adopted eco-innovations were process innovations (no product innovations). Table 2 provides an overview of the different kind of innovations.

The brewing process consists of multiple steps. The main steps include: malting, mashing, boiling, fermentation, and maturation (Nederlandse Brouwers, 2020). When the beer is ready it can be transported. Fig. 1 shows where in the production process the innovation took place. The eight eco-innovations at the top were all innovations to make the brewery (building) more energy efficient, e.g. led-lighting. In the first phases of the production process sixteen eco-innovations were adopted, such as new machinery, pipes isolation, and frequency controllers for instance. The fermentation phase consist mainly of heat recovery innovations. The maturation phase consists of four eco-innovations such as innovations that optimized the cooling process. Finally, innovation in transportation consists for instance of a lean and green project.

Since we analysed 40 eco-innovations, the maximum number of times a factor can be mentioned is 40. None of the factors, however, appear to be important for all 40 adoption processes. On average 4.5 factors were mentioned per adoption decision. The minimum number of factors mentioned for an adoption process was two and the maximum number was eight. Most of the time (28 adoption processes) it was a mix of internal and external factors. For none of the adoption processes only external factors were mentioned. 12 adoption processes were only driven by internal factors.

Table 3 shows the importance of the different factors for the brewing industry. The factors that were mentioned most often for the brewing industry were (Int4) management promoting [29 times], (Int2) financial advantage [26 times], and (Int3) ethical responsibility [23 times]. One of the respondents of the brewing industry also specifically highlighted the factors management promoting and its financial advantage; *'Our CEO is a strong promoter of the adoption of energy efficient innovations and has also set clear goals for our management. The focus is on energy savings, however a sustainable business case is needed' (Organisation B5).*

Overall, internal factors were mentioned more often by the respondents as having an influence on the adoption of eco-innovations in comparison to external factors. The factors that were only important in a few cases were all external factors: (Ext2)

[1] In line with agreements made with respondents, recordings have been deleted when transcription were completed.

Table 2
Overview of the innovations in the brewing industry.

Kind of innovation	Description	# of times observed
Heat recovery	Measures (at different places) in the processes to recover heat.	12
Fuel/Energy	The production and use of renewable energy and fuels, for example biogas and solar panels.	6
Isolation	Measures to isolate the building and/or parts of the production process (such as pipes).	4
Steam boiler	Measures to improve/change the steam boiler.	4
Cooling systems	Measures to improve cooling systems.	3
Heat exchanger	The application of heat exchangers.	2
Lighting	Efficient and better lighting used within the production area. For instance LED.	2
Heat pump	The application of a heat pump to heat the building.	1
Process optimisation	Changes in the production processes that result in efficiency. In this case optimisation of the temperature of the oxygen burner.	1
Lean & green	A lean & green project to reduce CO2 emission during transport.	1
Washing machine	Optimisation of the washing machine.	1
Steam generator	The application of a new steam generator.	1
Storage	Increase storage temperature (less cooling is needed and therefore less energy).	1
Frequency converters	The use of frequency converters to monitor the production process, which stimulates an efficient process.	1

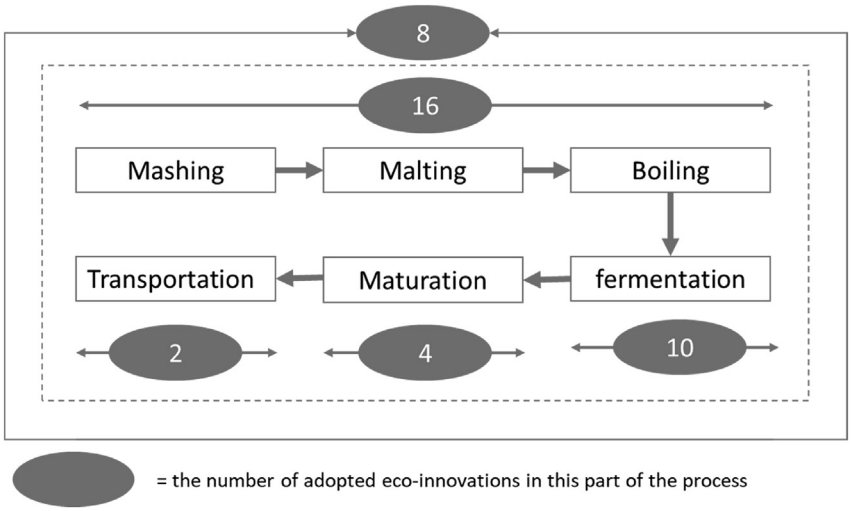

Fig. 1. Studied eco-innovations in the brewing industry (source used for steps production process: Nederlandse Brouwers, 2020)

Table 3
The number of times a factors is mentioned and the average ranking for the brewing industry.

Factors		Brewing industry	
		B1. Times mentioned	B2. Average ranking
Int1	Awareness	14	2.6
Int2	Financial advantage	26	2
Int3	Ethical responsibility	23	2.5
Int4	Management promoting	29	1.9
Int5	Corporate culture	13	2.8
Int6	Clear objectives and plans	14	2.1
Ext1	Regulatory pressure	15	3.7
Ext2	Threat of new regulation	10	5.3
Ext3	Subsidies	3	3.3
Ext4	Stakeholders	14	4.2
Ext5	Business opportunities	8	4.8
Ext6	Competitive advantage	11	5.4

threat of new regulation [10], (Ext5) business opportunities [8], and (Ext3) subsidies [3].

We see very similar patterns if we look at the average ranking. Since the factors were ranked from most influential to least influential, the lower the number, the higher the influence. Also here we see that the internal factors are more influential compared to external factors. Factor (Int4) management promoting is not only mentioned most often, it is also the most influential based on the ranking. We also observe some factors that are not mentioned often, but that are relatively important. For instance subsidies is only mentioned three times, but the average ranking is 3.3. On the other hand competitive advantage is mentioned more often (11 times), but it is least influential in terms of ranking (5.4 for the average ranking).

We also looked at the interaction between factors. In the brewing industry we observed 363 combinations of two factors in

total. The combination that is observed most often in the brewing industry is (Int2) financial advantage and (Int4) management promoting. These factors co-occur in 18 adoption processes. These two factors also co-occur often with (Int3) ethical responsibility [14 times each]. These findings are not surprising given that these three internal factors also occurred most often individually. But if we look further at the top-ten combinations (see also Table 4) we do see other combinations occurring frequently, also with external factors. (Int3) Ethical responsibility is mentioned in adoption processes in combination with (Ext4) stakeholders [12 times], (Int 1) awareness [10 times], and (Ext6) competitive advantage [10 times]. Whereas management promoting is mentioned in combination with (Ext1) regulatory pressure [11 times], (Int5) corporate culture [10 times] and (Int6) clear objectives and plans [10 times]. This latter factor (Int 6) clear objectives and plans is also relatively often mentioned in combination with (Ext1) regulatory pressure [10 times]. Despite the fact that (Int2) financial advantage is the second most observed factor in the brewing industry, it is, besides the two combinations mentioned above, not observed further in the top 10 combinations.

We also observed that certain factors are always mentioned in combination with another factor. For the brewing industry it appeared that whenever the respondent reported on the relevance of (ext5) business opportunities, they also mentioned (Int3) ethical responsibility and (Int4) Management promoting as being important for the adoption.

Seven combinations were not observed. Many of these concerned either (Ext3) subsidies or (Ext5) business opportunities. These two factors were also hardly observed in the adoption processes.

4.1.1. Comparing small and large breweries

Fig. 2 shows the differences between large and small firms in the factors they mention. This figure is corrected for the number of firms in the two groups (4 large breweries with 16 adoption decisions and 6 small breweries with 24 adoption decisions). The larger the number, the more the factor was mentioned by small or large firms. The maximum possible number is 1, indicating that this factor would be mentioned in all adoption processes of the small or large firms.

We do observe differences if we compare the two groups. For small firms, (Int1) awareness, (Int 3) ethical responsibility, (Ext2) threat of new regulation, (Ext4) stakeholders, (Ext5) business opportunities and (Ext6) competitive advantage are more often mentioned compared to large breweries. For the large firms (Int4) management promoting, (Int6) clear objectives and goals and (Ext1) regulatory pressure played more often a role in their decisions. As one of the respondents of a large brewery highlighted; *'Pressure from legislation always helps, (we)*[2] *need to reduce energy use with 2% and we do not do much with subsidies'* Organisation B1).

For the adoption processes of small firms in the brewing industry factors dealing with responsibilities, stakeholders and competitors/opportunities were mentioned as being relatively more often important, whereas for the large breweries, the culture, objectives and regulatory pressure were relatively more often important.

4.1.2. Barriers in the brewing industry

In addition to the factors that positively influenced the adoption processes, we asked the respondents to indicate if there were certain barriers that hampered the adoption of energy efficient eco-innovation. Half of the respondents in the brewing industry mentioned the high investments or limited availability of money as an important barrier. Related to this is the pay-back time that is experienced as a barrier (mentioned 3 times). The pay-back time breweries apply is not sufficient for certain eco-innovations. And the pay-back time government demands in policy is 5 year, which is too long according to breweries (1 time). Legislation in general is mentioned multiple times as hindering eco-innovation (3 times). Also the fact that the firm does not experience the need to be sustainable is mentioned as a barrier (1 time). Barriers related to the firms that were mentioned are: limited knowledge (2 times) and limited capability (1 time); the company being too small in the sense that the production is not 24/7 (2 times); and that sustainability is not part of the culture (KPIs) (1 time). Finally, several

Table 4
The top-ten of combinations of factors in the brewing industry.

Brewing industry	
Combination of factors	Number of times observed
Int 2 Financial advantage ↔ Int 4 Management promoting	18
Int 2 Financial advantage ↔ Int 3 Ethical responsibility	14
Int 3 Ethical responsibility ↔ Int 4 Management promoting	14
Int 3 Ethical responsibility ↔ Ext 4 Stakeholders	12
Int 4 Management promoting↔ Ext 1 Regulatory pressure	11
Int 1 Awareness ↔ Int 3 Ethical responsibility	10
Int 3 Ethical responsibility ↔ Ext 6 Competitive advantage	10
Int 4 Management promoting ↔ Int 5 Corporate culture	10
Int 4 Management promoting ↔ Int 6 Clear objectives and plans	10
Int 6 Clear objectives and plans ↔ Ext 1 Regulatory pressure	10

[2] *text between (…) added.*

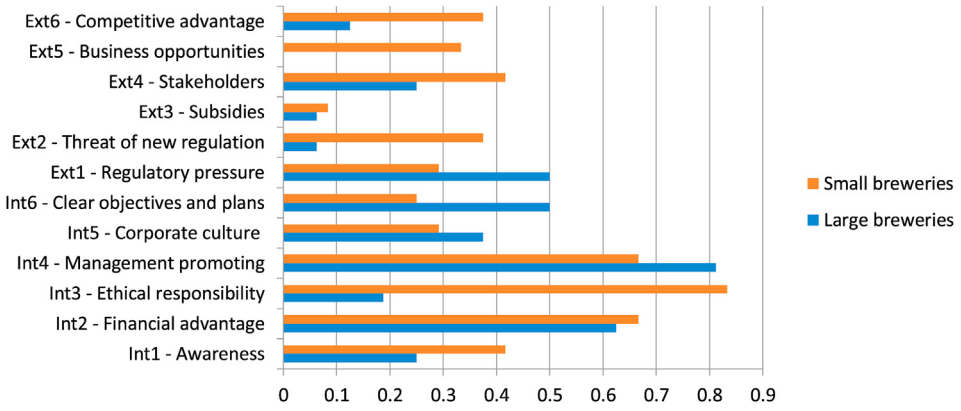

Fig. 2. Comparison large and small breweries.

barriers related to the eco-innovations were mentioned: the uncertainty inherent to innovation (2 times), the dynamic technological change (1 time), the complexity related to the innovation of changing the complete process (1 time). With the exception of the barriers that relate to eco-innovation, all barriers can be linked to the factors that motivate companies to adopt eco-innovation.

4.2. Paper and board industry

The 40 eco-innovations were adopted between 2005 and 2017. The highest number of adoptions are observed in the years 2010, 2012, and 2013 and the majority of the eco-innovations was adopted between 2011 and 2016.

Most of the adopted eco-innovations (34 out of 40) were process innovations. The adopted product innovations were for example, new types of paper or lower weight of the paper.

Table 5 provides an overview of the different kind of innovations.

The production process consists of multiple steps. The main sections are: forming press drying and calendaring section (Chu et al., 2011). Fig. 3 shows where in the production process the innovations took place. The four eco-innovations at the top were all innovations to make the production plant (building) more energy efficient, e.g. led-lighting. In the first phase of the production process, the forming section, eight eco-innovations were adopted, which concerned for instance a new type of filler and optimizations in the pulper line. The second phase (the press section) consist mainly of eco-innovation that optimize the press (7 adoption decisions). In phase three, the drying section, most eco-innovations were adopted (19 adoption decisions). The eco-innovations concerns the adoption of new drying systems and condensers, for instance. Finally, the last phase (the calendaring section) entails the adoption of two eco-innovations that for instance deal with the elimination of the pulp from the production line.

Also for this industry none of the factors was important in all 40 adoption processes. On average 4.6 factors were mentioned per adoption decision. The minimum number of factors mentioned was two and the maximum number was eight. Most of the time (28 adoption processes) it was a mix of internal and external factors. For none of the adoption processes only external factors were mentioned. 12 adoption processes were only driven by internal factors.

The importance of the different factors can be found in Table 6. The factors that were mentioned most often were (Int2) financial advantage [35], (Int4) management promoting [31] and (Int6) clear objectives and plans [27]. One of the respondents mentioned *'I think the most important factor was the financial incentive. When talking about energy, it is one of the highest costs for a pulp- and paper factory. It's about 10% of our costs, when you can reduce the energy consumption with 2% it will have a big impact on the total costs.'*

Table 5
Overview of the innovations in the paper industry.

Kind of innovation	Description	# of times observed
Heat recovery	Measures (at different places) in the processes to recover heat.	8
Product innovation	The development of new products, changes (less paper) in the design of existing products, and the use of new materials or components in the manufacturing of existing products.	6
Vacuum	Measures to improve/change the vacuum system to be more efficient and effective, including better protection.	4
Other heat related measures	Measures to improve/change the use of heat in the process such as new or improved drying systems.	4
Process efficiency	Changes in the production processes that result in efficiency. An example is process control.	3
Pulping system	Measures to change or improve the pulping system.	3
Frequency regulators	Improved/new frequency regulators to monitor the production process, which stimulates an efficient process.	2
Isolation	Measures to isolate the building and/or parts of the production process.	2
Shoe press	The application of a shoe press.	1
Heat pump	The application of a heat pump to convert hot air into steam.	1
Pumping	Efficient use of the pumping systems, which requires less energy and maintenance.	1
Biogas	The production of biogas which is used in the factory.	1
Lighting (LED)	Efficient and better lighting used within the production area.	1
Heat-exchanger	The application of a heat exchanger.	1
Transformer	The application of a new transformer.	1
Gasifier	The application of a gasifier.	1

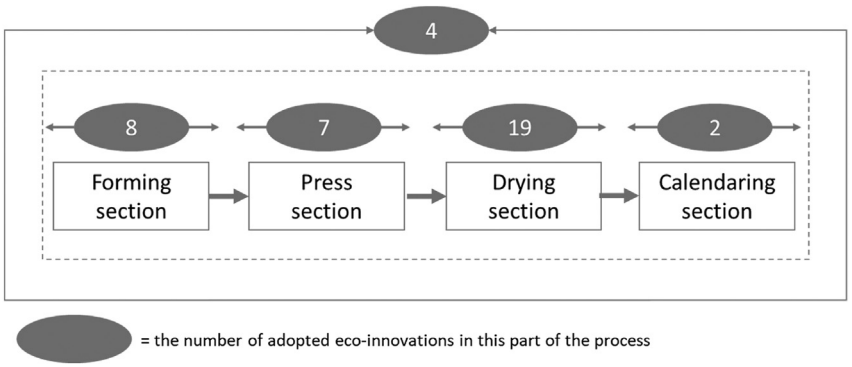

Fig. 3. Studied innovations in the paper factories (source used for steps production process: Chu et al., 2011).

Table 6
The number of times a factor is mentioned and the average ranking for the paper industry.

Factors		Paper industry	
		P1. Times mentioned	P2. Average ranking
Int1	Awareness	10	3.7
Int2	Financial advantage	35	1.6
Int3	Ethical responsibility	16	4
Int4	Management promoting	31	3.4
Int5	Corporate culture	14	2.8
Int6	Clear objectives and plans	27	3.1
Ext1	Regulatory pressure	16	3.3
Ext2	Threat of new regulation	3	5.3
Ext3	Subsidies	8	4.6
Ext4	Stakeholders	5	3.8
Ext5	Business opportunities	5	1.2
Ext6	Competitive advantage	13	3.5

(Organisation P8). Overall internal factors were mentioned more often by the respondents as having an influence on the adoption of eco-innovations in comparison to the external factors.

The most important external factors were (Ext1) regulatory pressure [16] and (Ext6) competitive advantage [13]. The factors that were only important in few adoption decisions were in addition to (Int1) Awareness [10] mostly external factors: (Ext3) subsidies [8], (Ext5) business opportunities [5], (Ext4) stakeholders [5], and (Ext2) threat of new regulation [3].

Looking at the average ranking of the factors, a slightly different pattern is observed. A lower number indicates a higher importance (most influential is ranked 1). Also here we see that (Int2) financial advantage, which was mentioned most often, was also second most influential. But the lowest ranking (highest importance) is (Ext5) business opportunities. It was only mentioned 5 times, but it seems that if they mentioned it, it is also relatively important. This might be explained by the fact that four times that it was mentioned it concerned product innovation, for which the business opportunities are in general more relevant compared to process innovation.

Also for (Int5) corporate culture we see that it was not necessarily mentioned very often (14 times), but compared to the other factors it had a rather high average ranking of 2.8.

In the paper industry we observed 375 combinations of two factors in total. The combination that is observed most often in the paper industry is (Int2) financial advantage and (Int4) management promoting. These factors co-occur in 29 adoption processes. These two factors also co-occur often with (Int6) clear objectives and plans [23 times each], (Int3) ethical responsibility [16 times each] and corporate culture [12 and 14 times, respectively].

The only external factor that is observed in the top-ten combinations (actually top-eleven as we have 2 combinations that occur equally frequent on place 10 (see also Table 7)) is (Ext1) regulatory pressure. This is mentioned often in combination with (Int6) clear objectives and plans [16 times], (Int4) management promoting [14 times], (Int2) financial advantage [13 times]. Finally the combination of (Int3) ethical responsibility with (Int6) clear objectives and plans is observed relatively frequent [12 times].

For the paper industry it appeared that whenever the respondent reported on the relevance of (Int3) ethical responsibility, they also mentioned (Int2) financial advantage and (Int4) management promoting as being important for the adoption. When they mentioned (Int 5) corporate culture they also always mentioned (Int4) Management promoting. (Ext 1) Regulatory pressure was always mentioned in combination with (Int6) clear objectives and plans. (Ext 2) Threat of new regulation was always mentioned in combination with (Int2) financial advantage, (Int4) management promoting, and (Int6) clear objectives and plans. Whenever (Ext 3) subsidies was mentioned the respondent also mentioned (Int2) financial advantage. Finally, with respect to (Ext 6) competitive advantage we observed that it was always mentioned in combination with (Ext 4) stakeholders and (Ext 5) business opportunities.

Nine combinations were not observed. These combinations concerned at least one of the following: (Ext2) threat of regulation, (Ext3) subsidies, (Ext4) stakeholders or (Ext5) business opportunities. These four external factors were also hardly observed in the adoption processes.

4.2.1. Comparing small and large paper factories

Fig. 4 shows the differences between large and small factories with regards to the factors they mention. This is corrected for the number of firms in the two groups (7 large paper factories with 28 adoption decisions and 3 small paper factories with 12 adoption

Table 7
The top-ten of combinations of factors in the paper industry (eleven combinations are listed here as two combinations share place ten).

Paper industry	
Combination of factors	Number of times observed
Int 2 Financial advantage ↔ Int 4 Management promoting	29
Int 2 Financial advantage ↔ Int 6 Clear objectives and plans	23
Int 4 Management promoting ↔ Int 6 Clear objectives and plans	23
Int 2 Financial advantage ↔ Int 3 Ethical responsibility	16
Int 3 Ethical responsibility ↔ Int 4 Management promoting	16
Int 6 Clear objectives and plans ↔ Ext 1 Regulatory pressure	16
Int 4 Management promoting ↔ Int 5 Corporate culture	14
Int 4 Management promoting ↔ Ext 1 Regulatory pressure	14
Int 2 Financial advantage ↔ Ext 1 Regulatory pressure	13
Int 2 Financial advantage ↔ Int 5 Corporate culture	12
Int 3 Ethical responsibility ↔ Int 6 Clear objectives and plans	12

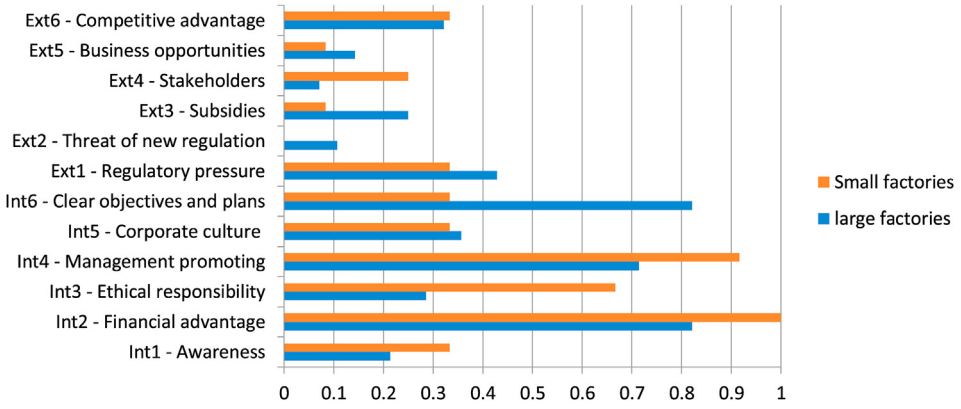

Fig. 4. Comparison large and small paper factories.

decisions).

We do observe differences if we compare the two groups. For small factories, (Int1) awareness, (Int2) financial advantage, (Int3) ethical responsibility, (Int4) management promoting, and (Ext4) stakeholders are more often mentioned compared to large factories. Since the score for (Int2) financial advantage is 1 for all adoption processes of small factories this factor was relevant in all processes. For the large factories (Int6) clear objectives and goals, (Ext1) regulatory pressure, (Ext2) threat of new regulation and (Ext3) subsidies played more often a role in their decisions. So, for the adoption processes of small firms the internal factors were relatively more often important, whereas the external factors were relatively mentioned more often by large firms.

4.2.2. Barriers in the paper industry

Similar to the brewing industry half of the respondents of the paper industry mentioned the high investments or limited availability of money as an important barrier (5 times). The pay-back time is also here seen as a barrier (4 times). And also here the fact that the pay-back government demands in policy is 5 year, is mentioned as a barrier (1 time).

Also hindering legislation is mentioned (2 times) as well as inconsistent policy that changes too often and too quickly (1 time). The available subsidies are mentioned as a barrier by two larger firms as they are not eligible for these subsidy schemes (2 times).

The barriers that relate to the firms mentioned by the paper factories are: limited capacity (1 time) and sustainability not being part of the culture (1 time). Also one respondent mentioned that the focus of the industry is on the short term which hinders eco-innovation.

Finally, also the respondents from the paper industry mentioned several barriers related to the innovations: the uncertainty inherent to innovation (2 times), the complexity of changing the whole process (1 time) and finally that they wait for a breakthrough innovation (1 time).

Also these barriers, with the exception of eco-innovation related barriers, can be linked to the factors that motivate companies to adopt eco-innovation.

4.3. Comparing the industries

If we compare the results from the two industries it becomes

clear that for both industries internal factors were overall more important than external factors (see also Fig. 5). The comparison also shows that for half the factors similar results were obtained with respect to the number of times a factor was mentioned, but they differed on the other six. The comparison shows that the respondents from the breweries mentioned the factors (Int3) ethical responsibility, (Ext2) threat of new regulation, and (Ext4) stakeholders more often (difference in total count at least 5). The respondents of the paper factories mentioned (Int2) financial advantage, (Int6) clear objectives and plans, and (Ext3) subsidies more often. These differences might indicate that the brewing industry was more aware of (or influenced by) their internal and external responsibilities, whereas the paper industry focused more on financial benefits.

If we compare the average ranking scores for the two industries we see the largest differences for the factors (Ext5) business opportunities [differences of 3.6] and (Ext6) competitive advantage [differences of 1.9]. These two factors were more important in the adoption decisions of the paper industry. We also observe large differences for (Int3) ethical responsibility and (Int4) management promoting. The difference for these two factors was 1.5 and these were more important for the breweries. These differences also show the importance of the responsibilities for the breweries and the financial elements for the paper industry.

If we compare the top-ten combinations of factors in the two industries we see many similarities: seven combinations are observed in both industries. But there are also some differences. In the brewing industry financial advantage is only observed twice, compared to five times in the paper industry. In the brewing industry more combinations are observed with ethical responsibility as well as different external factors. In the paper industry only regulatory pressure was observed in combinations with the top-ten combination of factors.

4.3.1. Barriers to adopt

If we compare the barriers mentioned by the respondents of the two industries we see many similarities. For both industries the high investments, the pay-back time, the legislation and the uncertainty and complexity of the eco-innovations were mentioned by multiple respondents as barriers. Typical for the brewing industry was the limited knowledge, whereas the inaccessible subsidy schemes was a barrier that was only mentioned by respondents from the paper industry.

5. Discussion and conclusion

5.1. Discussion and implications of the findings

Since most research so far focused either on external or on internal factors, or focused on the adoption of a specific technology and/or one industry, the aim of this research was to develop a framework of factors and to analyse the relative importance and the interactions among the factors for multiple eco-innovation adoption processes in different firms in two different industries. The framework focused on measuring the influence of twelve factors, consisting of six internal and six external factors on the adoption decisions.

It appeared to be relevant to distinguish between the internal as well as external factors. The results do show that internal factors were more important compared to the external factors. For the adoption of energy efficient eco-innovations the company needs to perceive the innovation as profitable and important enough. This is in contrast to the literature in the context of corporate sustainability for which external drivers are more prominent (Lozano, 2015). It might be that external factors might play a larger role for the adoption of other eco-innovations than energy efficient eco-innovations. For eco-innovation that concern for instance the

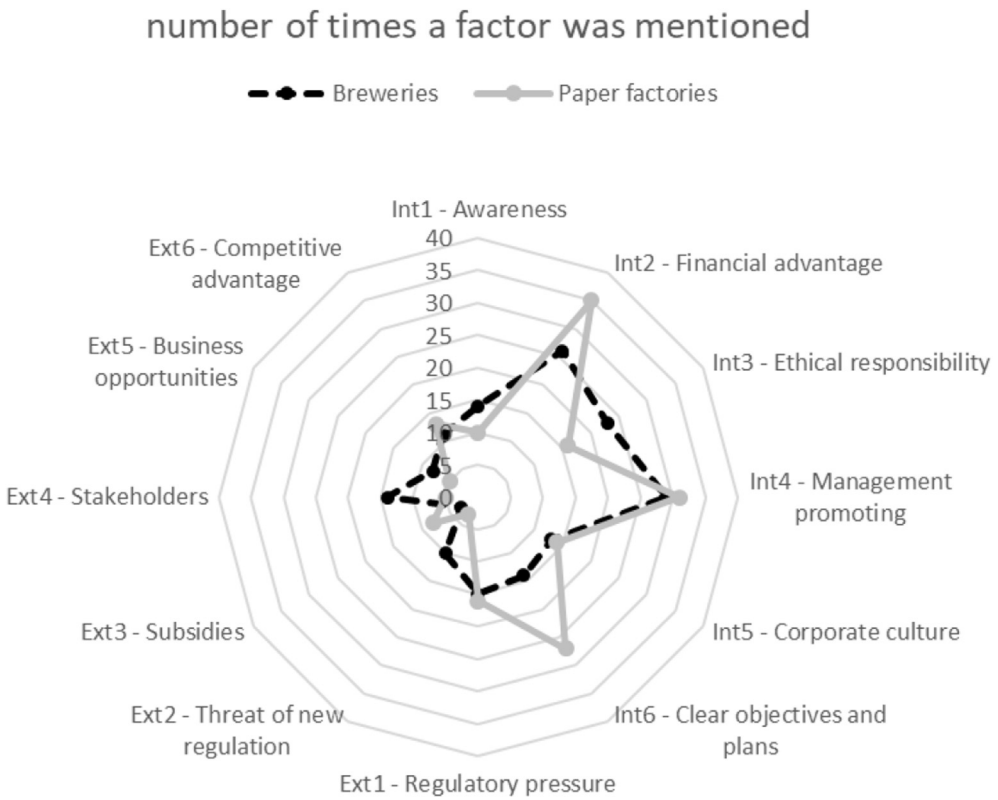

Fig. 5. Comparison of the two industries.

reduction of water pollution the link with and the possibility of the reduction of costs is less clear. Future research might focus on testing the framework on these other eco-innovations.

Moreover, the different factors of the developed framework were relevant since each of the identified factors has been mentioned at least in 11 (out of 80) adoption decisions.

It was also relevant to study different innovations in two different industries (and not just focus on the adoption of one technology in one industry (e.g. Chappin et al., 2009)) as the results were different for the two industries. The analysis of the individual as well as the interactions of factors show that financial advantage was important for both industries, but especially for the paper industry. For the brewing industry, ethical responsibility and stakeholders played a more important role. These differences between the two industries can be partly explained by the different positions they have in the supply chain and therefore the type of customer they have. The paper industry focuses on business-to-business and has limited direct contact with the end-consumer or other external stakeholders. The brewing industry is more visible to the end-consumers. As explained by Chappin et al. (2015) this influences the motivations of firms for environmental friendly behavior.

Finally, we also analysed and compared the results for small and large firms. Ethical responsibility and stakeholders are relatively more often mentioned by small firms, whereas clear objectives and regulations were mentioned more by large firms. These results, however, were less distinctive than the differences between the industries. They do suggest that a different mechanism is at play: small firms might be more receptive to normative institutional pressures, whereas large firms are more receptive to regulatory institutional pressures[3] and integrate sustainability more often in the strategy.

The findings also have some implications for stakeholders and policy makers as both of them can exert an influence on the adoption process. The results suggest that stakeholders have a larger potential to influence firms in business-(close) to-consumer markets and smaller firms. Those kind of firms appear to be more receptive to these pressures. For policy makers it is relevant to realise that the regulatory pressure does motivate companies to adopt eco-innovation. Policy makers can use this knowledge when developing new policy. Subsidies appeared to be less relevant in the adoption processes. So, if they aim to stimulate the adoption of eco-innovation, it will be more effective to use regulation compared to subsidies.

5.2. Limitations and future research

The following limitations should be noted. We developed the framework and tested it in two different industries. Nevertheless, the generalizability is limited to the brewing and the paper industry in The Netherlands. For future research it would be interesting to study these industries also in other countries and study other industries in The Netherlands. As indicated above it would be relevant to also study adoption of other types of eco-innovations.

Moreover, it would be interesting to also understand and study non-adoption. An option would be to study adoption decisions trajectory real time that can result in adoption as well as non-adoption.

Finally, it would be interesting to further study the interdependency and interactions among the factors. In this paper we have analysed combinations of two factors. This analysis showed for instance that for the paper industry it applied that whenever (Ext3) subsidies was mentioned also (Int2) financial advantage was mentioned. Although this was not always the case for the brewing industry this might suggest interdependency. Future research could refine this analysis by the use of QCA to identify for instance the different configurations, explaining adoption vs non-adoption or explaining product versus process innovation.

[3] see Scott (2001) for an overview of the different types of institutions, which he called pillars.

6. Conclusion

To conclude, our study clearly shows that the adoption of eco-innovation is a complex process with many different internal and external factors that influence the decision. Contrary to what may have been expected upfront, internal factors are more important than the external factors. Moreover, the position in the supply chain as well as the size of a firm are important: ethical considerations and stakeholders are more important for smaller firms and for firms in an industry that is more visible to the end-consumers.

CRediT authorship contribution statement

Maryse M.H. Chappin: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Visualization. **Maurice V.D. van den Oever:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Simona O. Negro:** Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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