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Master Thesis

Resource scarcity and eco-innovation

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Abstract: The effects of (over-) use of materials result in problematic environmental issues and require a change in our present detrimental way of living, doing business and managing society. Eco-innovation may help address these issues by increasing resource efficiency and several other factors along the triple bottom line of people, planet and profit. This paper analyses the eco-innovative behaviour of European small and medium firms in relation to material costs, in the form of the implementation of product, process and organisational eco-innovations. Logistic regression analyses are conducted on data from the Flash Eurobarometer survey 315 (FL315), "Attitudes of European entrepreneurs towards eco-innovation" (European Commission, 2011). The analysis contributes in finding determinants of eco-innovation related to material costs of a firm. Material intensive firms, firms with a high share of material cost of a company's total cost, are found to be more likely to invest in eco-innovation. Furthermore, no evidence is found that the past material costs of a firm are related to the eco-innovation investment strategy of a firm. Expected price increases were expected to motivate firms to eco-innovate, however, surprisingly the findings oppose the hypothesis. Additionally, no significant evidence is found that the positive associations between an increase in past or expected material costs and the introduction of an eco-innovation gets stronger as the material intensity of a firm increases. Finally, firm characteristics as firm size, turnover growth, sector of activity and country of origin are found to be significant determinants of eco-innovative behaviour.

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1. Introduction

Awareness of our present detrimental way of living, doing business and managing society has raised concern due to the mayor effects on the environment. Cohen and Winn (2007) argue that market imperfections (e.g. firms are not perfectly efficient) contribute to environmental degradation and that these market imperfections create opportunities for entrepreneurs who are interested in venturing under the triple bottom line, which exists out of solving social and environmental challenges, while obtaining entrepreneurial rents. In addition, York and Venkataraman (2010) show that environmental issues present opportunities for entrepreneurs in which they are particular alert to, because they argue that there is a lot of uncertainty around environmental topics such as climate change. In line with Knight (1921), York and Venkataraman (2010) argue that this high level of uncertainty creates market gaps in which entrepreneurs are willing to take risks, where incumbent firms are not. The more uncertain and unmanageable the issue, the more likely entrepreneurs are able to contribute in the solution.

Cohen and Winn (2007) indicate that solving market imperfections, as inefficient firms, could contribute to diminish environmental degradation. The inefficiencies of our economic systems are apparent in the existence of waste. For example, the production of a semiconductor chip can lead to a waste generation of 100,000 times its own weight (Hawken et al., 1999). More efficient resource management could be beneficial to company profit as well as the environment. In this paper, an analysis is made on the environmentally sustainable innovation behaviour by SMEs (small and medium enterprises) as a response to rising prices of resources and resource scarcity.

Market imperfections are a source of opportunity for the sustainable entrepreneur. Especially eco-innovations are able to contribute in solving market imperfections and reduce environmental impacts. Eco-innovation is "the introduction of any new or significantly improved product (good or service), process, organisational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle" (EIO, 2011, p.2). A distinction is made between specifically three types of innovation, namely, product, process and organizational innovation[1], promoting environmental performance from different angles. Product innovations result in improvements of existing products or the creation of new ones. Process innovations are used to reduce the input in producing the same output of products. Third, organizational innovations are changes of the

[1] These three types are from the generally accepted guidelines of using innovation data specified by the Organisation for Economic Cooperation and Development (OECD, 1997).

organisational processes and responsibilities of firms including management systems, e.g. EMS (Environmental Management System) resulting in more resource efficiency (Kesidou & Demirel, 2012).

The European Commission (EC) underlines the importance of eco-innovation in several key initiatives in the EU 2020 strategy[2]. Such as the flagship initiatives 'A resource efficient Europe', 'Innovation Union' and 'An Industrial Policy for the Globalisation Era', about eco-innovation diffusion, resource efficiency and related challenges. Emphasis is on both the challenge of the economic and environmental crisis and related business opportunities. The importance of innovation is apparent considering the mayor steps that have to be taken in order to improve our current detrimental relationship with the environment.

A focus on resources is important assessing the effects of (over-) use of materials resulting in problematic environmental issues. Furthermore, an increasing dependence on imported resources in the EU is creating problems when thinking of material security, increasing vulnerability of European citizens and industries to volatility and increasing scarcity (EIO, 2011). Imported products may additionally damage the environment as a result of transportation plus often cheaper but more harmful production methods used elsewhere across the globe. Focusing on resource efficiency and reducing material usage offers business opportunities in line with cost efficiency (DeSimone et al., 1997). The EIO (2011) provide the results of a case study conducted under 700 German manufacturing firms, revealing the possibility to save EUR 200.000 on average per company, with investment costs under EUR 10.000 for nearly half of the sample. Additionally eco-innovation, from a costs perspective, would make sense as resource costs are expected to increase in the future according to the sample firms from the Flash Eurobarometer survey 315 (FL315), "Attitudes of European entrepreneurs towards eco-innovation" (European Commission, 2011) used in this paper for the empirical analysis. From the firms in the sample, 69% experienced a rise in material costs and 87% of the firms expect resource prices to rise in the near future.

In order to implement sound innovation strategies, it is important to determine the main drivers behind eco-innovation. Rennings (2000) describes three categories of determinants of eco-innovation. This framework is composed of technology push, market pull and regulatory push determinants. Innovation economics is mainly concerned with the determinants of innovation being

[2] http://ec.europa.eu/europe2020/index_en.htm

the result of new technologies or market demand. Both are enforcing innovation, but these determinants seem not strong enough to encourage eco-innovation (Rennings, 2000). This difference between innovation and eco-innovation is explained by the double externality problem, which proposes a competitive disadvantage for eco-innovation, because additional costs are incurred by a firm to reduce environmental impact compared to the implementation of a general innovation. Regulation is therefore needed to induce eco-innovation compared to innovation. However, eco-innovation is also believed to be a source of competitive advantage as proposed by the Porter Hypothesis rather than the opposite argued for by the double externality problem (Demirel & Kesidou, 2012). The Porter Hypothesis by Porter and van der Linde (1995) proposes environmental advantages by positive spillovers and simultaneously economic benefits through competitive advantage. The benefits of selling products on the newly created market for environmentally friendly products, often with a premium, and/or the improved production efficiency may outweigh the costs.

The literature on the determinants of eco-innovation is well developed, especially positive relationships are found between eco-innovation and regulation. (Rehfeld et al., 2007; Horbach et al., 2012; Marin et al., 2014). Furthermore, cost minimization, particularly by resource savings, functions as motivator for eco-innovation, in order to comply with environmental regulation and realize production efficiency, as shown in literature (Horbach et al., 2013). However emphasis on material costs as determinant is absent in the literature.

This paper analyses the eco-innovative behaviour of firms in relation to material costs. Using the Flash Eurobarometer survey 315 (FL315), “Attitudes of European entrepreneurs towards eco-innovation” (European Commission, 2011). Regression analyses are used to find relationships between material costs variables and eco-innovation investment behaviour, contributing in finding determinants of eco-innovation related to material costs of a firm and providing insights in how to induce specific types of eco-innovation for different types of firms.

In this research, the share of material cost of total cost of a firm is proposed to be a technology push determinant of eco-innovation in the eco-innovation determinants framework of Rennings (2000). Material intensive firms, firms with a high share of material cost of a company’s total cost, are found to be more likely to invest in eco-innovation. Furthermore, an analysis on the market pull determinants of eco-innovation in the form of material costs of a firm is conducted. No evidence is found however, that the experienced material costs of a firm are related to the eco-innovation investment strategy of a firm. Additionally, eco-innovation investment strategy based on expected material costs are also tested as eco-innovation market pull determinant. The findings oppose the hypothesis that expected price increases would motivate firms to eco-innovate. Finally, the material intensities of a firm are tested to moderate the relationship of material costs or expected material costs and eco-innovation investment, however, such a moderation is not found in the results.

This thesis is structured as follows. First, a literature review will be presented in the first part of chapter 2, followed by the formulation of hypotheses of this research in the second part. Second, chapter 3 presents the data used in this paper and the methods in analysing the data. Third, results are provided of the statistical analyses in chapter 4. Finally, chapter 5 includes a conclusion and discussion of the results and provides future avenues of research on the topic.

2. Literature review & hypotheses formulation

In this section, the main concepts of this thesis will be reviewed. The main concepts are entrepreneurship, sustainable entrepreneurship, market failure and eco-innovation. The review will be followed by a discussion on the determinants of eco-innovation on which subsequently the hypotheses will be build.

2.1 Entrepreneurship

The concept of entrepreneurship is to date not specified in a single definition. While this paper will not contribute in the establishment of a definition for entrepreneurship, a review will be given to provide guidance and borders in which this paper operates.

The history of entrepreneurial thought is characterized by very different point of views from important economists as Schumpeter and Knight. The Schumpeterian entrepreneur is the bringer of innovations and the creative destructive force believed to bring the economy in a new economic paradigm (Hébert & Link, 1989; Schumpeter, 1934). The process of creative destruction is characterized by the driving force of opportunities created or discovered by entrepreneurial individuals, combined with advancements in knowledge, technology and the probability of profits, which prevents the market from reaching an equilibrium status. The economic actor, which pursues market power by innovating, may discover a new technology, which creates a new market and destroys an old market. A simple example of the process of creative destruction is the destruction of the vinyl market by the CD market and the cloud replacing CD and USB. Economists would typically characterize the entrepreneur as an agent of change, often associated with innovation.

Another view of entrepreneurship is specifically expressed by Kirzner (1973) who focussed in his definition on the discovery of opportunities, instead of Schumpeter who emphasized the creation of opportunities. The entrepreneur of Kirzner may be anyone who is alert to opportunities. The entrepreneur functions as an actor, which moves the market to equilibrium, as opposed to the view of Schumpeter, by discovering opportunities in markets resulting from market failure. The entrepreneur seeks profits by acting upon unnoticed opportunities until competition arises, which will eventually in market equilibrium eliminate those profits. Market failure depicts the barriers for markets to come into an equilibrium state of the perfect market from neo-classical literature. When the assumptions of a perfect market are violated, market failure arises. Market failure is one of the main concepts used in this thesis and will be further elaborated in a separate section of this review below. Another distinctive difference between the entrepreneur of Kirzner and Schumpeter is the handling of uncertainty. The Schumpeterian entrepreneur is a person who is willing to bear uncertainty or risk to create an opportunity, while the difference in perceived uncertainty creates opportunities for the entrepreneur of Kirzner (McMullen & Shepherd, 2006).

Scholars have tried to define the field of entrepreneurship in terms of the entrepreneur or in terms of what an entrepreneur does, but both are used inconsistently and in different contexts. Venkataraman (1997) argues that a definition on entrepreneurship should be based upon the central issues concerning entrepreneurship and not on basis of the entrepreneur. The research field of entrepreneurship is according to Venkataraman (1997) therefore: *"the research area which seeks to understand how opportunities to bring into existence future goods and services are discovered, created, and exploited, by whom, and with what consequences" (p.120).* The central issues out of which the research field is built upon in this definition is the arising of opportunities, actors that are able to exploit or create this opportunity and related consequences of such action. Entrepreneurship defined in the form of action is an often-made discrimination between occupational and behavioural entrepreneurship (Wennekers, 2006). Entrepreneurial behaviour may occur not only in business, for example, when it is defined as behaviour related to opportunities as with the Kirznerian entrepreneur. The occupational notion explains entrepreneurship as working on own account and risk, being self-employed.

Economic literature in general agrees upon the finding that entrepreneurship acts as a key driver for economic growth through innovation and job creation (Van Praag & Versloot, 2007). Policy-makers aim to stimulate economic development and therefore it is important to determine the main drivers behind entrepreneurship. However, an important issue with the absence of a consistent definition is the measurement of entrepreneurship. An entrepreneur is commonly associated with a manager of a small venture, in line with the occupational notion of entrepreneurship. In this thesis, the ambiguous term of entrepreneurship will have a very specific meaning. The data used to conduct the empirical analysis is based on a survey under SME managers. SMEs are in this survey defined as firms between 10 and 249 employees (EC, 2011). Micro-firms with less than 10 employees are not included. Entrepreneurs in this thesis are interchangeably used with the entrepreneurial firm and are defined as SMEs or the manager of a SME. While most entrepreneurial firms are SMEs, not all SMEs are entrepreneurial, but setting such boundaries is common practice in entrepreneurship literature, partly due to the lack of a common definition, to which this paper complies. The behavioural notion defines entrepreneurship often as the creation of new firms and/or the discovery of opportunities through often innovation. This paper uses the occupational notion and defines the entire sample as entrepreneurial, though not the entire sample is labelled as a sustainable entrepreneur. The next section will discuss sustainable entrepreneurship and explain how it is implemented in this paper.

2.2 Sustainable entrepreneurship

Awareness of our present detrimental way of living, doing business and managing society has raised concern due to the mayor effects on the environment. The recognition of this problem has created a beginning in the research field of sustainable development. (Hall et al., 2010) The term “sustainable development” is defined in a report of the World Commission on Environment and Development (1987) as “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (p.37). The assumption of making a trade-off between ecological sustainability and economic profitability is slowly being replaced by the perspective of sustainability. Integrating economic health, social responsibility and environmental relieve in a long-term perspective, called the triple bottom line, providing opportunities for win-win solutions. Solving social and environmental challenges, while obtaining entrepreneurial rents (Cohen & Winn, 2007).

Growing interest in entrepreneurship at one side and growing attention and recognition for environmental issues at the other side is giving rise to the sustainable entrepreneurship literature (Venkataraman, 1997; Dean & McMullen, 2007; Hall et al., 2010). A definition of sustainable entrepreneurship is provided by Shepherd and Patzelt (2011) who argue for a broad, diverse setup for the framework of sustainable entrepreneurship research, in particular when the field of entrepreneurship itself is still emerging. They define sustainable entrepreneurship as: *”the preservation of nature, life support, and community in the pursuit of perceived opportunities to bring into existence future products, processes, and services for gain, where gain is broadly construed to include economic and non-economic gains to individuals, the economy, and society” (p.142).* When you compare the cited definition of entrepreneurship from Venkataraman with the definition of sustainable entrepreneurship from Shepherd and Patzelt, it can be noted that the proposed key themes of entrepreneurship are still enclosed, but more specified with a sustaining goal in mind. The arising of opportunities is coupled with the preservation of nature, life support and community. The consequences are more specified, but still broadly indicated by economic and non-economic gains in order to emphasize the importance of other gains than exploiting opportunities for profit. While this paper focuses on environmental innovation initiatives, the non-economic gains of eco-innovative behaviour by sustainable SMEs do not have to be exclusively beneficial to the environment, however, may also benefit society and the economy. Sustainable SMEs are in this paper the firms which eco-innovate. Besides the occupational notion of being the manager of a SME, the behavioural notion of environmental innovation is defining a sustainable entrepreneur.

Entrepreneurship is seen as an important conduit or even panacea for stirring sustainable innovation. Supporters of the Panacea Hypothesis are sceptical about a solution to environmental issues provided by incumbent firms (Hall et al., 2010). The Panacea Hypothesis proposes the improvement and transformation of society through entrepreneurship in line with Schumpeter (1934). Radical change is needed and is believed to come from the sustainable entrepreneur. In the case of this paper the potentially destructive force for incumbent firms are the entrepreneurs who implement eco-innovations. Cohen and Winn (2007) add that business may even have the potential to lead the world into the 'next industrial revolution' by reversing instead of reducing environmental degradable behaviour.

In the research field of sustainable entrepreneurship, empirical analyses are almost non-existent due to the only recent interest of society and scholars, driven by the growing concern on our non-sustainable behaviour (Shepherd & Patzelt, 2011), changing the almost exclusive focus on financial gain (Cohen et al., 2008). Furthermore, a lack of empirical analyses exists, due to the only recent availability and gathering of data on the topic. Therefore, this paper will contribute and build upon past research about sustainable entrepreneurship with an empirical analysis on eco-innovation under European entrepreneurs. The research field of eco-innovation is far more advanced compared to sustainable entrepreneurship and will provide additional avenues in strengthening the base for the empirical analysis of this thesis as will be discussed in the eco-innovation section below next section about market failure. In next section market failure and the opportunities for sustainable entrepreneurs will be discussed.

2.3 Market failure

Cohen and Winn (2007) argue that market imperfections (e.g., firms are not perfectly efficient) contribute to environmental degradation and that these market imperfections create opportunities for entrepreneurs who are interested in venturing under the triple bottom line. Environmental degradation is amplified by specifically four types of market imperfections according to Cohen and Winn (2007). They are inefficient firms, information asymmetries, externalities, and flawed pricing mechanisms. These market failures and their relations to sustainable entrepreneurship are discussed below.

Solving market imperfections, as inefficient firms, could contribute to diminish environmental degradation. The inefficiencies of economic systems are apparent in the existence of waste. For example, the production of a semiconductor chip can lead to a waste generation of 100,000 times its own weight (Hawken et al., 1999). More efficient resource management could be beneficial to company profit as well as the environment.

Considering the market imperfection of information, neo-classical economics proposes the assumption of a free market with all agents having perfect information about all market aspects (Kirzner, 2000). However, such assumption may not hold, because of amongst others bounded rationality. An example by Hawken et al. (1999) states the lack of knowledge about energy consumption of most users. What opportunities are there to improve energy usage efficiently and thereby saving costs and the environment? Companies as energy provider Eneco[3] have jumped into such opportunities that resulted from an information asymmetry. They introduced a digital power-recording instrument, called Toon®, to provide transparency in energy usage and costs.

The third market imperfection of externalities is particular important for the uptake of sustainable entrepreneurship. Simplifying assumptions within economics propose ‘exclusivity’ related to the actions of economic actors. Actions of an actor only influence participants of an economic transaction. However, the opposite is indicated with externalities, when nonparticipants are affected, which occur in positive and negative form (Browning and Zupan, 1999). For example, a knowledge spillover is a positive externality for a receiving firm, without paying for the true value of the benefit. Knowledge spillovers occur when people exchange thoughts, which may let firms benefit from the R&D of other firms (Jaffe et al., 1993). Often this happens when start-ups exploit new opportunities created, but not appropriated by incumbent firms (Acs et al., 2009). One of the sources of success of Silicon Valley is the high density of tech-firms that benefit from the knowledge spillovers from each other. Positive spillovers are in another form associated with sustainable entrepreneurs who venture under the triple bottom line. They, besides making profits, create positive impacts for society and the environment. Negative externalities occur when anywhere in the life cycle of a product damage is incurred by the environment or society, without the proper internalization of the related costs. As a result, sustainable entrepreneurs often have to compete with products, that have higher external costs, which are not properly internalized and therefore unfair competition, or the market imperfection of externalities arises (Cohen & Winn, 2007).

[3] http://www.eneco.com/en/activities/saving-energy/

Finally, flawed pricing mechanisms occur when demand and supply reflect untrue market values of especially non-renewable resources, as fossil fuels, and eco-system demolishing deforestation or overfishing (Hawken et al., 1999; Kurz and Salvadori, 1997). Conventional economics assumes an infinitely resource supply, while on the contrary many resources are exhaustible. A good example is the oil industry versus renewable energy sources. The costs of fossil fuels, which are not endless sources of energy, are not properly priced according to the scarcity and damaging effects on the environment. Innovation in renewable energy is lacking behind, because the costs outweigh the economic benefits relative to the non-sustainable counterpart. Oil is 'cheaper', because it is not priced for the true value including the costs of negative externalities on the environment.

Market imperfections are a source of opportunity for the sustainable entrepreneur. Especially eco-innovations are able to contribute in solving market imperfections and reduce environmental impacts. In the next section eco-innovation as tool for the sustainable entrepreneur will be examined.

2.4 Eco-innovation

Environmental innovation, or in short eco-innovation, has its origin in environmental and innovation economics. Pressing environmental issues created a surge in innovation literature focussed on sustainable development (Rennings, 2000). Klemmer et al. (1999) introduce the term environmental innovation and propose a broad definition including all possible actors that may innovate in a broad range of innovation areas that contribute to the reduction of environmental burdens or sustainability targets. The eco-innovation definition used for this paper is: *"the introduction of any new or significantly improved product (good or service), process, organisational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle"* (EIO, 2011, p.2). The definition distinguishes between specifically three types of innovation, namely, product, process and organizational innovation. These three types are from the generally accepted guidelines of using innovation data specified by the Organisation for Economic Cooperation and Development (OECD, 1997). The three innovation types propose the following enhancements for the environment. Product innovations result in improvements of existing products or the creation of new ones. Process innovations are used to reduce the input in producing the same output of products. Third, organizational innovations are changes of the organisational processes and responsibilities of firms including management systems, e.g. EMS (Environmental Management System) resulting in more resource efficiency (Kesidou & Demirel, 2012).

The importance of a better understanding of eco-innovation has several reasons. Firstly, Changes to better the detrimental relationship with the environment have not been able to alter the current course of increasing pollution. Regulation strategies to force radical change in clean-tech use and innovation are needed. Without the understanding of the innovation process, policy implementation might not yield the targeted results. *"Even modest sustainability targets, as fixed in the Kyoto Protocol, require substantial innovation (Rennings, 2000, p.322)"* Secondly, innovation is able to improve efficiency, reducing costs, increase competitiveness, creating new (green) markets and improve several other factors along the triple bottom line of people, planet and profit. Although potential benefits of innovation seem apparent, not every firm shows innovation activity and therefore further research to firm behaviour and the innovation process is needed. Thirdly, for SMEs in the EU where eco-innovation is already common ground, further understanding of the eco-innovation process is important to provide tools for firms in managing eco-innovation. Finally, the EU and several other institutions implement initiatives to promote sustainability, mainly under firms. Therefore, finding determinants of the eco-innovation process to enhance policy instruments is an additional reason for further research on the topic (Marin et al., 2014; EIO, 2011; Rennings, 2000).

Availability of data on eco-innovation lacked behind until the inclusion of the topic in the Community Innovation Survey[4] (CIS) in 2008 and most recent available survey of 2010. This paper uses the FL315 Eurobarometer (EC, 2011), which is specifically designed on the eco-innovation topic and thus has the benefit of including both specific questions on eco-innovation investment and material costs. The targeted sample is the full EU27, in contrast to a sample of EU countries targeted by the CIS. Furthermore, the FL315 is the most recent conducted survey on the papers specific topic, with a dataset that has the potential of providing new insights on eco-innovation determinants related to resource efficiency.

In order to implement sound innovation strategies, it is important to determine the main drivers behind eco-innovation. In the next section, determinants of eco-innovation will be discussed.

2.5 Determinants of eco-innovation

Rennings (2000) describes three categories of determinants of eco-innovation (see Figure 1). This framework is composed of technology push, market pull and regulatory push determinants.

[4] http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis

First, the regulatory push component is elaborated. Second, the market pull determinant and finally the technology push factor.

Key determinant 1: Regulatory push

This section starts with arguing that eco-innovation compared to regular innovation has an additional key determinant category in the form of regulatory push. Subsequently, the regulatory push component is elaborated.

Innovation economics is mainly concerned with the determinants of innovation being the result of new technologies or market demand. Both are enforcing innovation, but these determinants seem not strong enough to encourage eco-innovation (Rennings, 2000). These determinants exist in the form of eco-efficient production techniques and a demand for environmentally friendly products, however are not competitive enough relative to common innovation forms as explained in the market failure section. Eco-innovation has a double externality problem, which hampers incentives to eco-innovate. The double externality problem arises with eco-innovation versus innovation, because positive spillovers exist for eco-innovations in both innovation and diffusion phase. Both innovation and eco-innovation produce positive spillovers in the innovation phase, both types enhance knowledge and technology from which other economic actors benefit without the innovating firm incurring the full produced value (Audretsch & Feldman, 1996). In other words, firms are not able to internalize the returns of the innovation phase for both types of innovation completely (Arrow, 1962). However, eco-innovations additionally produce positive or less negative externalities in the diffusion phase. Negative externalities of competing products, explained as higher external costs, are not properly internalized and therefore unfair competition, or the market imperfection of externalities arises (Cohen & Winn, 2007). When markets do not internalize externalities, competition between eco-innovations and innovations is impaired. Eco-innovation is in origin linked to policy to induce eco-innovation, creating an additional key determinant of a regulatory push (Rennings, 1998). This regulatory framework is needed to improve the competitiveness of eco-innovation and to promote a sustainable world. Positive spillovers created by eco-innovation, for which costs are incurred by sustainable entrepreneurs are not being paid for by the consumer or partly via a premium. Negative spillovers of non-sustainable innovation, for which no costs have been incurred, are not being paid for by the firm nor consumer, resulting in unfair competition. Figure 1 shows the key determinants of eco-innovation including regulatory push as a third key determinant used to solve the double externality problem related to a weaker technology push and demand pull (Rennings, 2000). A regulatory push through changed technological standards (explicit policy) or taxation instruments (implicit policy) like excise duties on gasoline or carbon footprints may oblige firms to eco-innovate even without the appropriation of net economic benefit as eco-innovation outcomes remain uncertain (Marin et al., 2014).

However, eco-innovation is also believed to be a source of competitive advantage as proposed by the Porter Hypothesis rather than the opposite argued for by the double externality problem (Demirel & Kesidou, 2012). The hypothesis proposes environmental advantages by positive spillovers and simultaneously economic benefits through competitive advantage. The Porter Hypothesis by Porter and van der Linde (1995) denounces the static view on environmental regulation, in which in a static world the obligation of an environmental regulation can only raise costs for firms. The static view ignores the competitive advantage of eco-innovation strategy and environmental performance, whether implemented due to mandatory regulation or not.

The literature on the determinants of eco-innovation is well developed, especially positive relationships are found between eco-innovation and policy frameworks. (Rehfeld et al., 2007; Horbach et al., 2012; Marin et al., 2014). Efficiency and related cost-savings are expected to motivate firms to eco-innovate, however, this technological push determinant does not prove to be supportive enough to recognize the resource optimization potential of eco-innovation (Rennings, 2000). Porter and van der Linde (1995) argue that firms are not experienced yet in dealing with environmental issues. Regulation is found to provide guidance and function as revelation. Additionally, policy helps solving the double externality problem (Horbach et al., 2013). Brunnermeier and Cohen (2003) find that regulations, in the form of pollution abatements, increased eco-innovation, but an increase in monitoring and enforcement related to the regulations did not increase eco-innovative behaviour. Firms may be reluctant to eco-innovate when they expect that an accomplished lower regulatory burden due to eco-innovations might induce the policy maker to create further stringent regulations and standards.

Marin et al. (2014) exploit the FL315 dataset (EC, 2011) which is also used for the empirical analysis of this paper. In their paper, they provide a taxonomy of SMEs concerning eco-innovation barriers, showing different eco-innovative behaviours under firms as a response to those barriers. The barriers are hindering-determinants of eco-innovation and are clustered in cost, knowledge and market barriers. Marin et al. mention that most firms are affected by market barriers, while cost barriers only affect specific firms but a specific relationship between barriers or determinants and eco-innovation is not provided. They find that their taxonomy incorporates significant differences in eco-innovation investments but has a faint overlap with sector classifications. In other words, being in a certain sector does not predict eco-innovative behaviour and thus specific care should be taken in constructing well-functioning eco-innovation policy which is targeted at firm differences and not sector origin. Barriers may hinder eco-innovation investment and additionally disturb EU policy and targets. Knowledge about eco-innovative behaviour should reveal obstacles to be removed and should improve policy effectiveness.

Key determinant 2: Market pull

Eco-innovation is becoming increasingly a strategic decision and a market addressing environmental issues is forming, called the green market. A shift from policy-driven to market-driven eco-innovation is happening (Ambec & Lanoie, 2008). Providing more strength to the market pull determinant.

The demand for environmental friendly products is becoming self-enforcing without the need of a regulatory push to change the behaviour of consumers, companies and other institutions. The realization of our present detrimental behaviour to the environment is growing, without the additional need of the government to alleviate non-sustainable competition. In the FL367 survey (EC, 2013) 77% of the European consumer is even willing to pay a premium for green products, compensating the double externality problem of eco-innovation.

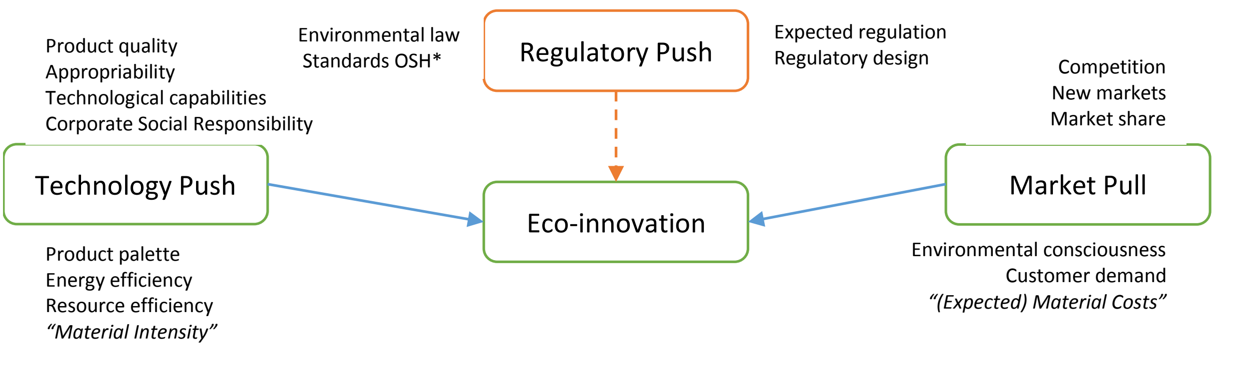
In a study by Horbach (2008), evidence is found for the market pull determinant. An expected increase in demand for green products stimulates eco-innovative behaviour under firms. In line with this finding, but with a decreasing effect, are the findings by Rehfeld et al. (2007) who argue that market pull is still not a strong factor for eco-innovation because the consumer has stronger preferences for alternatives when considering the more expensive eco-friendly products. However, they do find significant evidence in their econometric model for market pull through customer satisfaction when customer satisfaction of a product is an important factor for competitive advantage. Cleff and Rennings (1999) using German panel data did research to eco-innovation decisions of firms about product and process innovation, they find that product eco-innovation is more driven by market strategies of companies, while process innovations are more dependent on policy. Brunnermeier and Cohen (2003) find also evidence for a market pull effect. In a panel data study under US manufacturing firms they find that companies who are in a more internationally competitive environment are more likely to eco-innovate. Rehfeld et al. (2007) using a sample of German manufacturing firms do not find significant evidence on this matter by looking at the relationship between export activities and product eco-innovation. While export activity or international orientation is a proven determinant of innovation in general, they comment that it seems that eco-friendly products are still only marketed on regional or national niche markets, rather than on the global market fields. Evidence for another market pull determinant is found by Del Río González (2005). The study is targeted at finding reasons to adopt eco-innovations. Using a sample of Spanish pulp and paper manufacturers it is found that company image and additionally regulations are indicated to be the only two important factors to drive eco-innovation.

Key determinant 3: Technology push

The technology push for eco-innovation is becoming stronger when firms realize competitive advantages due to efficiency gains in production techniques. Cost savings occur when fewer resources are needed to produce a certain amount of output and at the same time economic and often environmental waste is reduced (DeSimone et al., 1997).

While policy and increasingly market pull factors have a main function in stimulating eco-innovation, technology push factors act also as key determinants for eco-innovation. Horbach et al. (2013) find when the implementation of eco-innovation yields environmental performance as well as cost savings, preference for eco-innovation will increase compared to other innovations. Cost minimization is found to trigger eco-innovation. In an earlier study, Horbach (2008) finds a relationship between the R&D improvements of technological capabilities and eco-innovation using a sample of German firms. Innovation in the past predicts in this sample eco-innovation in the present. Technological capabilities of a firm act as determinant of innovation. In line with these findings, also Rehfeld et al. (2007) find eco-innovation to be significantly influenced by R&D. Furthermore, they find that certification of EMS has a significantly positive effect on product eco-innovations. Product management concerning waste disposal or take-back systems of products are found to be an even more important determinant for product eco-innovations.

Figure 1. Determinants of eco-innovations.



Source: Rennings (2000), Horbach (2008) *OSH = Occupational Safety and Health

Determinants of eco-innovation considering resource inefficiency

In this paper, an analysis is made of the behaviour towards environmentally sustainable innovation by SMEs as a response to rising prices of resources and resource scarcity. As a response to rising prices, firms are expected to embrace the eco-innovation uptake and improve their resource efficiency. Cost minimization, particularly by resource savings, functions as motivator for eco-innovation, in order to comply with environmental regulation and realize production efficiency, as shown in literature (Horbach et al., 2013). However emphasis on material costs as determinant is absent in the literature. The analysis aims to contribute in finding determinants of eco-innovation considering resource inefficiency. Market push (pull) in the form of higher prices of resources has not been tested in an empirical analysis as determinant of eco-innovation, while the phenomenon of rising resource prices is no exception and eco-innovation might be a solution (Cohen & Winn, 2007).

2.6 Hypotheses formulation

In this section, the hypotheses are formulated proposing relationships between, firstly, material intensities of firms and eco-innovative behaviour, material intensity being complementary to the technology push factor of Rennings (2000). Secondly, between material costs and eco-innovation, where material costs is complementary to the market pull factor. Thirdly, between expected material costs and eco-innovation, where the expected material costs fits to the market pull dimension. Per main hypothesis, four sub-hypotheses are formulated: the first (a) for eco-innovation in general and the next three (b, c and d) for each of the three innovation types. Additionally, a sub-hypothesis (e) is formulated for hypothesis 2 and 3 to test if the material intensity of a firm influences the relationship between material costs or expected material costs and eco-innovation.

Material intensity and eco-innovative behaviour

While empirical research is lacking on the relationship between material intensity and eco-innovation effort, firms are expected to eco-innovate as a consequence of the resource trends in the EU, especially material intensive firms. The idea that innovation is influenced by economic incentives is articulated in the induced innovation hypothesis introduced by Hicks: “a change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind – directed to economizing the use of a factor which has become relatively expensive.” (1932, p.124). Increased material costs that lead to eco-innovation to reduce the use of those materials is an example of the induced innovation hypothesis. Eco-innovation literature provides a growing body of evidence on prices and especially regulation providing incentives to innovation (Popp, 2005). Popp (2002) shows in a study a relationship between energy technology patenting activity and changes in energy prices. Energy technology innovations follow the changes in energy prices significantly in that study.

Cost minimization through resource savings is found to be a stronger motivator for eco-innovation compared to innovation (Horbach et al., 2013). In line with the findings of a relationship between cost incentives and innovation, cost savings may be more relevant in material intensive firms as a larger share of costs incurred by the firms are material costs.

The first hypothesis tests for a relationship between the material intensity of a firm and eco-innovative behaviour in the form of implementation of an eco-innovation. Four sub-hypotheses are formulated: the first to test for a general relationship to eco-innovation and additionally one for each of the three innovation types, resulting in hypotheses 1a to 1c. The three innovation types are separately tested because each type may have other determinants. Cleff and Rennings (1999), for example, found that product eco-innovation is more driven by market strategies of companies, while process innovations are more dependent on regulation. Specific research into the eco-innovation determinants and types of eco-innovation should enable the creation of effective innovation strategies and provide proper tools for policy construction. Hypothesis 1 proposes that resource efficiency is of stronger concern for material intensive firms. The first hypothesis is formulated as follows:

Hypothesis 1a: A material intensive firm is more likely to introduce an eco-innovation

Hypothesis 1b: A material intensive firm is more likely to introduce an eco-innovative product to the market

Hypothesis 1c: A material intensive firm is more likely to introduce an eco-innovative production process

Hypothesis 1d: A material intensive firm is more likely to introduce an eco-innovative organisational innovation

Resource prices and eco-innovative behaviour

The second hypothesis has the same design as the first hypothesis. The determinant under consideration is the past material cost evolution of firms.

Eco-innovation compared to innovation is stronger motivated by cost savings (Horbach et al., 2013). Because cost savings, particularly caused by reducing material and energy use, are an important motivator for eco-innovation, increasing material costs are expected to strengthen this relationship.

This hypothesis proposes a positive relationship between increased material costs and the likelihood of eco-innovative behaviour of firms, in line with the induced innovation hypothesis by Hicks (1932). The hypothesis proposed is formulated as follows:

Hypothesis 2a: An increase in material costs in the past for a company is positively associated with the likelihood of the introduction of an eco-innovation

Hypothesis 2b: An increase in material costs in the past for a company is positively associated with the likelihood of the introduction of an eco-innovative product to the market

Hypothesis 2c: An increase in material costs in the past for a company is positively associated with the likelihood of the introduction of an eco-innovative production process

Hypothesis 2d: An increase in material costs in the past for a company is positively associated with the likelihood of the introduction of an eco-innovative organisational innovation

Additionally, a sub-hypothesis is constructed to test if the material intensity of a firm moderates the relationship between material costs and eco-innovation. A firm with higher material costs is proposed to react more strongly on changes in material costs and thus strengthen the relationship between material costs and eco-innovation resulting in the following sub-hypothesis:

Hypothesis 2e: The positive association between an increase in past material costs and the introduction of an eco-innovation gets stronger as the material intensity of a firm increases

Expected material costs and eco-innovative behaviour

The third hypothesis has the same design as the first two hypotheses. The determinant under consideration is the expected material costs for a company.

Resource based theory explains competitive advantage as a result of developing organizational capabilities associated with proactive environmental strategies (Aragon-Correa & Sharma, 2003). The resource-based theory considers firms to be dynamic institutions, which respond to external changes according to their resources and capabilities (Cañón-de-Francia et al., 2007). Especially the capacity to adapt and innovate provide firms with competitive advantage. The theory suggests a competitive advantage for early adopters of eco-innovation who anticipate on future environmental regulation (Christmann, 2000). However, in the empirical analysis of the study by Christmann (2000), this suggested relationship is positive but not significant. Not only environmental regulation may be a source of increasing future costs, also other sources as resource scarcity may increase resource prices. Anticipating costs following resource-based theory could provide competitive advantage. Hypothesis three tests if firms anticipate on future costs with eco-innovation.

Rising prices and resource scarcity are indicated by firms as drivers to save resources and thus costs (Crabbé et al., 2012). In this study, it is tested if the perceived driver, resource costs, is related to eco-innovative behaviour as indicated by firms and proposed by the induced innovation hypothesis.

Cost minimization is a motivator for eco-innovation (Horbach et al., 2013) and increasing costs in the future are hypothesized to be anticipated upon by eco-innovative behaviour. This hypothesis proposes a positive relationship between the future material costs trend and the likelihood of eco-innovative behaviour of firms. The hypothesis is proposed as follows:

Hypothesis 3a: An increase in the expected material costs for a company is positively associated with the likelihood of the introduction of an eco-innovation

Hypothesis 3b: An increase in the expected material costs for a company is positively associated with the likelihood of the introduction of an eco-innovative product to the market

Hypothesis 3c: An increase in the expected material costs for a company is positively associated with the likelihood of the introduction of an eco-innovative production process

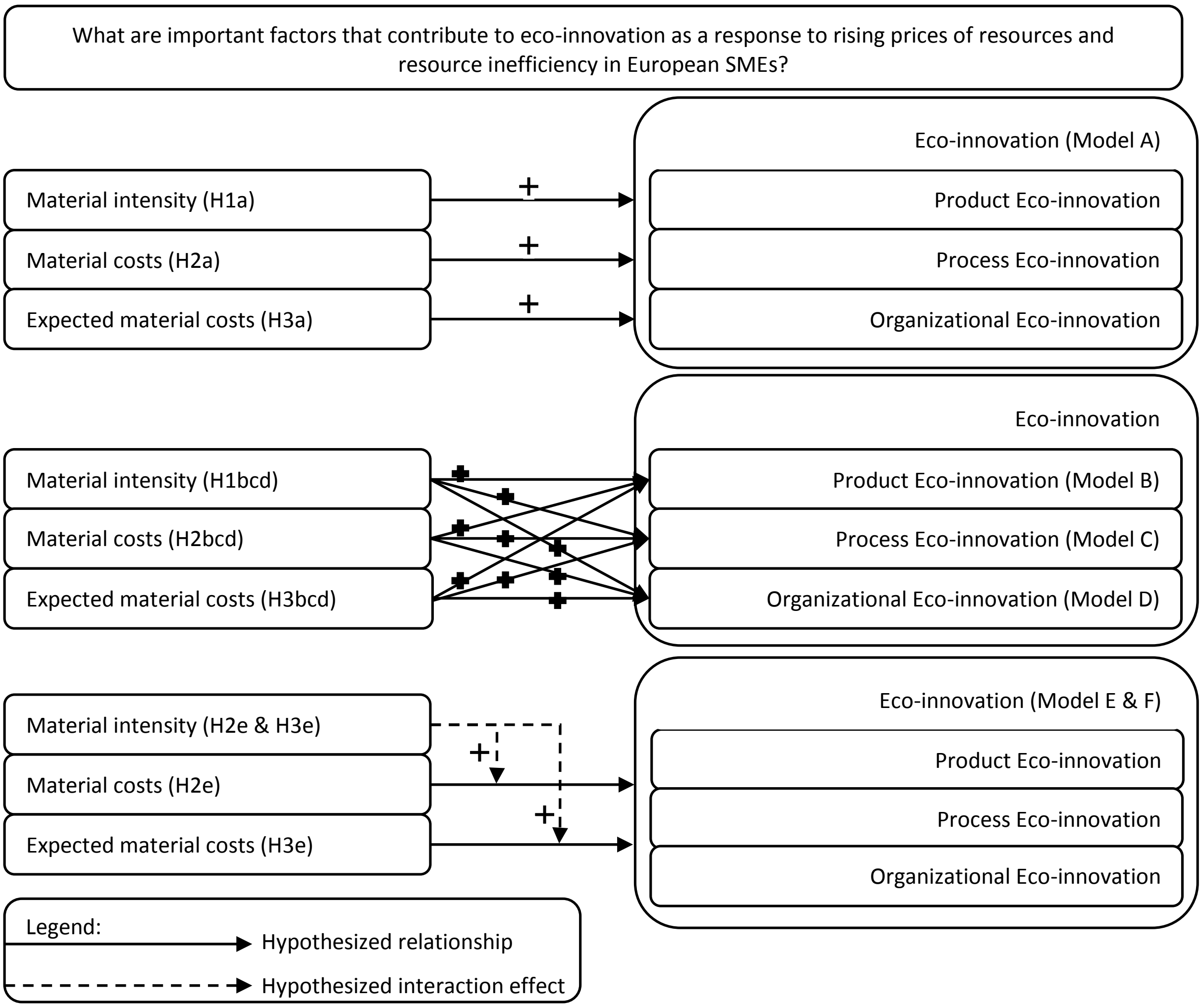
Hypothesis 3d: An increase in the expected material costs for a company is positively associated with the likelihood of the introduction of an eco-innovative organisational innovation

Additionally, a sub-hypothesis is constructed to test if the material intensity of a firm moderates the relationship between expected material costs and eco-innovation. A firm with higher material costs is proposed to react more strongly on expected changes in material costs and thus strengthen the relationship between material costs and eco-innovation resulting in the following sub-hypothesis:

Hypothesis 3e: The positive association between expected material price increases and the introduction of an eco-innovation gets stronger as the material intensity of a firm increases

Figure 2 shows the conceptual framework of this study. To test the three hypotheses and in total 14 sub-hypotheses, models A to F have been constructed. Model A is constructed to test for sub-hypotheses 1a, 2a and 3a. Model A is used to test for associations between the material costs variables and eco-innovation activity in general. Eco-innovation is measured as the implementation of at least one eco-innovation of any type. Models, B to D are used, to test per innovation type. Model B is constructed to test for sub-hypotheses 1b, 2b and 3b. Model C for sub-hypotheses 1c, 2c and 3c and model D for sub-hypotheses 1d, 2d and 3d. Model E is used to test for an interaction of firm material intensity on the relationship between material costs and eco-innovation, hypothesized by hypothesis 2e. Model F tests hypothesis 3e, the interaction of firm material intensity on the relationship between expected material costs and eco-innovation.

Figure 2. Conceptual Framework.



3. Data and methodology

This chapter presents and elaborates on the data and methods used for the empirical analysis of this study. First, a description of the data will be presented followed by an operationalization of the survey dataset. Subsequently, the methods used to assess the data will be elaborated.

3.1 Data

In order to contribute to our knowledge about eco-innovation and to explore which factors are important to European SMEs in eco-innovation investment decisions related to resource efficiency, this paper uses the Flash Eurobarometer survey 315, Attitudes of European entrepreneurs towards eco-innovation (European Commission, 2011).

The FL315 survey is conducted by The Gallup Organization, Hungary upon the request of Directorate-General Environment of the European Commission. Purpose of the survey was to "research the behaviour, attitudes and expectations of entrepreneurs towards the development and uptake of eco-innovation as a response to rising prices of resources and resource scarcity" (European Commission, 2011, p.4). The survey is conducted over telephone in the last week of January 2011 in the 27 member states of the EU by The Gallup Organization, Hungary and national partner institutes. The targeted group were 5222 managers[5] or persons responsible for strategic planning and decision making of SMEs operating in the 27 member states. The SME samples were randomly selected within five activity sectors[6], which are Agriculture, Manufacturing, Water supply and waste management, Construction and Food services. SMEs are defined as companies within the 1 to 249 employee range. A list of qualified companies to be interviewed was mainly based on the database of Dun and Bradstreet (D&B)[7]. For some countries, especially new member states, local statistical databases were used to supplement the D&B database. The targeted sample size was 200, but adjusted to 250 or 50 according to country size. In Table 1, included in the appendix a sample size distribution can be found. The three countries with only 50 observations, Cyprus, Luxembourg and Malta, are excluded from the data analyses to avoid statistical power issues as size effect overestimation and the interpretation of possible invalid results with the constructed country dummies. The interview on which the dataset is constructed consist of questions regarding the characteristics of a company,

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[5] In the text, managers, individuals and companies are mentioned interchangeably as respondents of the survey.

[6] Activity sectors are defined by the NACE Rev 2: Statistical classification of economic activities in the European Community. http://ec.europa.eu/eurostat

[7] http://www.dnb.com/

questions about companies' material costs, companies' eco-innovative activities and their perceived barriers and drivers for an accelerated uptake of eco-innovation. The survey[8] was held in the national language of a country, verified, and translated using a back-translation procedure.

3.2 Operationalization

In the following part, the operationalization of the survey dataset for the statistical analysis is discussed. Table 2 in the appendix offers a summary description of the variables. First, the dependent variables will be discussed, followed by the independent variables and subsequently the control variables.

Dependent variables

To measure eco-innovation in the individual firms the dependent variables "*Product", "Process"* and "*Organisational"* are constructed per type of eco-innovation. Additionally, the combined dependent variable "Eco-Innovation" is created.

Eco-innovation

The dependent variables "*Product"*, "*Process"* and "*Organisational"* measure the presence of three particular forms of eco-innovation within the SMEs. According to the definition of eco-innovation by the EIO (2011), eco-innovation includes the implementation of a product, process or organizational innovation. The individual companies are asked if they have implemented any of these innovations. For each of the three innovations, a dummy is constructed with value 1, when the manager answered: "yes, during the past 24 months (between 2009 and 2011) a new or significantly improved eco-innovative solution has been introduced". Dummy value is 0, when the manager answered "no". Reported observations of DK/NA ("don't know" / "not applicable") are recoded as missing.

The dependent variable "*Eco-Innovation"* measures eco-innovation in a company in general. It is constructed as a combined dummy from the "*Product"*, "*Process"* and "*Organisational"* variables. The dummy has value 1, when any eco-innovation has been implemented in a company and value 0 otherwise.

[8] The questionnaire can be consulted on the website of the European Commission: http://ec.europa.eu/public_opinion/archives/flash_arch_329_315_en.htm

Independent variables

In finding what important factors are that contribute to eco-innovation in European SMEs emphasis is on the response to rising prices of resources. The managers were asked questions related to the past and future of material costs and a question about the material intensity of their firms. This part operationalizes these questions into the main independent variables "*Material Costs"*, "*Expected Material Costs"* and "*Material Intensity"*.

Companies' material costs

The independent variable "*Material Costs"* is constructed as an ordered categorical variable measuring if material costs have changed in the past five years. The variable is recoded in four categories[9] from decreased (value 1) to increased dramatically (value 4). The variable is based upon question 2 in the FL315 survey:

Have material costs for your company increased, or decreased in the past five years?

- *Decreased*
- *Remained unchanged*
- *Increased moderately*
- *Increased dramatically*
- *DK/NA*

The independent variable "*Expected Material Costs"* is constructed as an ordered categorical variable measuring what companies expect to happen with the resource prices in the coming 5 to 10 years. The variable is coded in three categories[10] from decrease (value 1) to increase (value 3) and is based upon question 3 in the FL315 survey:

Do you expect price increases for materials in the coming five to ten years?

- *No, material costs will decrease*
- *No, material costs will remain approximately the same*
- *Yes, material costs will increase*
- *DK/NA*

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[9] Reported observations of DK/NA ("don't know" / "not applicable") are recoded as missing.
[10] See 9.

The independent variable "*Material Intensity"* is constructed as an ordered categorical variable, which measures what percentage of a company's total cost, i.e. the gross production value, is material cost. Material cost is the cost of all materials used to manufacture a product or perform a service. The variable is coded in four categories[11] from less than 10% (value 1) to 50% or more (value 4) and is based upon question 1 in the FL315 survey:

What percentage of your company's total cost is material cost?

- *Less than 10%*
- *Between 10% and 29%*
- *Between 30% and 49%*
- *50% or more*
- *DK/NA*

Control variables

The regression analysis will be conducted with taking into account several control variables, which are expected to influence eco-innovative behaviour as will be discussed in this part. The control variables are "*Turnover Trend*", "*Size*", "*Sector*" and "*Country*" and hence might be of influence on the eco-innovation variables.

Company characteristics

First, the firm-specific influence of "*Turnover Trend"* is included to control for the past two-year turnover trend, as this may influence innovation decisions. The turnover trend gives a small insight in short-term company health. Horbach (2008) shows that economic situations in the past have ambiguous results on eco-innovative behaviour, but a positive trend may implicate room for investment. The variable is an ordered categorical variable and coded in three categories[12] from decreased (value 1) to increased (value 3). The variable is based upon question D3 in the FL315 survey:

[11] See 9.
[12] See 9.

Has your company's annual turnover decreased, remained unchanged or increased over the past two years?

- *Decreased*
- *Remained unchanged*
- *Increased*
- *DK/NA*

Second, the variable "*Size*" is added to control for firm-specific influences due to employee-base differences. Del Río González (2005) argues that smaller firms tend to be less eco-innovative due to financial constraints. Larger firms consider more diverse reasons including corporate image as a motivation to eco-innovate. In line with these findings, Rehfeld et al. (2007) find that firm size has a positive significant influence on environmental product innovations. The variable is constructed as a dummy, which distinguishes between small (10-49 employees) and medium (50-249 employees) enterprises. Note that micro-firms with less than 10 employees are not included in the FL315 survey. The dummy gets value 0 for a small company and value 1 for a medium sized firm.

Third, the variable "*Sector*" is included to control for sector-specific differences. The different sectors companies belong to are also likely to influence the eco-innovation decisions as for example in some sectors efficiency gains are more apparent or needed and different regulations may apply to the sectors. Horbach (2008) finds significant differences between sectors, he argues that some branches have more incentives to engage in quality competition and innovate more. The variable is operationalized as five sector dummy variables for the following categories:

- *Agriculture and fishing*
- *Construction*
- *Water supply; sewerage; waste management and remediation activities*
- *Manufacture*
- *Food services*

Fourth, the control variable "*Country*" is included to control for country-specific influences. Eco-innovative behaviour is likely influenced by regional differences as culture, political environment and availability of resources. Each individual observation is linked to a country identifier, creating dummy variables for the EU24 countries, thus excluding Cyprus, Luxembourg and Malta from the analysis due to a too small sample size.

3.3 Methodology

In order to answer the research question, three hypotheses have been formulated after analysis of the existing literature. Subsequently the variables have been operationalized for the data analysis. In this section, the method of data analysis will be discussed.

Data analysis

The data analysis is executed in the following steps. First, descriptive analyses are conducted, to increase the understanding of the variables that influence the eco-innovative behaviour of firms. Second, logistic regressions are performed, which take into account the binary structure of the dependent variables. The first logit regression is used to analyse the hypothesized relationship between the independent variables and the dependent variable "*Eco-Innovation*", tested in model A. Subsequently, models B to D, are used to test three binary logit regressions, which provide further insight in, what the independent variables contribute to, specifically which of the three types of eco-innovations under European entrepreneurs. Model B tests the independent variables on "*Product*" eco-innovation. Model C on "*Process*" eco-innovation. Model D on "*Organisational*" eco-innovation. Additionally, model E and F are constructed testing for an interaction effect of "*Material Intensity*" on the relationships between "*Material Costs*" or "*Expected Material Costs*" and "*Eco-Innovation*".

Model A to D are tested with binary logit regressions. From the logit regression, the sign and significance of the coefficients are interpretable, for a clear interpretation, the average marginal effects are computed. The average marginal effects measure the average increase or decrease in the probability of showing eco-innovative behaviour following from being in one category compared to a base category of a material costs variable. The interpretations of the regression results should be done with caution. The results do not imply causality. The analysis is constructed to find relationships between resource scarcity and the probability to invest in eco-innovation.

Model E and F are constructed as a four-step logit regression. First, the main independent variable is regressed on "Eco-Innovation". Second, the *"Material Intensity"* variable is added to explore for initial influence on the possibly moderated relationship between "*Material Costs*" or "*Expected Material Costs*" and "*Eco-Innovation".* Third, the interaction term is added, to test for the moderating relationship. Finally, the control variables are added to test for further validity of the proposed moderating relationship. Only the sign and significance are interpretable from the logit regressions. No marginal effects are constructed of the moderating effect of the factor variables.

In all models, the control variables are added to test for the effect of other variables on the relationship under investigation. Variables are included to control for firm, sector and country specific effects. The models have been tested on a 1%, 5% and 10% significance level. Furthermore, all models are tested based upon heteroscedasticity-robust standard errors. The regressions are tested on joint significance with the Wald statistic (Wooldridge, 2009). The Wald statistic is significant on a 1% significance level for all models, but only included in model E and F in the appendix, which present the coefficients of the binary regressions in Table 9 and 10. To check whether correlation is present, but not problematic, a Spearman correlation matrix is constructed. The Spearman rank correlation coefficient matrix shows the strength of dependency of the variables. The results can be consulted in Table 3 of the appendix. Collinearity might lead to imprecise estimates in the form of large standard errors and biased coefficients. The correlations between "*Material Intensity*", "*Material Costs*", "*Expected Material Costs*" and the three eco-innovation types shows that most correlations are very weak and not significantly dependent. Only the correlations between "*Material Costs*" and the eco-innovation types are significantly and positively correlated. The table does not show signs of multicollinearity since correlation coefficients are low.

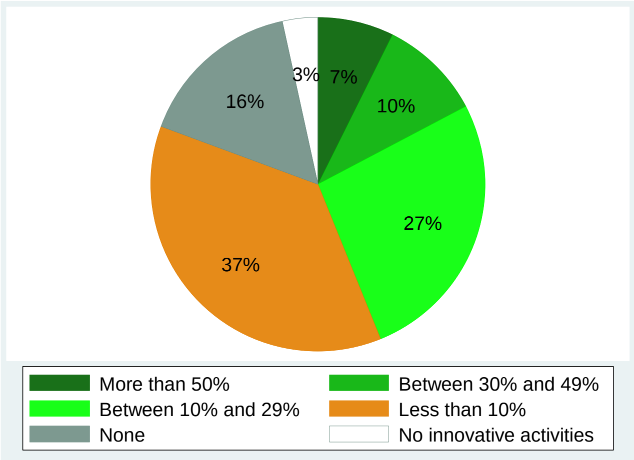
4. Results

In this chapter, the results of the empirical analysis of the FL315 survey will be elaborated following the steps of the data analysis. First, the descriptive statistics will be discussed, followed by the findings from model A to F. Finally, the results and findings in relation to the hypotheses will be summarized.

4.1 Descriptive statistics

The dataset consists of survey data on the firm level, meaning that the observations are composed of company information of 5222 European firms. Table 4 in the appendix shows the descriptive statistics of the dataset, including the number of observations, mean, standard deviation and minimum and maximum value for each variable. The sample of 5222 firms exists for 79% out of small firms (10-49 employees). Only 29% of the firms have experienced an increase in the annual turnover in the past two years before the survey, a probable explanation could be the economic crisis and the reported rise in material costs. Figure 3 provides a descriptive pie chart of the shares of eco-innovation related investments undertaken by European SMEs in the last 5 years. Care should be taken with the interpretation of this figure. The question asked upon which this pie chart is constructed provides a relative orientation of the share of eco-innovation investment by the firms, e.g. a firm that invested in just one small eco-innovation has a share of 100%, which may have negligible effect on the company and the environment compared to a firm with a much lower share. However, the figure can be used to provide a description of eco-innovation adoption in EU SMEs. The figure shows that 81% of the sample is involved in eco-innovation, but only 7% strongly commits to eco-innovation, having a share of eco-innovation investments of more than 50%, but the amount and magnitude are unknown. The figure and the percentages sketch awareness of eco-innovation, 81% of the firms invests at least a minor part of their innovation budget on eco-innovation. However, no broad implementation of eco-innovation is present. Only 45% of the firms had implemented an eco-innovation in the two years up to the survey, while 69% of the sample experienced a rise in material costs and 87% of the firms expect resource prices to rise in the near future.

Figure 3. Share of innovation investments related to eco-innovation in last 5 years.

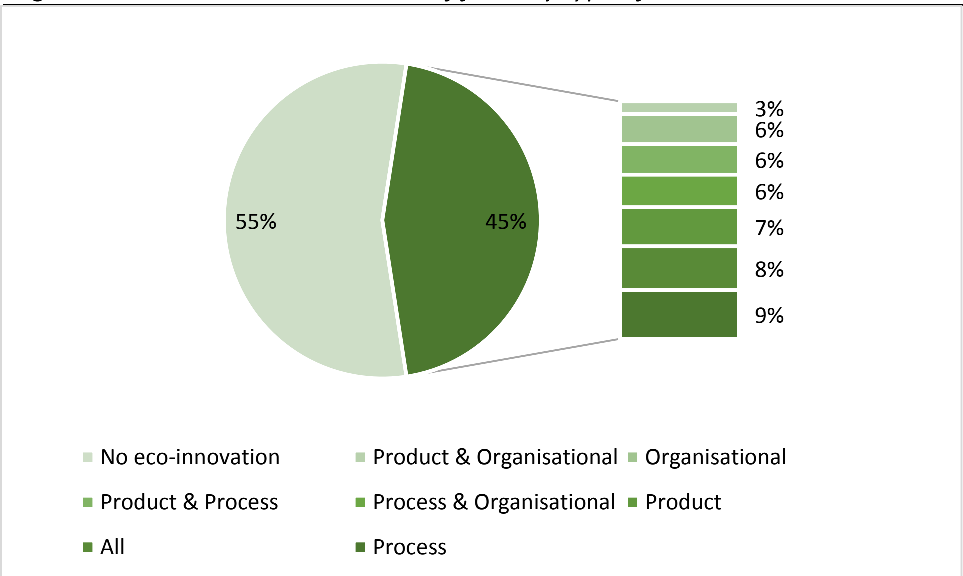


Source: FL315 (EC, 2011) Base: n/N all companies (4935/5222), % EU27

Note: Figure is derived from Q6: "Over the last 5 years, what share of innovation investments in your company were related to eco-innovation, i.e. implementing new or substantially improved solutions resulting in more efficient use of material, energy and water?" Non-responding firms on this question have not been included in the figure. From the sample of 5222 firms, 4935 have responded on this question.

Under eco-innovating firms (45%), process eco-innovations have been implemented most often. Eco-innovating firms often invest in more than one type of innovation. Even 8% of the firms implemented each type of eco-innovation in the past 2 years before the survey. A distribution of eco-innovating firms and type(s) of implemented innovation is shown in figure 4.

Figure 4. Eco-innovation behaviour of firms by type of innovation.



Source: FL315 (EC, 2011) Base: n/N all companies (5081/5222), % EU27

4.2 Bivariate analysis

In Table 5 in the appendix, the distributions of non-eco-innovating firms (value 0) and eco-innovating firms (value 1) from the "*Eco-Innovation*" dummy are presented across the values of the independent and control variables. Hypothesis 1 proposes that eco-innovating firms are more represented by material intensive firms. The table shows that 66% of the eco-innovating firms have material costs of 30% or more, only 8% of the eco-innovating firms has less than 10% material costs of total costs. Non-eco-innovating firms are with 64% slightly less represented in the upper groups of 30% material costs or more and have 10% of the firms with less than 10% material costs of total costs. The table shows a small difference between eco-innovating and non-eco-innovating firms regarding the distribution levels across material intensity. This finding is verified by the Pearson $\chi2$ statistic ($\chi2$ = 8.09, p-value = 0.04) provided along the side of Table 5. The table does not provide convincing support for hypothesis 1, but shows that eco-innovating firms are more likely to have a higher share of material costs.

Increasing material costs of a firm are in hypothesis 2 proposed to increase eco-innovation investments. The table shows that eco-innovating firms are with 74% represented by firms who have experienced an increase in material costs. Non-eco-innovating firms are for 69% represented by firms who have experienced an increase. The Pearson $\chi2$ indicates that the groups are significantly independent of each other ($\chi2$ = 20.67, p-value = 0.00).

Hypothesis 3 proposes that an expected increase in material costs will increase the likelihood of eco-innovating behaviour. Table 5 shows for hypothesis 3 a similar, but weaker result as for hypothesis 1 and 2. The Pearson $\chi2$ is significant on a 5% significance level ($\chi2$ = 6.01, p-value = 0.05), however, it should be noted that large sample sizes may induce statistical significance with even small differences.

Three quarters of the non-eco-innovating firms have experienced no growth in the annual turnover over the past two years. Only 25% experienced an increase in the turnover trend compared to 36% of the eco-innovating firms. It seems that the financial situation in a firm is important to facilitate the possibility to eco-innovate. Though, still the majority of the eco-innovating firms did not experience turnover growth. These findings are supported by the Pearson $\chi2$ on a significance level of 1% ($\chi2$ = 69.59, p-value = 0.00).

The majority of the sample consists of small firms, 79%. In both groups, the majority of firms are also small firms, but the eco-innovating firms exist for 26% out of medium firms compared to 17% in the non-eco-innovating group. This finding might suggest that medium firms are more likely to eco-innovate relative to small firms. The information is supported by a significant $\chi 2$ value ($\chi 2$ = 69.59, p-value = 0.00).

The sector distributions indicate small but significant differences ($\chi 2$ = 17.71, p-value = 0.00). It seems that eco-innovating firms are more represented by manufacturing firms and less represented by construction and food services firms.

To have an idea if there might be a relationship between material intensive firms and eco-innovation performance, a two-sample t-test is conducted to compare the means on material intensity of the firms who responded "No" and "Yes" on the question if they had introduced any eco-innovation in the past two months (question D5). The results of the two-sample t-tests are included in Table 6 in the appendix. The average value of the "*Material Intensity"* variable is 2.90 for eco-innovating firms, whereas it is 2.83 for non-eco-innovating firms ($p<0.02$). The difference indicates more eco-innovation activity in material intensive firms opposed to less material intensive firms in line with the hypotheses. The separate eco-innovations, show that the means of the "*Material Intensity"* of firms for product eco-innovations are less significantly different ($p<0.10$) and even not significantly different for the process and organisational eco-innovations ($p<0.20$, $p<0.97$). This may imply that product innovations are related to more material intensive firms opposed to process and organisational innovations. The average value of the "*Material Costs"* variable is 2.91 for eco-innovating firms, whereas it is 2.81 for non-eco-innovating firms ($p<0.01$). The average value of the "*Expected Material Costs*" variable is not significantly different ($p<0.69$). Firms who eco-innovate are possibly more likely to have experienced material costs increases, opposed to non-eco-innovating firms. Such a difference is not observed related to the material costs expectations of firms.

4.3 Multivariate analysis on average marginal effects

The marginal effects of the binary logistic regressions of model A to D are displayed in Table 7 in the appendix. Firms who indicated to be the most material intensive, belonging to the 50% or more category, have also the highest probability to be eco-innovative compared to the less than 10% reference category in model A. That is, on average in the sample, for a firm which has 50% or more of the total firms' costs as material costs compared to a firm with less than 10% material costs, the probability of being eco-innovative increases by 5.1 percentage points, ceteris paribus. The average marginal effect is significant at a significance level of 10%. The marginal effect of the firms with material costs between 10% and 29% is not significantly different from the marginal effect of the base category. The marginal effects of "*Material Intensity"* are increasingly positive compared to the less material intensive reference category, the probability to eco-innovate increases with 4.1, 4.8 and 5.1 percentage points, respectively, which supports the general direction of hypothesis 1. Companies with higher material costs are more likely to eco-innovate.

The average marginal effects of the "*Material Costs"* categories are not significant. Eco-innovative behaviour is in model A not related to the differences in material costs changes of the past five years. In model A, no evidence is found for the general direction of hypothesis 2.

Firms which expect material costs to remain the same in the near future have the lowest probability to eco-innovate compared to firms which expect material costs to become cheaper, 17.7 percentage points lower. On average in the sample, firms which expect increasing material costs compared to firms which expect decreasing material costs, the probability of being eco-innovative decreases by 12.0 percentage points, ceteris paribus. The marginal effect is significant at a significance level of 10%. These findings are opposed to the general direction of hypothesis 3.

Model B is used to test the hypotheses on product eco-innovative behaviour. Firms, which indicated to have a share of material costs between 30% and 49% of firm total costs, have the highest probability to be eco-innovative compared to the less than 10% reference category. That is, on average in the sample, for a firm which has between 30% and 49% of the total firms' costs as material costs compared to a firm with less than 10% material costs, the probability of being eco-innovative increases by 4.4 percentage points, ceteris paribus. The average marginal effect is significant at a significance level of 10%. The marginal effects of the firms from the other categories are not significantly different from the marginal effect of the base category. The marginal effects of "*Material Intensity"* are not increasingly positive compared to the less material intensive reference category, which does not provide support for hypothesis 1b. Companies with higher material costs are not more likely to eco-innovate than companies in lower categories, only companies with a share of material costs between 30% and 49% compared to the base group are more likely to eco-innovate, providing partial evidence for hypothesis 1b.

The average marginal effects of the "*Material Costs"* categories are not significant. Product eco-innovative behaviour is in model B not related to the differences in material costs changes of the past five years. In model B, no evidence is found for hypothesis 2b.

Firms that expect material costs to remain the same in the near future have the lowest probability to implement a product eco-innovation compared to firms that expect material costs to become lower, 19.6 percentage points lower. On average in the sample, firms which expect increasing material costs compared to firms who expect decreasing material costs, the probability of implementing a product eco-innovation decreases by 16.1 percentage points, ceteris paribus. The marginal effect is significant at a significance level of 5%. These findings are opposing hypothesis 3b. The findings suggest that an increase in the expected material costs for a company will negatively influence the likelihood of the introduction of an eco-innovative product to the market.

Model C is used to test the hypotheses on the implementation of a process innovation. The average marginal effects of the independent variables are not significant. Process eco-innovative behaviour is in model C not related to the differences in material intensities of firms, or to material costs changes of the past five years, or expected changes in material costs. In model C, no evidence is found for sub-hypotheses 1c, 2c and 3c.

Model D, testing the hypotheses on the implementation of an organisational eco-innovation shows similar results as model B. Significant evidence are found for "*Material Intensity"* and "*Expected Material Costs*". The marginal effects of "*Material Intensity"* are not increasingly positive compared to the less material intensive reference category, which does not provide support for hypothesis 1d. Companies with a higher share of material costs are not significantly different from companies in lower categories in implementing organisational eco-innovations. Only companies with a share of material costs between 10% and 29% compared to the base group are more likely to eco-innovate providing partial evidence for hypothesis 1d. Hypotheses 2d and 3d are not supported in Model D.

Subsequently Table 7 provides information about the control variables. In all models, consistent evidence is found for the relationship between increasing firm turnover and eco-innovative behaviour. For example in model A, on average in the sample, for a firm which has experienced an increase in annual turnover compared to a firm which experienced a decrease in annual turnover, the probability of being eco-innovative increases by 11.7 percentage points, ceteris paribus. The average marginal effect is significant at a significance level of 1%.

In each model, also consistent results are found regarding the size of a company. Medium sized firms are more likely to eco-innovate, compared to small firms. For example in model A, on average in the sample, for a medium sized firm compared to a small firm, the probability of being eco-innovative increases by 10.8 percentage points, ceteris paribus. The average marginal effect is significant at a significance level of 1%.

Several sector differences are found. In general, looking at model A, C and D firms from the agricultural sector are most likely to implement a process or organisational eco-innovation. Model B indicates that firms from the water and waste management sector are more likely to implement a product eco-innovation, an increase of 11.7 percentage points compared to the agricultural sector, ceteris paribus.

Additionally differences between countries are found. Table 8 provides the marginal effects of model A to D, which are excluded from Table 7. The marginal effects are relative to the base country Belgium. Model A reveals that firms from Poland are most likely to show eco-innovative behaviour and firms from Hungary are the least likely to implement eco-innovations. Poland is known to have a large agricultural sector and consistent with the sectorial findings, firms from Poland are more likely to implement process and organisational eco-innovations.

4.4 Multivariate analysis on the interaction effect of material intensity

The following part will discuss the results of the logistic regression of *"Material Costs"* on *"Eco-Innovation"* moderated by *"Material Intensity".* Table 9 provides the results of model E in four steps for this regression with a possible interaction effect between *"Material Costs"* and *"Material Intensity"*.

Step 1. Having experienced a dramatic increase in material costs, compared to a decrease positively influences eco-innovative behaviour. The results display a coefficient of 0.232 at a significance level of 5%. This finding supports the direction of hypothesis 2.

Step 2. Adding "*Material Intensity*" changes the *"Material Costs"* coefficient to 0.200. The relationship between "*Material Costs*" and "*Eco-Innovation*" seems to weaken, when "*Material Intensity*" is added, providing evidence that "*Material Intensity*" might moderate the relationship, although negatively and not positively as hypothesized by sub-hypothesis 2e.

Step 3. Adding the interaction effects to model E results in no significant evidence as displayed in the table for step 3.

Step 4. In addition, when the control variables are added, no significant evidence is provided for an interaction effect. Adding the control variables in step 1 and 2 reduces also coefficient sizes and significance. These findings are not included in the table. It seems that no significant interaction effect exists between "*Material Intensity*" and "*Material Costs*". Sub-hypothesis 2e, a higher material intensity of a firm will strengthen the positive effect of the influence of material costs on the introduction of an eco-innovation, is rejected by these findings.

Quite similar results are found for model F, testing the binary regression of *"Expected Material Costs"* on *"Eco-Innovation"* moderated by *"Material Intensity".* Table 10 provides the results of model F.

In step 1, we find consistent results with the marginal effects from Table 7 opposing the direction of hypothesis 3. A firm that expects material costs to remain the same, compared to a firm that expects material costs to decrease, is less likely to eco-innovate. The results display a negative coefficient of -0.578 at a significance level of 5%.

Step 2. Adding "*Material Intensity*" changes the *"Expected Material Costs"* coefficient to -0.696. The relationship between "*Material Costs*" and "*Eco-Innovation*" seems to weaken even further, when "*Material Intensity*" is added, providing evidence that "*Material Intensity*" might moderate the relationship, although negatively and not positively as hypothesized by sub-hypothesis 3e.

However, as with model E. Step 3 and 4 do not provide significant evidence when adding the interaction effects to model F. Sub-hypothesis 3e, a higher material intensity of a firm will strengthen the positive effect of the influence of expected material costs on the introduction of an eco-innovation, is rejected by these findings.

4.5 Summary of the results

Table 1 summarizes the findings on the hypotheses. Evidence is found that firms with a higher share of material cost are more likely to eco-innovate in general. This finding is built upon partial evidence that firms with a higher share of material cost are more likely to implement a product or organisational eco-innovation. Providing support for hypotheses 1a, b and d. No support is found for a relationship between increasing material costs for a firm and eco-innovation. Rejecting hypothesis 2a to 2d. Furthermore, the opposite relationship is found for the expected increase in material prices and eco-innovation. Providing no support for hypothesis 3a to 3d. Additionally, no support has been found for hypotheses 2e and 3e. There is no significant moderating effect of the material intensity of a firm and the relationship between material costs or expected material costs and eco-innovation.

Table 1. Summary of the results.

Dependent Variable:	Eco-Innovation			Product			Process			Organisational		
	Empirical result	Hypotheses	Support	Empirical result	Hypotheses	Support	Empirical result	Hypotheses	Support	Empirical result	Hypotheses	Support
Material Intensity (H1)												
Less than 10% (base)												
Between 10% and 29%	0			0			0			+		
Between 30% and 49%	+			+			0			0		
50% or more	+	H1a	A	0	H1b	A/R	0	H1c	R	0	H1d	A/R
Material Costs (H2)												
Decreased (base)												
Remained unchanged	0			0			0			0		
Increased moderately	0			0			0			0		
Increased dramatically	0	H2a	R	0	H2b	R	0	H2c	R	0	H2d	R
Expected Material Costs (H3)												
Decrease (base)												
Remain unchanged	-			-			0			-		
Increase	-	H3a	R	-	H3b	R	0	H3c	R	-	H3d	R
Material Costs x *Material Intensity* (H2e)	0	H2e	R									
Expected Material Costs x *Material Intensity* (H3e)	0	H3e	R									

Note: 0 means the probability of investing in eco-innovation is not significantly influenced by the independent variable.
+ means the probability of investing in eco-innovation increases as the independent variable increases in value.
- means the probability of investing in eco-innovation decreases as the independent variable increases in value.
A: Accepted. The hypothesis is supported. R: Rejected. The hypothesis is not supported. A/R: Partially supported.

5. Discussion and conclusion

In this section, the results and literature are linked to discuss the meaning of the findings. Limitations of the research are discussed and the research question is answered. Finally, avenues for future research are proposed.

Discussion

Awareness of our present detrimental way of living, doing business and managing society has raised concern due to the mayor effects on the environment. According to Cohen and Winn (2007) our present way of doing business suffers from multiple market imperfections that contribute to environmental degradation. The focus of this study is on the market imperfection of firm inefficiency, specifically in relation to resources. A focus on resources is important assessing the effects of (over-) use of materials resulting in problematic environmental issues. Eco-innovation may help address these issues. Eco-innovation is seen as being able to improve efficiency, reducing costs, increase competitiveness and improve several other factors along the triple bottom line of people, planet and profit. Although potential benefits of eco-innovation seem apparent, not every firm shows innovation activity and therefore this research focussed specifically on the determinants of eco-innovative behaviour. The literature on the determinants of eco-innovation is well developed, however, emphasis on material cost as determinant is absent in the literature.

In this research, the share of material cost of total cost of a firm, the material intensity, is proposed to fit under the technology push determinants of eco-innovation, in the eco-innovation determinants framework of Rennings (2000). Material intensive firms, firms with a high share of material cost of a company's total cost, are found to be more likely to invest in eco-innovation. These results are however only partially found for product and organisational eco-innovations and not for process eco-innovations. Cleff and Rennings (1999) using German panel data did research to eco-innovation decisions of firms about product and process innovation and found that process innovations are more dependent on policy. Significant results were nonetheless expected, because process innovations are used to reduce the input of resources while producing the same output of products. Reducing the amount of input resources, decreases material costs, which was expected to be more relevant for material intensive firms.

Furthermore, an analysis on the market pull determinants of eco-innovation in the form of material costs of a firm is conducted. No evidence is found however, that the experienced material costs of a firm are related to the eco-innovation investment strategy of a firm. Concerns of the EU about resource scarcity and possible cost benefits for companies are not translated into action.

Rising prices of resources were hypothesized to trigger eco-innovation, as a tool to minimize costs. However, increasing costs are not found to induce eco-innovation. While eco-innovation might be an opportunity to reduce costs, firms are not experienced yet in dealing with environmental issues according to Porter and van der Linde (1995). Cost minimization, particularly by resource savings, functions as motivator for eco-innovation, in order to comply with environmental regulation and realize production efficiency, as shown in literature (Horbach et al., 2013). This research, however, does not find relationships between changes in resource prices and eco-innovative behaviour. The induced innovation hypothesis by Hicks (1932) is also rejected by these findings. Increased costs of resources are not leading to innovation to reduce the use of those resources. These results may be explained by possible barriers to innovate. Even when firms want to respond on the increased costs of resources, innovation might be impossible due to other factors as possibly the economic crisis. The risk of the innovation investment might be too high. Innovation is at least in this research not associated with increasing material costs.

Additionally, eco-innovation investment strategy based on expected material costs are also tested as a market pull determinant of eco-innovation. The findings oppose the hypothesis that expected price increases would motivate firms to eco-innovate. The results provide significant evidence that when firms expect prices to increase in the future, compared to firms that expect prices to decrease, the likelihood of eco-innovative behaviour is reduced. This is a surprising finding, namely, under increasing resource scarcity and rising resource prices, firms were expected to innovate. The results regarding the negative relationship between expected increases in material prices, compared to expected decreases, and eco-innovative behaviour, might be caused by the economic downturn. A majority of the firms in the FL315 survey (EC, 2011) even indicated to realise the opportunities of saving material costs. However, economic downturn reduces investment on the consumer and producer side. An expected increase in costs may inhibit all forms of investment due to the economic climate. Most important barriers to eco-innovate were indicated in the FL315 survey to be related to economic and financial factors as uncertain market demand, lack of funds and uncertain return on investments. Firms, which expect material prices to decrease in the future, might foresee better circumstances to invest in eco-innovation. Eco-innovation outcomes remain uncertain (Mazzanti & Zoboli, 2006). Porter and van der Linde (1995) argue that firms are not experienced yet in dealing with environmental issues. Regulation is found to provide guidance and function as revelation, but firms probably need more experience with eco-innovations to de-risk investment decisions significantly.

Besides eco-innovations, several other tools, for example recycling, can help firms reduce material costs and may act as substitute for eco-innovation. Nine in ten firms of the sample have implemented changes, but it should be noted that it is ambiguous if changes may be eco-innovations or related to eco-innovation. The possible substitute changes provide similar results regarding possible associations with material costs. Furthermore, the same trend for company characteristics are found. Medium sized firms, companies with turnover growth, were more likely to have introduced changes (EC, 2011). The surprising results are in this case not explained by other changes that produce similar outcomes.

Another view on these results can be made with the Prospect theory by Kahneman and Tversky (1979). A behavioural economic theory that analyses decision making under risk from a psychological perspective. This theory includes differences in reference points, allowing the behaviour of loss aversion, instead of the behaviour of a rational agent in utility theory, which maximizes utility in any given situation (Tversky & Kahneman, 1986). Over two third of the sample experienced a decreasing or stable turnover creating a probable risk averse reference point in making investment decisions as proposed by prospect theory. In other words, the decision to undergo price increases without implementing changes, an unfavourable settlement of certain loss, is chosen out of fear of a large loss, may, with slimmer chance, the eco-innovation investment not repay its promises.

Finally, the material intensities of a firm are tested to moderate the relationship of material costs or expected material costs and eco-innovation investment. A direct association is found when "Material Intensity" is added in the regression, providing evidence that "*Material Intensity*" might moderate the relationships, although negatively and not positively as hypothesized by sub-hypotheses 2e and 3e. A material intensive firm may have a decreased probability of implementing eco-innovations when an increase in material costs has been experienced or an increase in material prices is expected. However, such a moderation, positive or negative, is not found in the results for the indirect interaction effects.

Some remarks can be made about the firm characteristics added in the analysis. It seems that firms with increasing annual turnover have more room for investing in eco-innovation. Maybe not a surprising finding, an explanation might be found in the capability and investment room of companies. Past material costs were not found to have an association with eco-innovative behaviour. However, rising material prices might influence the annual turnover negatively, contributing to a difficult investment climate. Reverse causality may also be present. Firms that implemented an eco-innovation may have been more likely to experience an increase in annual turnover. Furthermore, it seems that small firms are less capable and/or have less room for investing in eco-innovation. It is found that medium sized firms are more likely to eco-innovate, compared to small firms. Subsequently, sector differences have been found. In general, firms from the agricultural sector are most likely to implement a process or organisational eco-innovation and firms from the water and waste management sector are more likely to implement a product eco-innovation. In line with hypothesis 2, proposing an association between past material costs and eco-innovative behaviour, the sectors that were more likely to have implemented an eco-innovation, SMEs from the agricultural and water supply and waste management sectors, were more likely to indicate that material costs had increased in the past five years compared to the firms from the other sectors. Marin et al. (2014) did not found that being in a certain sector predicts eco-innovative behaviour using the same dataset, but this conclusion is based upon the divergence of SMEs belonging to certain clusters of a created taxonomy and the belonging to the sectors of activity. Additionally, country differences are found. Firms, from for example Poland, are more likely to eco-innovate compared to firms from Belgium. This difference may be caused by the large agricultural sector of Poland. Country differences were expected, though the cause of country specific differences were not of main interest to this research.

Limitations

The empirical analysis of this research is based on the data of the Flash Eurobarometer Survey number 315 conducted on behalf of the European Commission (2011). Some main limitations are associated with survey datasets. The perceptions of the firms are from a single moment in time, the survey was conducted in the beginning of 2011. Time invariant effects are controlled for by the survey data and time variant effects are held constant, but not specifically controlled for. The crisis, for example, may have had a substantial effect on the survey results. Panel data includes time variant effects and therefore future analysis on this topic should additionally be conducted using panel data. Furthermore, survey questions are sensitive to self-reporting biases. Respondents might for example answer untruthfully to answer in a social desirable manner. Additionally, the sample might be unbalanced. The sample of 5222 firms exists for 79% out of small firms (10-49 employees) and may therefore be less generalizable for all SMEs especially regarding medium sized firms. Small or micro firms with under 10 employees are not at all included in the dataset. Furthermore, the sample sizes of the countries are rather small (between 50 and 250). Higher sample sizes will increase the power of the dataset and generalizability of the results. Cyprus, Malta and Luxembourg were excluded from the analysis because of the small sample size. The variables are mainly constructed as dummies or ordered categorical variables, restricting the sensitivity of the results. Variables used to measure eco-innovation indicate if any eco-innovation has been implemented, but they do not reveal the impact an eco-innovation has. It is therefore not possible to compare eco-innovations between firms in this dataset reliably. The survey includes some ambiguities in measuring eco-innovations and other changes implemented to reduce material costs. A more comprehensive survey, including a clear list of innovations, eco-innovations and possible other changes could increase the specificity of the results. Improved questions concerning the relative measurements of material costs and eco-innovations and their impacts should increase the validity and meaning or ease of understanding of the results. Finally, a wider range of control variables could have helped in explaining more of the variance and ruling out possible confounding associations.

Conclusion

Regression analyses have been used to find relationships between material costs variables and eco-innovation investment behaviour, contributing in finding determinants of eco-innovation related to material costs of a firm and providing insights in how to induce specific types of eco-innovation for different types of firms. From the research, it can be concluded that material intensities of firms, being complementary to the technology push factor of Rennings (2000), positively influences eco-innovative behaviour. Although, process eco-innovations seem not to be related to the independent variables in this study. Second, material costs, cannot be concluded to be complementary to the market pull factor and thirdly, expected material costs might be a determining market pull factor on eco-innovation, however, a negative relationship has been found. Finally, medium sized firms and firms that have experienced an increase in annual turnover are more likely to eco-innovate. Additionally, differences in eco-innovative behaviours are found over sectors and countries.

The results of this research maybe worrying. Most firms do not eco-innovate to improve their resource efficiency. The circumstances most firms are in, should spur action. Only 29% of the firms has experienced an increase in the annual turnover in the past two years and 69% of the firms experienced a rise in material costs. Furthermore, 87% of the firms expect resource prices to rise in the near future. Instead of spurring action however, it seems to promote inaction. The implications of this study are a call for action. Awareness of environmental issues related to overconsumption and externalities, the observation of material dependency and security and the possibilities for firm efficiency improvements and material costs savings are not translated into action. At least, not enough. Policy makers in the EU could be more aggressive in eco-innovation regulation, but should carefully consider the differences between firms, sectors and countries. Influencing resource costs cannot be concluded to induce more eco-innovation, although, if firms expect prices to decrease in the near future, product and organisational innovations are more likely to be implemented. The financial and economic climate, firms are confronted with, seems to influence their eco-innovative behaviours significantly. Providing economic incentives and implementing intelligent mass customization funding mechanisms could be more effective. The SMEs should consider eco-innovation as an investment to save costs and to stay competitive under resource price pressures. Learning from good practices of others and familiarizing with environmental issues and innovations may help de-risk the investment. Inaction might only be a surviving option in the short term, however, will probably not suffice to break the negative turnover cycle under rising prices of materials.

Future research

Future research should include panel data with additional and improved measures on eco-innovation to improve the knowledge of the determinants of eco-innovation and create the possibility to compare firms in order to explore the rationale behind eco-innovation strategies. Economic incentives, as increased material costs, are proposed to influence innovation investments, this is however not confirmed in this research and therefore further empirical evidence should be gathered to understand the possible relationship between resource costs and innovation. Expected price increases are associated with less eco-innovative behaviour. Further research on the topic should underpin these findings. Is for example economic downturn the sole driver behind this finding? General acknowledgement of our detrimental behaviour to the environment is not translated into business strategies according to this paper’s analysis. Further research may focus on why some firms implement eco-innovations and others do not, especially considering the proposed advantages. A counter argument to eco-innovation by Brunnermeier and Cohen (2003) is the fear of increasing stringency of regulations when firms eco-innovate. It could be interesting to explore if regulation may be a burden or a revelation to resource efficiency. Additionally the analyses show differing results for the implementation of the eco-innovation types per sector. It may be useful to research why certain sectors are more likely to implement certain eco-innovations and other sectors are more likely to lack behind. Such information could provide insights to further stimulate eco-innovation in firms and provide data to increase effectiveness of environmental policy. While firm level analysis is important to provide knowledge and tools for the implementation of eco-innovation. The way of using resources is relevant for the whole society. Differences per country in eco-innovation adoption are found. Therefore, as well country level research as individual level research should be on the future agenda to explain country differences to improve best practice sharing and spur environmental innovation via social change.

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Appendix

Table 1. Sample size per country.

Total interviews conducted					
AT	Austria	200	LT	Lithuania	202
BE	Belgium	201	LU	Luxembourg	51
BG	Bulgaria	204	MT	Malta	50
CY	Cyprus	50	NL	Netherlands	200
CZ	Czech Republic	200	PL	Poland	200
DK	Denmark	201	PT	Portugal	201
EE	Estonia	200	RO	Romania	200
FI	Finland	205	SK	Slovakia	200
FR	France	250	SI	Slovenia	200
DE	Germany	250	ES	Spain	250
EL	Greece	201	SE	Sweden	200
HU	Hungary	202	UK	United Kingdom	251
IE	Ireland	200			
IT	Italy	251	TOTAL		5222
LV	Latvia	202	TOTAL EU24		5071

Note: EU24 is the EU27 sample excluding Cyprus, Luxembourg and Malta.

Table 2. Description of Variables.

Variable	**Description**
Eco-Innovation activity (DV)	
Product	Dummy = 1 when during the past 24 months (between 2009 and 2011) a new or significantly improved eco-innovative product or service has been introduced to the market. Dummy = 0 otherwise.
Process	Dummy = 1 when during the past 24 months (between 2009 and 2011) a new or significantly improved eco-innovative production process or method has been introduced. Dummy = 0 otherwise.
Organisational	Dummy = 1 when during the past 24 months (between 2009 and 2011) a new or significantly improved eco-innovative organisational innovation has been introduced. Dummy = 0 otherwise.
Eco-Innovation	Dummy = 1 when during the past 24 months (between 2009 and 2011) any eco-innovation has been introduced. Dummy = 0 when no eco-innovation has been introduced.
Companies' material costs (IV)	
Material Intensity	(categorical) Share of material cost, less than 10%, between 10% and 29%, between 30% and 49% or 50% and more, from company's total cost (gross production value).
Material Costs	(categorical) A company's past five years material costs dramatic increase, moderate increase, unchanged status or decrease.
Expected Material Costs	(categorical) A company's expected material costs increase, unchanged status or decrease for the coming five to ten years.
Company demographics (control)	
Turnover Trend	(categorical) A company's past two years turnover increase, unchanged status or decrease.
Size	Dummy = 1 if a company is small (10-49 employees), 0 when a company is of a medium size (50-249 employees).
Sector	Sector identifier of a company.
Country	Country where company is based. Country identifier dummies.

Table 3. Spearman rank correlation coefficients. Strength of dependency.

		1	2	3	4	5	6	7	8	9	10	11
1	Product	1.000										
2	Process	0.360*	1.000									
3	Organisational	0.308*	0.413*	1.000								
4	Eco-Innovation	0.616*	0.716*	0.603*	1.000							
5	Material Intensity	0.013	0.018	0.002	0.026*	1.000						
6	Material Costs	0.027*	0.062*	0.040*	0.049*	0.105*	1.000					
7	Expected Material Costs	0.004	0.029*	0.014	0.016	-0.004	0.133*	1.000				
8	Turnover Trend	0.050*	0.088*	0.073*	0.100*	-0.017	0.142*	0.003	1.000			
9	Size	0.047*	0.108*	0.060*	0.097*	0.047*	-0.009	-0.002	0.062*	1.000		
10	Sector	0.014	0.019	-0.012	0.016	0.000	0.040*	0.004	-0.001	0.024	1.000	
11	Country	0.003	0.033*	0.002	0.014	0.087*	-0.005	0.025	0.059*	0.049*	0.004	1.000

Source: FL315 (EC, 2011) Significance: * p<0.1 (obs=4157)

Table 4. Descriptive statistics.

Variables	N	Mean	Std. Dev.	Min.	Max.
Product	5104	0.239	0.427	0	1
Process	5094	0.294	0.456	0	1
Organisational	5062	0.227	0.419	0	1
Eco-Innovation	5081	0.451	0.498	0	1
Material Intensity	4702	2.862	0.954	1	4
Material Costs	5053	2.857	0.918	1	4
Expected Material Costs	4996	2.894	0.349	1	3
Turnover Trend	5107	1.856	0.847	1	3
Size	5222	0.209	0.407	0	1
Sector	5222	3.222	1.173	1	5
Country	5071	12.29	6.840	1	24

Source: FL315 (EC, 2011)

Table 5. Bivariate analysis: the distributions of non-eco-innovating firms (value 0, No) and eco-innovating firms (value 1, Yes) from the *"Eco-Innovation"* dummy are presented across the values of the independent and control variables.

	Eco-innovating firm:	No	Yes	χ2	p-value	Obs.
DV						
Eco-Innovation		54.89	45.11			5081
IV						
Material Intensity	Less than 10%	10.20	7.96	8.09	0.04	4608
	Between 10% and 29%	25.67	25.77			
	Between 30% and 49%	34.91	34.87			
	50% or more	29.21	31.40			
Material Costs	Decreased	11.46	10.54	20.67	0.00	4935
	Remained unchanged	19.22	15.02			
	Increased moderately	45.95	47.35			
	Increased dramatically	23.36	27.09			
Expected Material Costs	Decrease	1.13	1.67	6.01	0.05	4874
	Remain unchanged	8.55	7.07			
	Increase	90.32	91.26			
Controls						
Turnover Trend	Decreased	47.26	40.31	69.59	0.00	4985
	Remained unchanged	28.03	24.14			
	Increased	24.71	35.55			
Size	Small	83.26	74.21	62.37	0.00	5081
	Medium	16.74	25.79			
Sector	Agriculture	7.78	8.99	17.71	0.00	5081
	Construction	30.41	25.92			
	Water/waste management	3.05	3.80			
	Manufacture	51.45	54.93			
	Food services	7.31	6.37			

Source: FL315 (EC, 2011)

Note: χ2 is the Pearson chi-squared statistic, which tests the hypothesis that the rows and columns in a two-way table are independent. Obs. are the observations per two-way table.

Table 6. Two-sample t-tests comparing means of Material Intensity. Material Costs and Expected Material Costs on Eco-Innovation and the three eco-innovation types.

Material Intensity by Eco-Innovation

Group	Obs.	Mean	Std. Err.	Std. Dev.
No	2509	2.831	0.019	0.964
Yes	2099	2.897	0.020	0.938
comb	4608	2.861	0.014	0.953
diff		-0.066	0.028	
diff = mean (No) - mean (Yes)				
Ha: diff ≠ 0		p-value:		0.020
t =	-2.332			
DOF =	4606			

Material Costs by Eco-Innovation

Group	Obs.	Mean	Std. Err.	Std. Dev.
No	2705	2.812	0.018	0.922
Yes	2230	2.910	0.019	0.914
comb	4935	2.856	0.013	0.919
diff		-0.098	0.026	
diff = mean (No) - mean (Yes)				
Ha: diff ≠ 0		p-value:		0.000
t =	-3.720			
DOF =	4933			

Expected Material Costs by Eco-Innovation

Group	Obs.	Mean	Std. Err.	Std. Dev.
No	2654	2.892	0.007	0.345
Yes	2220	2.896	0.008	0.356
comb	4874	2.894	0.005	0.350
diff		-0.004	0.010	
diff = mean (No) - mean (Yes)				
Ha: diff ≠ 0		p-value:		0.690
t =	-0.406			
DOF =	4872			

Material Intensity by Product eco-innovation

Group	Obs.	Mean	Std. Err.	Std. Dev.
No	3511	2.851	0.016	0.961
Yes	1107	2.904	0.028	0.928
comb	4618	2.864	0.014	0.954
diff		-0.053	0.033	
diff = mean (No) - mean (Yes)				
Ha: diff ≠ 0		p-value:		0.104
t =	-1.630			
DOF =	4616			

Material Intensity by Process eco-innovation

Group	Obs.	Mean	Std. Err.	Std. Dev.
No	3249	2.849	0.017	0.963
Yes	1363	2.888	0.025	0.935
comb	4612	2.861	0.014	0.955
diff		-0.040	0.031	
diff = mean (No) - mean (Yes)				
Ha: diff ≠ 0		p-value:		0.199
t =	-1.290			
DOF =	4610			

Material Intensity by Organisational eco-innovation

Group	Obs.	Mean	Std. Err.	Std. Dev.
No	3535	2.862	0.016	0.958
Yes	1051	2.861	0.029	0.939
comb	4586	2.862	0.014	0.954
diff		0.001	0.034	
diff = mean (No) - mean (Yes)				
Ha: diff ≠ 0		p-value:		0.973
t =	0.034			
DOF =	4584			

Source: FL315 (EC. 2011)

Note: Comb is combined. Diff is difference. DOF is degrees of freedom.

Table 7. Binary logistic regressions of material intensity, material costs and expected material costs on eco-innovation activity. Average marginal effects are shown with their standard errors of models A to D.

	Model A		Model B		Model C		Model D	
Dependent variable:	*Eco-innovation*		*Product*		*Process*		*Organisational*	
Variables	margins	se	margins	se	margins	se	margins	se
Material Intensity (H1)								
Less than 10% (base)								
Between 10% and 29%	0.041	(0.029)	0.036	(0.024)	0.033	(0.026)	0.043*	(0.024)
Between 30% and 49%	0.048*	(0.028)	0.044*	(0.024)	0.037	(0.026)	0.033	(0.023)
50% or more	0.051*	(0.029)	0.038	(0.024)	0.020	(0.026)	0.016	(0.023)
Material Costs (H2)								
Decreased (base)								
Remained unchanged	-0.039	(0.029)	-0.014	(0.026)	-0.042	(0.027)	-0.029	(0.025)
Increased moderately	-0.013	(0.026)	-0.005	(0.023)	-0.007	(0.024)	-0.024	(0.022)
Increased dramatically	0.024	(0.028)	0.014	(0.025)	0.035	(0.026)	0.018	(0.025)
Expected Material Costs (H3)								
Decrease (base)								
Remain unchanged	-0.177***	(0.068)	-0.196***	(0.066)	-0.046	(0.062)	-0.169***	(0.064)
Increase	-0.120*	(0.063)	-0.161**	(0.063)	0.007	(0.058)	-0.110*	(0.061)
Control variables								
Turnover Trend								
Decreased (base)								
Remained unchanged	0.010	(0.019)	0.012	(0.016)	0.002	(0.017)	0.009	(0.016)
Increased	0.117***	(0.019)	0.056***	(0.016)	0.092***	(0.017)	0.089***	(0.016)
Size	0.108***	(0.019)	0.053***	(0.017)	0.109***	(0.018)	0.062***	(0.017)
Sector								
Agriculture (base)								
Construction	-0.092***	(0.030)	0.030	(0.026)	-0.141***	(0.030)	-0.039	(0.027)
Water/waste management	-0.027	(0.052)	0.117**	(0.048)	-0.073	(0.049)	-0.064	(0.043)
Manufacture	-0.059**	(0.029)	0.015	(0.025)	-0.085***	(0.028)	-0.058**	(0.025)
Food services	-0.061	(0.041)	0.050	(0.036)	-0.122***	(0.038)	-0.016	(0.036)
Observations	4,248		4,248		4,247		4,229	
Control	YES		YES		YES		YES	

Source: FL315 (EC, 2011)

Note: Country dummies are not displayed but included when Control indicates a YES. Marginal effects for factor levels is the discrete change from the base level. Robust standard errors (se) in parentheses. *** denotes significance at 1% p<0.01, ** at 5% p<0.05, * at 10% p<0.1.

Table 8. Marginal effects of country dummy variables in models A to D (relative to Belgium).

	Model A		Model B		Model C		Model D	
Variables	margins	se	margins	se	margins	se	margins	se
Czech Republic	0.039	(0.056)	-0.002	(0.047)	-0.017	(0.050)	0.029	(0.049)
Denmark	0.057	(0.054)	-0.008	(0.045)	0.034	(0.050)	-0.066	(0.043)
Germany	0.034	(0.052)	0.025	(0.044)	-0.024	(0.046)	-0.020	(0.042)
Estonia	-0.043	(0.055)	-0.083*	(0.043)	-0.026	(0.049)	-0.015	(0.046)
Greece	0.107*	(0.056)	0.096*	(0.050)	0.078	(0.052)	0.066	(0.049)
Spain	0.119**	(0.053)	0.053	(0.046)	0.137***	(0.050)	0.141***	(0.048)
France	-0.061	(0.052)	-0.004	(0.044)	-0.072	(0.045)	-0.034	(0.042)
Ireland	0.110**	(0.056)	0.060	(0.048)	0.105**	(0.051)	0.084*	(0.049)
Italy	0.047	(0.055)	0.115**	(0.049)	0.045	(0.050)	0.009	(0.047)
United Kingdom	0.011	(0.055)	0.054	(0.047)	0.037	(0.050)	-0.035	(0.044)
Latvia	-0.016	(0.056)	0.031	(0.048)	-0.005	(0.051)	-0.012	(0.047)
Lithuania	-0.096*	(0.056)	-0.001	(0.048)	-0.072	(0.049)	-0.076*	(0.045)
Bulgaria	-0.012	(0.056)	-0.028	(0.046)	-0.000	(0.050)	0.071	(0.050)
Hungary	-0.137***	(0.053)	-0.103**	(0.042)	-0.113**	(0.045)	-0.085**	(0.043)
Romania	0.011	(0.057)	0.061	(0.049)	0.076	(0.053)	0.077	(0.050)
Netherlands	0.083	(0.056)	0.011	(0.047)	0.066	(0.052)	0.065	(0.049)
Austria	0.063	(0.055)	0.043	(0.046)	0.012	(0.049)	-0.012	(0.045)
Poland	0.199***	(0.055)	0.029	(0.047)	0.173***	(0.052)	0.134***	(0.050)
Portugal	0.072	(0.055)	0.092*	(0.049)	0.117**	(0.052)	0.135***	(0.050)
Slovenia	0.060	(0.055)	0.016	(0.046)	0.034	(0.050)	-0.016	(0.045)
Slovakia	0.051	(0.057)	0.009	(0.048)	0.009	(0.051)	0.054	(0.049)
Finland	-0.010	(0.054)	-0.032	(0.044)	-0.001	(0.049)	-0.159***	(0.038)
Sweden	0.022	(0.055)	-0.009	(0.045)	0.034	(0.050)	-0.042	(0.044)

Source: FL315 (EC, 2011)

Note: Marginal effects is the discrete change from the base level country Belgium (BE). Robust standard errors (se) in parentheses. *** denotes significance at 1% p<0.01, ** at 5% p<0.05, * at 10% p<0.1.

Table 9. Binary logistic regressions of material costs on eco-innovation activity. The probability coefficients are shown with their standard errors of model E in four steps.

Model E	Step 1		Step 2		Step 3		Step 4	
Dependent variables:	*Eco-Innovation*		*Eco-Innovation*		*Eco-Innovation*		*Eco-Innovation*	
Variables	coef	se	coef	se	coef	se	coef	se
Material Costs (H2)								
1 Decreased (base)								
2 Remained unchanged	-0.163	(0.111)	-0.145	(0.116)	-0.469	(0.341)	-0.498	(0.345)
3 Increased moderately	0.114	(0.096)	0.082	(0.100)	-0.050	(0.315)	-0.041	(0.321)
4 Increased dramatically	0.232**	(0.104)	0.200*	(0.108)	0.433	(0.349)	0.473	(0.356)
Material Intensity								
1 Less than 10% (base)								
2 Between 10% and 29%			0.212*	(0.116)	0.168	(0.322)	0.116	(0.323)
3 Between 30% and 49%			0.198*	(0.112)	0.067	(0.313)	0.168	(0.316)
4 50% or more			0.257**	(0.115)	0.154	(0.322)	0.260	(0.323)
Material Costs x *Material Intensity*								
2 x 2					0.086	(0.411)	0.211	(0.416)
2 x 3					0.427	(0.394)	0.379	(0.400)
2 x 4					0.551	(0.406)	0.528	(0.413)
3 x 2					0.159	(0.368)	0.137	(0.375)
3 x 3					0.157	(0.359)	-0.005	(0.366)
3 x 4					0.118	(0.369)	-0.110	(0.375)
4 x 2					-0.327	(0.412)	-0.332	(0.420)
4 x 3					-0.165	(0.396)	-0.302	(0.403)
4 x 4					-0.267	(0.401)	-0.469	(0.408)
Control variables								
Turnover Trend								
Decreased (base)								
Remained unchanged							0.015	(0.081)
Increased							0.465***	(0.078)
Size								
Small size (base)								
Medium size							0.457***	(0.078)
Sector								
Agriculture (base)								
Construction							-0.392***	(0.126)
Water/waste management							-0.170	(0.213)
Manufacture							-0.243**	(0.119)
Food services							-0.246	(0.170)
Constant	-0.277***	(0.087)	-0.446***	(0.130)	-0.361	(0.272)	-0.454	(0.345)
Observations	4,935		4,547		4,547		4,366	
Control	No		No		No		YES	
Wald chi-square	20.59		21.23		29.68		194.6	
Log likelihood	-3387		-3123		-3118		-2901	
Pseudo R2	0.00306		0.00338		0.00489		0.0349	

Source: FL315 (EC, 2011)

Note: Country dummies are not displayed but included when Control indicates a YES. Robust standard errors (se) in parentheses. *** denotes significance at 1% p<0.01, ** at 5% p<0.05, * at 10% p<0.1.

Table 10. Binary logistic regressions of expected material costs on eco-innovation activity. The probability coefficients are shown with their standard errors of model F in four steps.

Model F	Step 1		Step 2		Step 3		Step 4	
Dependent variables:	*Eco-Innovation*		*Eco-Innovation*		*Eco-Innovation*		*Eco-Innovation*	
Variables	coef	se	coef	se	coef	se	coef	Se
Expected Material Costs (H3)								
Decrease (base)								
Remain unchanged	-0.578**	(0.267)	-0.696**	(0.281)	-0.762	(0.662)	-0.924	(0.695)
Increase	-0.378	(0.248)	-0.477*	(0.262)	-0.389	(0.588)	-0.461	(0.619)
Material Intensity								
1 Less than 10% (base)								
2 Between 10% and 29%			0.242**	(0.118)	0.981	(0.890)	0.673	(0.950)
3 Between 30% and 49%			0.258**	(0.114)	-0.134	(0.775)	-0.163	(0.807)
4 50% or more			0.322***	(0.115)	0.442	(0.718)	0.339	(0.741)
Expected Material Costs x					0.00	(0.00)	0.00	(0.00)
Material Intensity								
2 x 2					-0.291	(0.972)	0.068	(1.036)
2 x 3					0.574	(0.861)	0.558	(0.896)
2 x 4					-0.219	(0.811)	-0.136	(0.838)
3 x 2					-0.787	(0.899)	-0.529	(0.959)
3 x 3					0.375	(0.785)	0.388	(0.816)
3 x 4					-0.118	(0.729)	-0.081	(0.752)
Control variables								
Turnover Trend								
Decreased (base)								
Remained unchanged							0.030	(0.080)
Increased							0.499***	(0.077)
Size								
Small size (base)								
Medium size							0.460***	(0.079)
Sector								
Agriculture (base)								
Construction							-0.425***	(0.127)
Water/waste management							-0.145	(0.217)
Manufacture							-0.265**	(0.119)
Food services							-0.263	(0.170)
Constant	0.210	(0.246)	0.069	(0.273)	-0.000	(0.577)	0.006	(0.642)
Observations	4,874		4,472		4,472		4,290	
Control	No		No		No		YES	
Wald chi-square	5.971		15.13		20.54		189.1	
Log likelihood	-3356		-3076		-3073		-2855	
Pseudo R2	0.000897		0.00249		0.00346		0.0345	

Source: FL315 (EC, 2011)

Note: Country dummies are not displayed but included when Control indicates a YES. Robust standard errors (se) in parentheses. *** denotes significance at 1% p<0.01, ** at 5% p<0.05, * at 10% p<0.1.