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Master Thesis Marketing

# Go Green or Go Home: The Effect of Pollution on Innovation Activity

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# Abstract

In his 2013 TedTalk Michael E. Porter introduces the, in his words, largest business opportunity called: ‘shared value’. This opportunity addresses a social issue with a business model, creating both social and economic value simultaneously.

Triggered by this philosophy this study builds further on the understanding of the intersection between society and corporate interests. The aim of this thesis is to provide insight in the effects of pollution, firm size and customer interaction regarding innovation activity. Specifically this is done by studying the impact of greenhouse gas emissions on the number of patents moderated by the amount of employees and number of tweets.

The panel data used in this study contains statistics of 225 stock listed firms from the United States and Western-Europe active in eleven different industries. To analyse the data a linear mixed model is performed.

The findings in this thesis show that the level of pollution has a negative effect on innovation activity and this negative effect is weakened by customer interaction. Additionally the size of a firm does not influence the correlation between pollution and innovation.

These findings provide scientific support for the environmental technology ‘pollution prevention’ and encourages companies to look at sustainability in a different way.

Keywords: sustainability, innovation, pollution, firm size, customer interaction, environmental technology

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# 1. Introduction

In this first chapter the main topics and the context of the study are introduced. The first section describes the research context, the second discusses the problem statement followed by the central research question. The final section is about the motivation of this thesis.

## 1.1. Research context

The Paris agreement in late 2015 was hailed as a landmark emphasizing the urgency and importance of topics like sustainability and climate change. The agreement aims to limit the increase in global average temperatures to well below 2°C above pre-industrial levels. After several decades of warning by regulators, environmentalists and scientists the world is becoming more aware of its polluting activities (Telegraph Reporters , 2018). An online survey among millennials shows this reversal in awareness. The group of consumers between 18 and 34 years demand sustainable products, not only socially responsible companies. More than three-fourth of this group want fundamental sustainability of products and is willing to pay more for products that meet this expectation (Mahler, 2015). Similarly, a recent global consumer survey by Unilever reveals a $1 trillion market opportunity for businesses that market themselves as eco-innovators. One-third of the consumers would purchase a product if they believe it benefits society and the environment (Sustainable Brands, 2017).

Business is gradually recognizing this trend and reacting on this change, especially start-ups and innovative companies like Uber, SolarCity and Tesla. These companies incorporate sustainability and environmental issues in their business models and supply chains. The World Economic Forum sees parallels between increases in profit margins and eco-innovations, which can be defined as; an economic effort that operates with respect for the environment (Semerad, 2017). According to the World Economic Forum: "a growing body of evidence from companies around the world

**Climate change tackling innovations**

- *Solar communities*, this idea allows people to derive energy from a shared solar project installed on their building or elsewhere.

- *Vegetarian meat,* several meatless meat options are available to decrease the polluting effect of the agricultural sector.

- *Electric cars,* by using electric cars chargeable at home or at special recharging stations along the highway there is an alternative for the polluting combustion engine (Milman, 2017).

Figure 1. Climate change tackling innovations

suggests that the relationship between ecology and economy is not as competitive as many assume, it is possible to advance both pursuits simultaneously (Khandelwal, 2017)". The solution is the phenomena 'eco-innovation', some examples of eco-innovation concepts are briefly explained in figure one.

Building further on the proposed relationship between ecology and economy, the World Economic Forum explains that sustainable companies are promoting innovation. The rationale behind this is the fact that firms who operate sustainable require careful self-control and in-house auditing that often reveals opportunities to innovate new products and processes. This suggested relationship is used as a stepping stone to research this phenomenon in more detail.

The past decades environmental issues, like the one described above, have grown in publicity and became a central part of political debates. Measures such as carbon dioxide emissions and water usage are part of investors' considerations and firms are required to show their performance and are becoming more transparent. As a result managers are increasingly obligated to actively implement sustainability as a central factor to stay competitive in the long run (Lubin & Esty, 2010).

## 1.2. Problem statement

The uncertainty associated with the sustainability topic in business is researched in this thesis. Executives do not have a clear view on the consequences and influencers of sustainability concerning innovation. They feel stuck, disillusioned and hampered by the complexity of sustainability in their supply chain and lack of action by regulators (Confino, 2014). A frequently heard excuse is that 'going green' will place the company at a disadvantage compared to rivals in developing countries that do not face the same pressure. Besides this, sustainable manufacturing demands new equipment and processes while customers will not pay more for eco-friendly products (Nidumolu, Prahalad, & Rangaswami, 2009).

A survey from The Boston Consultancy Group in cooperation with MIT Sloan Management Review among more than 3,000 executives confirms this limited view of sustainability. There is a miscommunication between investors and executives. Investor relations professionals are not clearly communicating with investors about the value of sustainability for a firm's performance. Considering the fact that investors believe that sustainability creates tangible assets and that they are even prepared to divest in companies with a record of poor sustainability performance (Unruh, et al. 2016, Bockxmeer 2018, Kiron, Kruschwitz, Reeves Martin, & Goh 2013).

This thesis focuses on the above described problem by providing more insight in the relationship of sustainability regarding innovation and possible moderators.
The research question is: 'what is the effect of a firm's sustainability performance on its innovation activities'? Two sub-questions are added to provide more clarity:

1. How does this effect of sustainability on innovation activity vary depending on a firm's level of customer interaction?
2. How does this effect of sustainability on innovation activity vary depending on the size of a firm?

## 1.3. Research motivation

The motivation of this study is divided in two types of relevance: managerial relevance and scientific relevance. Both topics are respectively represented as sub-sections.

### 1.3.1. Managerial relevance

This study contributes to managerial knowledge in two ways. First, the pressure of stake- and shareholders to focus on sustainable strategies make managers obliged to improve management of energy and lower carbon emissions (Katsikeas, Leonidou, & Zeriti, 2016). Sophisticated corporate transparency, responsibility and accountability standards increase the complexity for business leaders in becoming sustainable (Deloitte, 2012). This study helps managers to deal with this pressure by obtaining insight into possible outcomes and moderators of a sustainable business approach.

Second, in the network of managers people need to be convinced of the added value of sustainability. For instance, several executives believe that investments in sustainability will increase costs and not deliver financial results. That is why some executives treat the need to become sustainable as corporate social responsibility, without involving it as real business objectives (Nidumolu, Prahalad, & Rangaswami, 2009). This thesis supports managers in the substantiation of sustainable business towards their executives.

### 1.3.2. Scientific relevance

Research in sustainability combined with a marketing strategy is a promising scientific area. The recent emergence of sustainability issues as a dominant topic in the literature indicates the influence of environmental capabilities on marketing assets (Chabowski, Mena, & Gonzalez-Padron, 2011). For future research Leonidou, Katsikeas and Morgan

(2013) suggest to develop a deeper insight in the relationship between green marketing activities and their performance outcomes.

This thesis contributes to academic research in two ways. First, it provides insight into a new possible driver of innovation. Over the years several drivers of innovation have been researched, varying from CEO attention to a firm's willingness to cannibalise. Sustainability is an underestimated driver in this context. A number of authors have highlighted the potential and growing importance of this relation. In a business setting people are more and more suspecting this relation and this study gives a scientific answer to these suggestions.

Second, with the addition of customer interaction and firm size as moderating variables this research gives insight on contextual factors potentially influencing the performance effects of sustainability. The current literature shows mixed results and pays little attention to these factors. These inconsistencies and shortcomings hint at the need to identify elements who possibly enhance or inhibit the relationship of sustainability and effectiveness outcomes (Katsikeas, Leonidou, & Zeriti, 2016).

# 2. Literature & hypotheses

The first section of this chapter reviews the literature about the three central topics and their relation regarding innovation. The second section develops the three hypotheses that are outlined and tested.

## 2.1. Literature review

In this section the current literature of three marketing topics and how they relate to innovation is discussed. First, the literature of sustainability in combination with innovation is described. Second, an overview of the literature of innovation is presented focused on the discussion regarding firm size. Third, the current literature of customer interaction in the innovation process is discussed.

### 2.1.1. Sustainability

Sustainability is for several decades generally accepted as business strategy input and marketing material. It can be defined as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). The importance of sustainability changed over the years from being a government regulation to a social norm and, currently, to a business megatrend determining the survival of an organisation (Lubin & Esty, 2010). Responding to this change, scholars examine different aspects of sustainability in a business setting. Relevant topics like corporate social responsibility, cause related marketing, corporate citizenship and corporate environmentalism emerge as important marketing subjects (Chabowski, Mena, & Gonzalez-Padron, 2011).

Klassen and Whybark (1999) characterise a sustainability strategy as an environmental technology which has it basis in the resource based view and the manufacturing strategy of a firm. They divide environmental technologies in three general categories: ‘pollution prevention’, ‘management systems’ and ‘pollution control’. ‘Pollution prevention’ technologies is referred to as structural investments in operations that involve fundamental changes to a basic product or primary process. Typical for this technology is the improvement of environmental performance up-front in the process rather as an afterthought (Porter & Van der Linden, 1995). The emphasis for ‘pollution prevention’ is on the product or process adaptation which means a significantly modification to an existing product or process that reduces any negative impact on the environment.

Management systems are defined as infrastructural investments that affect the way manufacturing is managed, including efforts to formalize procedures for evaluating environmental impacts. These systems are a combination of 'pollution control' and 'pollution prevention'. Finally, 'pollution control' represents the structural investments of a firm in technologies that treat or dispose pollutants or harmful by-products at the end of a manufacturing process, either immediately or later. 'Pollution control' technologies can be further characterised as remediation or end-of-pipe controls. Klassen and Whybark (1999) found that 'pollution prevention' positively affects manufacturing and environmental performance.

Marketing sustainability literature changed over the past decades, the following trends in three different eras are recognized. Sustainability research from the 1950s to the 1980s emphasized three main topics. First, ethics which was divided in the practical application of managerial marketing ethics and marketing ethics frameworks. Second, environmentalism that focused on consumer energy consumption and conservation. Third, the importance of corporate culture and rituals.

In the 1990s some noteworthy trends in marketing sustainability research came up, such as corporate social responsibility (CSR), citizenship behaviour, resource dependence, competitiveness and profitability who introduced the economic element into the literature. Also in this era the corporate stakeholder theory entered the stage examining the relevance of external organizational factors. This theory provided opportunities to further contribute to sustainability research.

In the 2000s CSR, together with organisational citizenship continued as an integral research area. The stakeholder theory was extended to include issues related to social and financial performance. Additionally, methods such as moderation and mediation effects indicate the maturation of the sustainability research domain in this era (Chabowski, Mena, & Gonzalez-Padron, 2011).

One of the most famous marketing sustainability concepts from the second era is enviropreneurial marketing. This term was first coined up by Varadarajan (1992) where he shortly introduced the topic. A clear definition is provided by Menon and Menon (1997): "The process for formulating and implementing entrepreneurial and environmentally beneficial marketing activities with the goal of creating revenue by providing exchanges that satisfy a firm's economic and social performance objectives". Enviropreneurial marketing differentiates itself from other environmentally based approaches in three

ways. It adopts the perspective of an innovation and technology solution rather than a legal or public pressure one, it adopts an entrepreneurial philosophy and it represents a confluence of social performance, environmental and economic objectives.
The first empirical research that operationalizes the enviropreneurial marketing concept was conducted by Baker and Sinkula (2005). They draw the hypothesis that according to the resource based view, a resource like enviropreneurial marketing should directly influence a firm's capabilities. Their research shows that enviropreneurial marketing is directly and positively related to a firm's new product success in its principal market segment.

Another popular marketing stream of literature regarding the environment is 'sustainable innovating'. It builds further on the theory of enviropreneurial marketing and describes the relation between new product development and environmental performance. Issues related to innovating for environmental sustainability have risen in importance for both managers and academics over the years. Varadarajan (2017) defines the term 'sustainable innovation' as: "a firm's implementation of a new product, process, practice or modification of an existing product, process, or practice that significantly reduces the impact of the firm's activities on the natural environment". Compared to other innovations, 'sustainable innovation' is riskier, requires greater financial commitment, and usually accrues returns in the long term. This kind of innovation contributes to the firm's environmental reputation and builds a competitive advantage. Moreover, sustainable product development is expected to grow in importance in the future.

Under various headings scholars have worked to understand the subject of 'sustainable innovations'. In the existing literature the following terms are used to refer to 'sustainable innovations': eco-design practices, green product innovation, green product development, green product programs, environmental new product development and environmentally conscious product strategies. In both marketing and business this stream of literature has contributed to the understanding of the importance of sustainable product practices. Studies in this area fall apart into three streams. The first stream focuses specifically on the kind of innovation, differentiating their nature in terms of content like type, scope and measurement. While scholars are providing various definitions of sustainable innovation they do not succeed in finding a consistent one, in terms of scope, clarity, domain and operationalisations (Katsikeas, Leonidou, & Zeriti, 2016).

The second stream discusses the performance effects of sustainable strategies. Some contradictory results on this topic generated a debate about the value of corporate sustainability. One stream in this discussion suggests that there is a negative relationship between sustainability investments and financial performance. Scholars argue that firms who try to enhance social performance draw resources and management effort away from core areas of the business, resulting in lower profits. They state that managers are not able to combine both competitive and social improvements (Siegel and McWilliams, 2000). Other scholars claim that if there is a relation, it is too complex to be found (Margolis and Walsh, 2003).
The counterpart is convinced that there is a positive relation between sustainability and financial performance. Leonidou, Katsikeas and Morgan (2013) conclude that green product and distribution programs positively affect a firms' product market performance. Overall, there are several reasons to believe that investing in sustainability is positively related to firm performance. In many cases the costs of adding value sustainable are lower than the benefits. Possible advantages of investments in sustainability are attracting and retaining quality employees, reduce costs, increase operational efficiency and increase market opportunity and quality. Most of the research in the area does support a positive relationship (Hull & Rothenberg, 2008).
The third stream in literature focuses on possible drivers of environmental product developments. For instance, the pressure of stakeholders has an indirect effect on eco-design through environmental training. Dangelico and Pujari (2010) found several key drivers of green product innovation. At first the need for regulatory compliance, second the opportunity of enhanced competitiveness and third value- and ethically driven factors. Institutional pressures can also trigger sustainable innovation, especially in firms displaying a greater deficiency gap compared to their industry peers (Berrone, Fosfuri, Gelabert, & Gomez-Meija, 2013). Other drivers of sustainable development are international experience, firm size, mimicry and media attention (Bansal 2005).

However, a limitation in the literature about 'sustainable innovations' is the little attention payed to contextual factors possibly moderating the effects of the relation between sustainable innovation and related outcomes (Katsikeas, Leonidou, & Zeriti, 2016). Scholars that do take moderators into account are Hull and Rothenberg (2008). They researched the effects of innovation and industry differentiation as moderators in the sustainability performance and financial performance relation. They found that environmental performance has a more positive impact on financial performance in relatively undifferentiated industries and for companies low on innovation. Furthermore Leonidou, Katsikeas and Morgan (2013) found that a firm's industry level of environmental reputation moderates the relationship between green marketing initiatives and product market performance.

Summary

Sustainability in marketing is not a short-term business movement but a long-term vision determining supply chains, business models and manufacturing strategies. Firms can implement environmental technologies in three ways via 'pollution prevention', 'pollution control' or 'management systems'. The main difference between 'pollution control' and prevention is that to prevent pollution some fundamental changes in the product or process have to occur. However, to control pollution the process must be remediated, the original product or process can be left unaltered. Over the years sustainability changed from an ethical and social view to a separate business approach into an integral way of research and a fundamental part of firm performance. This status that sustainability has acquired as a fundamental part of businesses is partly due to enviropreneurial marketing. This view on sustainability combines social performance with environmental and economic objectives. Based on this view of sustainability, firms can introduce new products or processes that reduce the impact of the firm's activities on the environment, this phenomena is called 'sustainable innovating'. In the long run this will contribute to the firm's environmental reputation and increases the competitive advantage. Three different streams in the literature describe 'sustainable innovating' into more detail, however a limitation is that there is little attention payed to possible contextual factors who possibly moderate the relation between innovation and the related outcomes.

> "Firms who become environmental friendly lower costs because they end up reducing their inputs. On top of this, the process generates additional revenue from better products or enables companies to create new businesses. By treating sustainability as a corporate goal, early movers will develop competencies that can lead to innovation" (Nidumolu, Prahalad, & Rangaswami, 2009)

### 2.1.2. Innovation & firm size

The topic innovation and how this relates to the size of a firm will now be further discussed. First, several drivers of innovation are reviewed after this the discussion regarding firm size and innovation is introduced. Innovation in this study is defined as the "generation, acceptance and implementation of new ideas, processes, products or services (Thompson, 1965)".

Innovation is one of the most important issues in business research. The literature distinct two types of innovation, introduced to the market. First, incremental innovation which involve relatively minor changes in technology and provide low customer benefits per dollar. Second, radical innovations contain on the one hand a substantially different technology. While on the other hand it has to offer a substantial increase in customer benefit (Chandy & Tellis, 1998).

Possible drivers of innovation have been studied over the years, four different categories are associated with a firm's ability to innovate.

- The environment of the firm, were competition, turbulence and urbanization are positively and unionization negatively influencing innovation.
- The structure of the firm only consists of positive indicators like, clan culture, complexity, formalization interfunctional coordination and specialization.
- The firm demographic indicators like management education, professionalism and age are also positive related to innovation.
- Finally, the method factors used by the studies also influence innovation, dichotomous measures of innovation have a negative influence while the use of cross-sectional data have a positive influence on innovation (Vincent, Bharadwaj, & Challagalla 2004, Hauser, Tellis & Griffin 2006).

Furthermore, some breakthrough studies in innovation drivers are now described in more detail. For instance Chandy and Tellis (1998) introduced the concept of 'willingness to cannibalize' as an innovation driver. Sorescu, Chandy and Prabhu (2003) found that the fear of obsolescence is a more powerful motivator than the lure of enhancement regarding radical innovation investments. Besides this, the people who lead firms also have an important role in driving innovation, the attention of the CEO is positively related to the innovation outcome of the firm (Yadav, Prabhu, & Chandy, 2007).

By far the most controversial structural driver of innovation is firm size. There are two streams in the debate that has risen concerning this variable, one stream is convinced that small firms are better suited for radical innovation while the other stream is convinced that this is the case for big firms. Schumpeter (1934, 1942) noted the concept of ‘creative destruction’ were he stated the hypothesis: “large firms innovate more ‘intensively’ than small firms do” (Chandy & Tellis, 1998). Authors that agree with Schumpeter explain that large firms have several advantages to introduce radical innovations compared to small firms. They claim that large firms benefit economies of scale in research and development and marketing, have a greater knowledge base and have greater technological, financial and market related resources. Undertaking radical innovations have become more complex, with the large amount of resources to bear the costs, the risk for big firms can be minimized (Sorescu, Chandy, & Prabhu, 2003).

The counterpart is convinced of the theory of inertia. According to this theory a firm, as it grows large, is exposed to the forces of bureaucratic inertia and the company will face problems to adapt when the technological environment is changing. The growing number of employees, organizational routines and organizational filters make it difficult to react to radically new products.

Organizational filters are structures that screen out information unrelated to the organization’s important tasks to focus its attention on these tasks. The success of large firms is partly due to these filters, they maximize the utility of current technology for current customers. However, radical innovations involve a significant new technology, organizational filters may cause incumbents to be less effective than non-incumbents at spotting, developing and marketing radical innovations.

Organizational routines are developed to carry out the repetitive tasks of manufacturing and distributing large volumes of the product efficiently. The routines or procedures are designed to develop incremental innovations based on current technology. Adoption of radical innovation would obsolete many of these routines and requires the development of new routines which is difficult, costly and risky. Since the current routines have been successful to the firm, managers tend to be reluctant to embrace radical innovations. In the worst case scenario these bottlenecks limit the supply of innovation (Chandy & Tellis, 2000).

According to Christensen and Bower (1995) the fundamental reason that lies at the heart of this theory is one of the most popular management dogmas: ‘leading companies stay close to their customers’. They warn managers to beware of ignoring new technologies that do not initially meet the needs of their mainstream customers, because radical innovations typically present a different package of attributes that are not valued by existing customers.

Summary

Innovation is increasingly becoming more important for business research over the years. Generally there are two types of innovation: radical and incremental innovation. Possible drivers of both kinds of innovation are a firm's environment, structure and demographics. One of the most researched driver of innovation is firm size. In an ongoing debate academics argue whether small or large firms innovate more. Large firms benefit economies of scale and a resource advantage, however large firms are disadvantaged by their organizational routes and filters that makes them miss out potential valuable information compared to small firms.

### 2.1.3. Customer interaction

The insight of customers can be used to develop innovation, the literature behind this concept is now described. Respectively the different research streams, implementations and contextual factors are discussed.

To develop new innovative products a firm must acquire an in-depth understanding of user needs. One way to obtain this is customer participation in the product development process. Customers offer a wide range of skills, sophistication and interests. Companies that use these sources can capitalize on customer competencies during the course of their innovation activities (Blazevic & Lievens, 2008).

Chang and Taylor (2016) define customer participation as: "the customer knowledge provision phenomenon whereby customers share their needs and solution related inputs in the firm's new product development process". They include topics like open innovation with customers, innovation through the lead-user approach and crowdsourcing.

The first practices of user innovation were found in the 1980s in a few high-tech areas, after product design costs grew to high levels. In this new approach manufacturers outsourced key 'need related' innovation tasks to the users, by providing them with the right toolkit. The first move towards this toolkit was the release of a software design tool so customers could design products for themselves (Hippel & Katz, 2002).

Mainly two research streams have provided insights in the importance of user input in facilitating marketing objectives.

The first stream of literature is the company customer collaboration in services marketing. In this domain studies have addressed various degrees of customer participation during the service encounter. Positive outcomes that were discovered are cost reductions, increased economic efficiency and customer satisfaction. Additionally other studies within this stream focus on strategies to manage customer participation and argue that customers must be considered as partial employees. Another part of this stream gives insight on the roles of customers, this includes customers as productive resources, valuable contributors and competitors to the service organization (Alam, 2002). In addition to these roles Bettencourt (1997) examines customer voluntary behaviour, like the customer as a human resource or as an organizational consultant. These studies consider the consumer role in a face-to-face encounter, research that move beyond those encounters study the concept of self-service technologies. These technologies are based on customers that produce services for themselves without interacting with firm employees.

The second stream of literature is the 'company customer collaboration' in innovation. This area discusses the evaluation and transformation of customers from passive buyers to active value co-creators. Electronic service deliveries facilitates network collaborations and causes companies to turn increasingly to customer for innovative ideas. This results in rising absorptive and innovative capacity of the firm, which in turn provide competitive advantage in dynamic and complex environments (Blazevic & Lievens, 2008).

The value of knowledge obtained by customer co-creation increases with greater benefits in terms of novelty and relevance and decreases with greater costs. Customer co-creation acknowledges the central role of using external customers' knowledge to develop innovations (Blazevic & Lievens, 2008).

There are several ways of how to implement user innovation in a company.

- One way is the lead user approach introduced by Von Hippel (1986). In this context users are manufacturers rather than innovators, and expect a return for their efforts. But, lead users are scarce and only a limited amount of users can participate in this concept.
- Urban and Hauser (2004) therefore recommend 'listening in' on customer interactions. By monitoring internet searches companies are able to identify desired but yet unfulfilled needs, this can lead to innovation opportunities and it provides the company with a continuous stream of up-to-date data (Blazevic & Lievens, 2008).
- Finally Hippel and Katz (2002) also suggest that companies can identify need related information with user toolkits for innovation. With specific design tools customers can design their own innovations with their preferred features, this results in valuable information for the firm and customized products (Blazevic & Lievens, 2008).

Regarding contextual factors between customer participation and new product development Chang and Taylor (2016) executed a recent meta-analysis. They include new product development with three aspects of success: operational, financial and marketing performance. The new product development process is divided in three stages: ideation, development and launch. They suggest that small firms in low-tech business-to-business industries and in emerging countries should consider involving customers in new product development. Furthermore, they found that the effect of customer participation in the ideation- and launch stage enhances new product financial performance. In contrast, customer participation in the development phase slows down speed to market and in turn damages the new product financial performance.
Not only financial performance is positively influenced, innovativeness of the product can also be positively influenced. This is particularly affected by the network connectivity between retailers and distributors, when this connectivity in the supply chain is high customer participation has a negative influence on innovativeness but a positive effect when it is low (Fang, 2008).

Summary

Customer participation in the new product development of a firm can be defined as: ‘a way to provide knowledge where customer share their needs and solutions that firms can use in the development of new products.’ Customers in this context are seen as valuable resources of knowledge that can be extracted outside the firm. Two different streams of literature can be recognized, the first one focuses on the collaboration with customers regarding services and the second stream is about the transformation of customers from passive buyers to active value creators. To implement customer participation in companies’ new product development, three possibilities are suggested: the lead user approach, the ‘listening in’ approach and the user toolkit approach. Furthermore, incentives for firms to implement customer participation in their innovation processes are the positive effects on financial performance and on the innovativeness of the product.

## 2.2. Hypotheses

The importance of firm sustainability performance is growing and changing into a business mega trend decisive for companies' future existence. Several drivers who initiate a firm's sustainability efforts can be concluded from the theory, like stakeholder pressure, institutional pressure, and ethical factors. After a firm is faced with the necessity to 'go green' they have, according to Klassen and Whybark (1999) three environmental technologies they can choose: 'pollution prevention', 'management systems' and 'pollution control'. For this study the effect of 'pollution prevention' is further tested, this environmental technology can be characterised as structural investments in operations that involve fundamental changes to a basic product or primary process. This technology can be further defined as 'product or process adaptation'. Both adaptations encompass all fundamental investments that significantly modify an existing product design or manufacturing process that reduces pollution.

"The fundamental rethinking of a product or manufacturing process also places fewer constraints on the means of achieving environmental improvement, thereby offering greater opportunity for innovation" (Klassen & Whybark, 1999)

Scholars argue that this method of pollution reduction tends to be underestimated by managers (Majumdar & Marcus 2001, Klassen & Whybark 1999, Hart 1995, Porter & Van der Linde 1995). They state that preventing pollution provides unexpected and valuable information about process improvement opportunities. The explanation behind this is that waste prevention allows improved measurement of the production process and thereby facilitates process innovation (King & Lennox 2002, King 1995). Furthermore, Majumdar and Marcus (2001) state on this topic that pollution reveals inefficient use of inputs and flaws in product design and production paving the way to innovation.

In other words, 'pollution prevention' leads to decreasing pollution which might result in increasing innovation activity (Klassen & Whybark, 1999). In this study the relationship has been turned around: an increase of pollution will thus lead to decreasing innovation activity. Therefore the first hypothesis states that:

**H1. A firm's level of pollution negatively influences its innovation activity.**

Academics who are convinced of large firms as a better environment to innovate argue on the fact that large firms benefit greater knowledge about customers and greater capabilities. The counterpart in this discussion claims that large firms suffer from the theory of inertia (Chandy & Tellis, 2000). This means that organizational routines and filters in a firm exclude certain information that do not contribute to current consumer expectations. This can be due to the fact that the ability of a firm to recognize the value of information and to further process it, is positively related to small firms but negatively related to large firms (Zou, Ertug, & George, 2018).

The previous hypothesis state that 'pollution prevention' reveals a certain piece of information or inefficient use in the product design or the production process, eventually this may lead to rethinking, redesigning or remanufacturing the product or process. Organizational filters and routines may filter out crucial 'pollution prevention' information resulting in decreasing innovation activity of large firms compared to the innovation activity of small firms. Firms with less hierarchal and bureaucratic structures enhance the abilities of organizational members to explore and integrate learning about unanticipated environmental practices, thereby facilitating the accumulation of knowledge that might result in the development of new products (Surroca, Tribo, & Waddock, 2010). Therefore the second hypothesis that can be concluded is:

**H2. The negative effect of the level of pollution on innovation activity will be amplified by increasing firm size.**

Traditionally, professional R&D employees were responsible for designing innovations for consumers. However, various firms start to adopt customer interaction in their new product development process. Academic research over the years showed that interaction with customers for new product development enhances new product financial performance and lead to positive outcomes with respect to purchase intentions, willingness to pay and consumers' willingness to recommend the firm (Chang & Taylor, 2016) (Schreier, Fuchs, & Dahl, 2012). Furthermore, under the right circumstances customer participation has a positive effect on innovativeness (Fang, 2008). The emphasis for 'pollution prevention' is on the physical product and/or process change. The implementation of this technique depends on organizational and knowledge-based resources (Klassen & Whybark, 1999). Customer interaction can enrich a firm's knowledge base by integrating customers as knowledge input beyond the firm's control (Mahr, Lievens & Blazevic 2013, Chang & Taylor 2016). In more detail, the rationale behind this is two-sided. Knowledge-sharing processes allow firms to gain insights into socially generated knowledge. While on the other hand knowledge-sharing develops a strong sense

> "Participation transforms customers into a knowledge resource through which firms can improve their innovation performance and competitiveness" (Vargo & Lusch, 2004)

of belonging to communities that enables strong social relationships, which increases individual customers' willingness to share their knowledge with the company. Eventually both dimensions of knowledge support new product development (Sawhney, Verona, & Prandelli, 2005). In summary, organisations can use customer interaction to increase their knowledge base resources which in turn can be used to come up with 'pollution preventing' solutions. This results in the following hypothesis:

**H3. Customer interaction weakens the negative link between the level of pollution and innovation activity.**

2.2.1. Conceptual model

The conceptual model is schematically shown in figure two. All four variables, the relations and the three hypotheses are included. In brief this thesis researches the effect of the pollution level on innovation activity which is expected to be negative (indicated by a minus sign). Furthermore, this relation is expected to be amplified by firm size (indicated by a plus sign) and weakened by customer interaction (indicated by a minus sign).

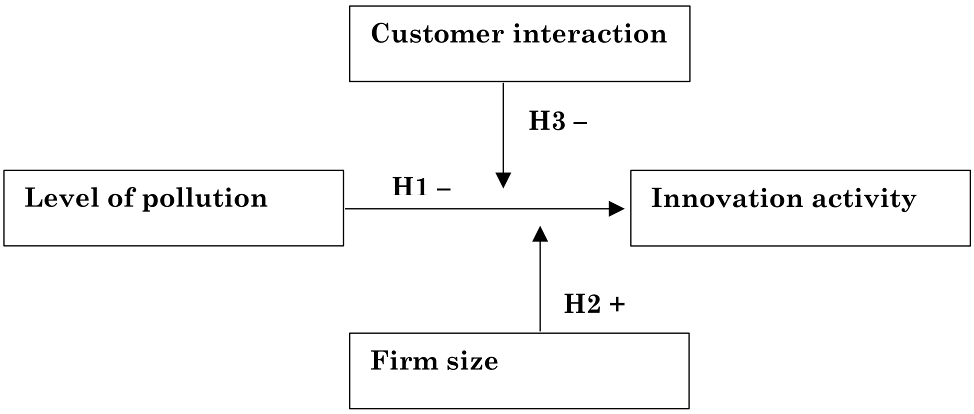


Figure 2. Conceptual model

# 3. Research methodology

This chapter explains in more detail how the research is conducted. First, the data is discussed followed by the measures of the variables and finally the research model is defined.

## 3.1. Data

For this study the hypotheses are tested with secondary data which is collected over two databases. The choice for secondary data instead of primary data is because the variables used in this study can be broadly and inconsistently defined and interpreted by managers when asked in a survey. Moreover, the alternative of surveying managers can suffer from severe memory or self-report biases (Chandy & Tellis, 2000). The panel data is gathered from stock listed US and West-European firms active in eleven different industries. An overview of the variety of sectors and countries is shown in appendix one. The variables pollution level, innovation activity and firm size are collected annually from 2015 up to and including 2017. The variable customer interaction is collected daily and aggregated to an annual number. Because the Bloomberg database does not provide data that goes further back than 2015 for this variable, the complete dataset has been adapted to this time span.
The entire dataset eventually captures 675 observations in total per variable. There are 225 different firms represented and the variables are measured over three different years.

## 3.2. Measures

*Pollution level;* this independent variable is measured as a firm's greenhouse gas emissions over time. In line with Hart and Ahuja (1996) and King and Lenox (2002) an index is used which is the ratio of reported emissions to the firm's revenues. This variable is the outcome of a firm's waste generation and its possible efforts to reduce this waste by prevention (King & Lenox, 2002). The data is extracted from the Bloomberg database and stands for greenhouse gas emissions to firms' revenue.

*Innovation activity;* to measure a firm's innovative activity as the dependent variable the number of patent publications is used. Acs, Anselin and Varga (2002) found that the measure of patented inventions provides a good representation of innovative activity, supporting the use of patents counts when examining technological change. Even in industries where practically all inventions would be introduced without patent protection, the bulk of the patentable inventions are patented. Firms generally do not prefer to rely on trade secret protection when patent protection is possible (Mansfield, 1986). The number of patent publications in the years 2015, 2016 and 2017 are extracted from the Orbis database and are measured as a continuous variable over time.

*Firm size;* in line with Chandy and Tellis (2000) firm size is operationalised as the number of employees in the firm. The variable firm size has many measures, the most common are number of employees, sales volume or value of assets. Firm size as number of employees is chosen because it is the most common measure in the innovation literature. It is theoretically appealing since many of the problems of large firms, like organizational filters and routines, are due to the increased need for coordination as a firm employs more people (Chandy & Tellis, 2000). The amount of employees is derived from the Bloomberg database and is added as a continuous measure.

*Customer interaction;* as mentioned before 'listening in' can be a way to involve customers in the new product development process. In line with Schweidel and Moe (2014) and Ma, Sun and Kekre (2015) Twitter statistics are used to track down social media activity.
Twitter hosts more brand central content than other social media channels because of its focus on sharing news, information and opinions, making it a perfect channel to interact with customers (Smith, Fischer, & Yongjian, 2012). The firm generated content that is posted on the microblogging website (tweets) helps firms to develop one-on-one relationships with their customers through its interactive nature (Kumar, Bezawada, Rishika, Janakiraman, & Kannan, 2016). Furthermore, tweets can create a sense of community and foster active engagement, enhancing brand attachment and activity (Keller, 2010). The number of tweets is used from the Bloomberg database to measure the level of social media activity over time.

*Time;* since the data is repeatedly measured over three different years, 2015 till 2017, this variable is measured in years. All other variables are measured with this same annual regularity.

*Sector;* the innovation activity can depend on the sector of a firm, for example due to competition. In the analysis there is controlled for sector.

*Country;* besides sector the innovation activity of firms may differ per country, for instance due to certain policies that promote innovation.

In table one a schematic overview is presented with the variables used in this study.

| **Conceptual variable** | **Measured variable** | **Source** | **Abbreviation** |
|---|---|---|---|
| Pollution level | GHG/revenue ratio | Bloomberg | P |
| Innovation activity | Number of published patents | Orbis | I |
| Firm size | Number of employees | Bloomberg | FS |
| Customer interaction | Number of tweets | Bloomberg | CI |
| Time | Years | Bloomberg/Orbis | T |
| Sector | Industry | Bloomberg | S |
| Country | Country of domicile | Bloomberg | C |

Table 1. Variables and data sources used in this study

### 3.3. Model specification

To analyse the data a linear mixed model is performed. This model consist of both fixed and random effects in the same analysis. Because the firms are repeatedly measured over time for different variables with different measurements, the linear mixed model is suitable to analyse this data. According to West, Welch and Galecki (2014) the fixed effects describe the relationship between the dependent variable and predictor variables therefor in this case the variables pollution level, firm size, customer interaction and the two moderating effects are added in the model with fixed effects. Furthermore, West, Welch and Galecki (2014) state that fixed effects may describe contrast or differences between groups of fixed factors therefor the control variables country and sector are both added as fixed effects.

The random effects make it possible to create personal values for each subject or firm. This personal value or intercept consist of the fixed effect plus a random deviation from that fixed effect. For this thesis, pollution level, firm size and customer interaction are therefore also included with random effects (Seltman, 2009).

With this in mind the following model is created, were $t$ indicates a time point and $i$ being used for subjects (West, Welch, & Galecki, 2014).

$$I_{it} = (\beta_0 + u_0) + (\beta_1 + u_1)P_{ti} + (\beta_2 + u_2)FS_{ti} + (\beta_3 + u_3)CI_{ti} + (\beta_4 P * FS_{ti}) + (\beta_5 P * CI_{ti}) + \beta_6 S_{ti} + \beta_7 C_{ti} + \varepsilon_{ti}$$

As described above this model contains both fixed as random effects. The $\boldsymbol{\beta}$ parameters represent the fixed effects of the associate variable. While the $\boldsymbol{u}$ parameters represent the random effect of the variables to explain the between subject variation, the first three variables thus consist of both effects. Moreover, the intercept also has a random and fixed effect. Finally, $\boldsymbol{\varepsilon}$ indicates the residual associated with the $t$-th observation on the $i$-th subject (West, Welch, & Galecki, 2014).

# 4. Results

In this chapter the results of the data analysis are discussed in four different parts. The first section gives a general overview of the data, the second discusses the outcomes of a linear mixed model. The third section describes the discussion of the results concerning the hypotheses, followed by robustness checks of the hypotheses.

## 4.1. Data and summary statistics

The descriptive statistics SPSS output can be found in appendix one up to four. As mentioned before there are a total of 675 observations for all measured variables divided over three different years. The mean emissions per million of sales are rising from 2015 to 2016 and are declining in 2017. The same pattern is visible for the Twitter activity of firms and the number of patents, however in total 461 observations for this last variable display a zero which indicates that no patent was published by a firm for that year. The average amount of employees grows steadily over the years.

The sample is divided into eleven different sectors. The sector industrials is best represented with 52 firms active in this industry and the telecommunication services sector is the smallest group, represented by six firms in the sample. The information technology sector has the most average innovation activity followed by health care and materials. The consumer staples industry contains the largest firms, hereafter comes consumer discretionary and financials. The on average most polluting sector is utilities, while the cleanest sector is financials. Finally the most interactive industry is information technology followed by consumer discretionary and telecommunication services.

The 225 firms are from sixteen different countries, the United Kingdom with 82 firms is best represented and Luxembourg with one firm is the least represented country. Germany is most active in innovation with a mean of 680 published patents in the last three years, the countries Austria, Ireland and Luxembourg did not publish a patent at all. Germany furthermore also delivers the largest average firms followed by Belgium and Spain. Moreover, Finland is by far the most polluting country with Belgium and Norway as number two and three. Finally, the three countries in the sample with the most interactive firms are the United States, Germany and Belgium. The countries are divided into three main groups in the following analysis: the United Kingdom, the United States and the rest of West-European countries.

To further analyse the data a repeated measures analysis of variance is executed, the output of this analysis is showed in appendix three and four. The assumption of sphericity is violated therefore the degrees of freedom are Greenhouse-Geisser corrected. Furthermore, the error variances are not homogenous across groups as shown in the Levene's test (all p-values < 0.05) (Janssens, Wijnen, Pelsmacker, & Kenhove, 2008).

The results in appendix three show that the innovation activity differs significantly over time (sig. 0.00). The pairwise comparisons table displays that in 2015 there was significant less innovation activity than in 2016 but significant more than in 2017. Additionally, in 2016 there was significant more innovation activity than in 2017. Furthermore, there is a significant difference in terms of innovation activity (sig. 0.01) between the three groups of countries, which are the United Kingdom, the United States and the other European countries. The pairwise comparisons table shows that the United Kingdom has significantly less innovation activity than the United States.
Moreover, there appeared to be a significant interaction effect between time and country on innovation activity (sig. 0.03). This means that the effect of time on innovation activity differs for firms depending on their country of domicile.

In a second performed repeated measures ANOVA, displayed in appendix four, the variable sector is analysed. The results indicate that there is a significant difference between the several sectors in terms of innovation activity (sig. 0.00). The pairwise comparisons table shows that the sector information technology has significantly more innovation activity than all other sectors. The other sectors do not differ significantly from each other. The significant interaction effect (sig. 0.00) clarifies that the effect of time on innovation activity differs for firms depending on their sector.

## 4.2. Linear mixed model

The results of the linear mixed model as described in section 3.3. are added in appendix five. The model dimension table gives an overview whether the model fits the data. For the quantitative independent variables the column 'number of levels' show one level. The categorical explanatory variables country and sector have respectively three and eleven levels. Furthermore, the number of subjects in the model is 225 representing the 225 firms. The random effects contain four different levels, which represent the three variables plus the intercept. The repeated effects show the variable time in years with accordingly three different parameters indicating the three different points in time: 2015, 2016 and 2017.

There can be concluded that this table prove that the linear mixed model interprets the data correctly.

Table two shows the fixed effects results of the linear mixed model, the complete table is added to the appendix. The first variable is the pollution level which is significant (sig. 0.03) with an estimated effect of -0.37, followed by the main effects of firm size and customer interaction which are both insignificant (respectively sig. 0.36 & 1.00). The interaction effect between the level of pollution and firm size is insignificant (sig. 0.32). However, the other interaction effect between pollution level and customer interaction is statistically significant (sig. 0.00) with an estimated effect of -0.00002. Furthermore there is controlled for the sector and the country in which the firms operate and all control variables do not affect innovation activity significant compared to the reference groups.

**Estimates of fixed effects**

| Parameter | Estimate | Sig. | Hypothesis |
|---|---|---|---|
| Intercept | 318.74 | 0.67 | |
| Pollution_level | -0.37 | 0.03 | H1* |
| Firm_size | 0.00 | 0.36 | |
| Customer_interaction | 0.00 | 1.00 | |
| Interaction effect: pollution_level * firm_size | 0.00 | 0.32 | H2 |
| Interaction effect: pollution_level * customer_interaction | -0.00002 | 0.00 | H3* |
| Control variable sector: consumer discretionary | -118.85 | 0.88 | |
| Control variable sector: consumer staples | -202.83 | 0.79 | |
| Control variable sector: energy | -190.05 | 0.85 | |
| Control variable sector: financials | -338.41 | 0.66 | |
| Control variable sector: health care | -290.63 | 0.71 | |
| Control variable sector: industrials | 5.38 | 0.99 | |
| Control variable sector: information technology | 1198.64 | 0.14 | |
| Control variable sector: materials | -190.99 | 0.81 | |
| Control variable sector: real estate | -170.10 | 0.91 | |
| Control variable sector: telecommunication services | -243.61 | 0.79 | |
| Control variable sector: utilities (reference group) | 0.00 | - | |
| Control variable country: United Kingdom | -217.74 | 0.41 | |
| Control variable country: United States | -47.18 | 0.85 | |
| Control variable country: other European Countries (reference group) | 0.00 | - | |

Table 2. Linear mixed model, estimates of fixed effects

* Significant at a p-value less than 0.05

## 4.3. Discussion of results

In this part the above described results are further discussed considering the hypotheses determined in section 2.2.

### 4.3.1. Hypothesis one

The first formulated hypothesis is: 'a firm's level of pollution negatively influences its innovation activity.' The effect of pollution on innovation activity is statistically significant (sig 0.03) with a negative estimated effect. This means that the first hypothesis is accepted; for every one unit increase in a firm's level of pollution, innovation activity decreases by 0.37.

### 4.3.2. Hypothesis two

The second hypothesis in this thesis is: 'the negative effect of the level of pollution on innovation activity will be amplified by increasing firm size.' The moderating effect of firm size on the relationship between pollution level and innovation activity is not significant (sig. 0.32) which means that hypothesis two is not accepted.

### 4.3.3. Hypothesis three

The third hypothesis is: 'customer interaction weakens the negative link between the level of pollution and innovation activity.' The interaction between pollution and customer interaction is statistically significant (sig. 0.00) with an estimated effect of -0.00002. This shows that the third hypothesis is accepted; the relationship between the level of pollution and innovation activity is weakened by increasing customer interaction.

## 4.4. Robustness checks

In this section the robustness of the hypotheses is checked with different kinds of analyses. First a linear regression is executed followed by a negative binominal regression analysis.

In the performed linear mixed model the variable time was used as the repeated measure, now there is accounted for time performing a linear regression with, besides country and sector, time as a control variable. To obtain robust results the bootstrapping method is performed. This method estimates the properties of the sampling distribution from the sample data. The sample data are treated as a population from which smaller samples are taken, this process is repeated 1000 times. Eventually this leads to robust standard errors and confidence intervals (Field, 2013). The SPSS output can be found in appendix six.

First of all it is noteworthy that all sectors compared to the sector information technology are significant. Regarding the variable country the European countries have a significant effect on innovation activity compared to the United Kingdom and the years 2015 and 2016 are both insignificant compared to 2017.
Regarding the three hypotheses it is clear that the pollution level has a significant (sig. 0.04) negative effect (beta value -0.17) on innovation activity which means that the first hypothesis is robust. The interaction effect of firm size is almost significant (sig. 0.10), however the beta value of the variable is negative which is contradictory to hypothesis two. The third hypothesis which describes the moderating effect of customer interaction is not robust (sig. 0.69). Additionally the main effects of firm size and customer interaction are both significant (respectively sig. 0.00 & 0.02).

The second analysis that is performed to check whether the hypotheses are robust is a negative binominal regression. The variable innovation activity contains, as mentioned before, 461 zero observations. A zero in this context means that the firm for that specific year did not publish a patent. Since the phenomenon of overdispersion is recognized for the dependent variable the negative binominal regression is performed instead of the poisson model. The negative regression is a form of the poisson regression that includes a random component reflecting the uncertainty about the true rates events which occur for singular cases (Gardner, Mulvey, & Shaw, 1995). The regression is executed with a time lag of one year between the dependent and the independent variables since a possible time lag is expected because of the fact that it takes time before a patent is officially granted (United States Patent and Trademark Office 2018, European Patent Office 2018).

The following model is tested in SPSS, the output is displayed in appendix seven.

$$I_t = \exp(ln\, \beta_0 + \beta_1 P_{t-1} + \beta_2 FS_{t-1} + \beta_3 CI_{t-1} + \beta_4 P * FS_{t-1} + \beta_5 P * CI_{t-1} + \varepsilon i)$$

The omnibus test table shows that the overall model is significant (sig. 0.00). All independent variables have a significant effect on innovation activity (sig. 0.00). Regarding hypothesis one, the effect of the level of pollution on innovation activity with a time lag of one year is significant and negative (Exp(B) 0.993). This means that for a one unit increase of pollution the innovation activity of a firm decreases by 0.007. This result indicates that the first hypothesis is again robust. The second and third hypotheses are significant, however they do not have an effect on the dependent variable (Exp (B) 1.0).

# 5. Conclusion

This chapter is divided in four sections, the first section zooms in on the study in general and the conclusions that can be drawn. The second section describes the academic implications followed by the managerial implications. Finally, in the last section the limitations and directions for future research are discussed.

## 5.1. General discussion

In this study the effect of the level of pollution on innovation activity with two moderating effects has been researched. In an extensive panel dataset, using a linear mixed model the relations between the level of pollution, innovation activity, firm size and customer interaction are examined.

The results indicate that the level of pollution negatively influences innovation activity. This means that the environmental technology 'pollution prevention' pays off in terms of innovation activity. Because pollution negatively influences innovation activity, firms are better off reducing their emissions.

Furthermore, there is found that the size of a firm in number of employees does not influence the relation between pollution and innovation. Large firms which suffer bureaucratic inertia are therefore not at a disadvantage compared to smaller, more agile companies when it comes to the effect of pollution.

Finally, there is confirmed that customer interaction can weaken the negative link between emissions and innovation activity. Interaction with customers leads to knowledge based resources that can be used to make products or processes less polluting.

These conclusions result in the following answer on the research question: as soon as companies prevent their emissions, this will benefit their innovation activity. The size of a company makes no difference regarding 'pollution prevention' and its effect on innovation. However customer interaction can diminish the negative effect of pollution level on innovation activity.

## 5.2. Academic implications

The findings showed in the previous section have the following academic implications. First, they provide a contribution to the ongoing debate whether a sustainable strategy is negatively or positively related with performance outcomes. The conclusion of this study supports the group who claims that being sustainable is positively related to firm performance. Specifically in this case the proven negative relation between the level of pollution and innovation shows that it pays to prevent pollution.

Second. the findings give more insight in possible contextual factors moderating the relationship between pollution and innovation. Prior literature paid little attention to contextual factors possibly moderating the effects of sustainability and related outcomes (Katsikeas, Leonidou, & Zeriti, 2016). With firm size and customer interaction as moderators the conclusions of this study provide clarity regarding this limitation and give reason to further research other possible moderators.

## 5.3. Managerial implications

The conclusion described in the general discussion results in the following managerial implications. First, managers can according to this study justify increased investments into 'pollution prevention' because it is not only costing money but it also provides innovation opportunities. Specifically regarding the research and development division, managers should invest in research that reviews their own product/production process and the associated emissions which can then lead to innovation opportunities.

One way to do this, is by setting up a program that supports 'pollution prevention' initiatives like 3M did, see figure three.

Second, on the same note managers are not limited to their own internal research and development divisions. With increased social media activity they can use external customer knowledge to come up with 'pollution preventing' solutions. Therefore managers should 'listen in' on customer

**3M's Pollution Prevention Pays Program**

The 3P program is based on the reality that pollution prevention is more environmentally effective, technically sound and economical than conventional pollution control equipment. 3P seeks to eliminate pollution at the source through product reformulation, process modification, equipment redesign, and the recycling and reuse of waste materials. Over the last 34 years, the program has prevented 2.9 billion pounds of pollutants and saved more than 1.2 billion dollars worldwide. Over the last 32 years, 3M employees have completed more than 6,300 3P projects (3M, 2009).

Figure 3. 3P Program of 3M

conversations and stimulate social media activity with a focus on sustainability, Twitter is an excellent tool for this.

Third, managers can use this study to convince executives of sustainable strategies. This study can be the support for managers to show that pollution negatively influences the firm's performance regarding innovation and that a strategy with 'pollution prevention' can counteract this effect, regardless the size of the firm.

## 5.4. Limitations and directions for future research

Two limitations in this study are recognised. First, the dependent variable, innovation activity, faces the phenomena of overdispersion and has a lot of zero counts this indicates that a negative binominal regression analysis would be needed to analyse the data correctly. Furthermore, a mixed model is the ideal way to analyse the data because of its repeated measures over time. The best way to analyse the data would thus be a combination of a negative binominal regression with a linear mixed model. However, since the complexity of this analysis and the fact that SPSS does not support this combination of analysis, there is decided to execute both analysis separately. For future research, when dealing with the same kind of data the suggestion is to make use of a combination of both analysis to create a model that fits the data better.

Second, regarding the robustness checks performed in section 4.4. the linear regressions used in this case do not treat the data in an optimal way. The linear regression analysis does not recognise the repeated measures over time but treat the data without the different points of measurement. A better way to analyse the robust data for future research is with an analysis that do take the repeated measures into account and have the possibility to bootstrap the results.

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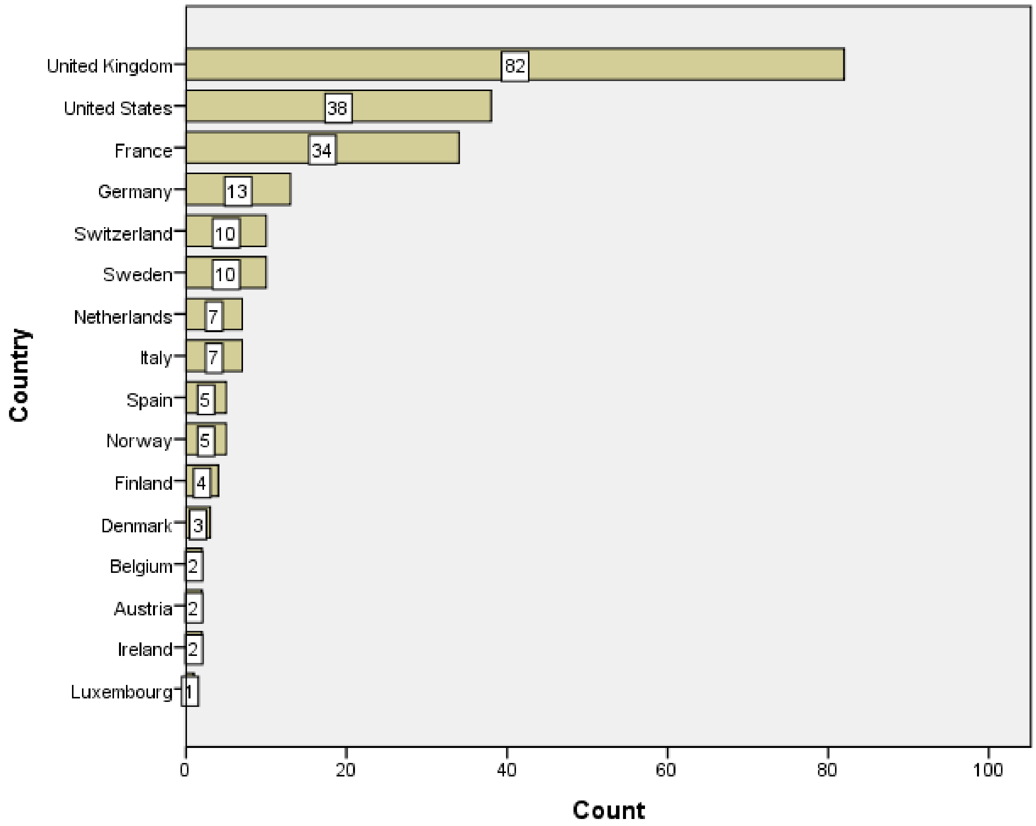
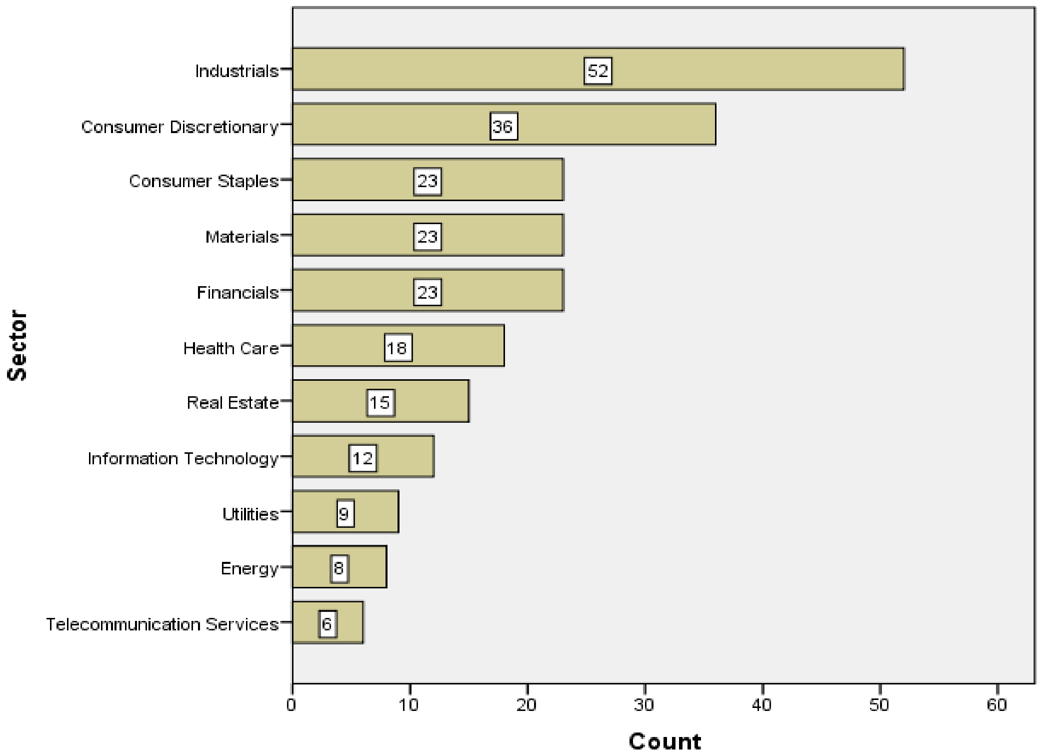
# Appendix 1. Represented sectors and countries




All countries represented in the sample




All sectors represented in the sample based on the S&P Global Industry Classification Standards (GICS)

# Appendix 2. Descriptive statistics

| | | Time | | |
|---|---|---|---|---|
| | | 2015 | 2016 | 2017 |
| Innovation_activity | Mean | 134 | 147 | 89 |
| | Maximum | 4245 | 4739 | 2670 |
| | Minimum | 0 | 0 | 0 |
| | Standard Deviation | 553 | 609 | 353 |
| Pollution | Mean | 198.22 | 204.55 | 189.54 |
| | Maximum | 5048.91 | 4700.35 | 3625.01 |
| | Minimum | .11 | .15 | .08 |
| | Standard Deviation | 493.55 | 502.16 | 450.51 |
| Firm_size | Mean | 55921 | 56930 | 58049 |
| | Maximum | 610076 | 626715 | 642292 |
| | Minimum | 71 | 75 | 75 |
| | Standard Deviation | 91988 | 93994 | 97923 |
| Customer_interaction | Mean | 20094 | 26306 | 20856 |
| | Maximum | 1916620 | 2272338 | 1469591 |
| | Minimum | 0 | 0 | 0 |
| | Standard Deviation | 138732 | 169651 | 115356 |

| | | Innovation_activity | Firm_size | Pollution | Customer_interaction |
|---|---|---|---|---|---|
| | | Mean | Mean | Mean | Mean |
| Sector | Consumer Discretionary | 90 | 85443 | 64.98 | 15810 |
| | Consumer Staples | 50 | 102612 | 56.04 | 8755 |
| | Energy | 12 | 28802 | 680.09 | 6154 |
| | Financials | 1 | 66988 | 7.61 | 16820 |
| | Health Care | 180 | 51951 | 34.97 | 10762 |
| | Industrials | 88 | 59243 | 111.51 | 6303 |
| | Information Technology | 1086 | 39918 | 23.27 | 253751 |
| | Materials | 101 | 32762 | 738.72 | 6733 |
| | Real Estate | 0 | 2801 | 61.14 | 155 |
| | Telecommunication Services | 12 | 35093 | 36.45 | 14542 |
| | Utilities | 1 | 12179 | 1149.57 | 2959 |

| | | Innovation_activity | Firm_size | Pollution | Customer_interaction |
|---|---|---|---|---|---|
| | | Mean | Mean | Mean | Mean |
| Country | Austria | 0 | 25012 | 268.58 | 224 |
| | Belgium | 57 | 102939 | 607.84 | 15017 |
| | Denmark | 30 | 31562 | 380.94 | 1483 |
| | Finland | 17 | 15838 | 1213.97 | 362 |
| | France | 35 | 61646 | 152.63 | 3317 |
| | Germany | 680 | 155841 | 269.40 | 31613 |
| | Ireland | 0 | 11640 | 35.70 | 422 |
| | Italy | 16 | 37478 | 140.72 | 3206 |
| | Luxembourg | 0 | 17689 | 40.13 | 660 |
| | Netherlands | 335 | 46159 | 451.80 | 2488 |
| | Norway | 6 | 15838 | 539.69 | 4199 |
| | Spain | 3 | 89618 | 310.06 | 6720 |
| | Sweden | 314 | 32084 | 183.53 | 1460 |
| | Switzerland | 45 | 32558 | 20.92 | 4936 |
| | United Kingdom | 7 | 38830 | 145.91 | 7802 |
| | United States | 284 | 86778 | 143.77 | 96956 |

# Appendix 3. Repeated measures ANOVA country

## Assumptions testing

**Mauchly's Test of Sphericity[a]**

Measure: MEASURE_1

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon[b] Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
|---|---|---|---|---|---|---|---|
| Time | .155 | 411.506 | 2 | **.000** | .542 | .548 | .500 |

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept + Country_new
Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

**Levene's Test of Equality of Error Variances[a]**

| | F | df1 | df2 | Sig. |
|---|---|---|---|---|
| Innovation_activity_2015 | 15.439 | 2 | 222 | **.000** |
| Innovation_activity_2016 | 15.298 | 2 | 222 | **.000** |
| Innovation_activity_2017 | 16.550 | 2 | 222 | **.000** |

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Country_new
Within Subjects Design: Time

## Results

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Time | Sphericity Assumed | 505104.514 | 2 | 252552.257 | 13.230 | .000 | .056 |
| | Greenhouse-Geisser | 505104.514 | 1.084 | 465868.299 | 13.230 | **.000** | .056 |
| | Huynh-Feldt | 505104.514 | 1.095 | 461192.859 | 13.230 | .000 | .056 |
| | Lower-bound | 505104.514 | 1.000 | 505104.514 | 13.230 | .000 | .056 |
| Interaction effect Time * Country | Sphericity Assumed | 276166.597 | 4 | 69041.649 | 3.617 | .006 | .032 |
| | Greenhouse-Geisser | 276166.597 | 2.168 | 127357.071 | 3.617 | **.025** | .032 |
| | Huynh-Feldt | 276166.597 | 2.190 | 126078.919 | 3.617 | .025 | .032 |
| | Lower-bound | 276166.597 | 2.000 | 138083.299 | 3.617 | .028 | .032 |
| Error(Time) | Sphericity Assumed | 8475534.594 | 444 | 19089.042 | | | |
| | Greenhouse-Geisser | 8475534.594 | 240.697 | 35212.433 | | | |
| | Huynh-Feldt | 8475534.594 | 243.137 | 34859.042 | | | |
| | Lower-bound | 8475534.594 | 222.000 | 38178.084 | | | |

**Pairwise Comparisons**

Measure: MEASURE_1

| (I) Time | (J) Time | Mean Difference (I-J) | Std. Error | Sig.[b] | 95% Confidence Interval for Difference[b] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 2015 | 2016 | -16.458* | 5.399 | **.008** | -29.483 | -3.434 |
| | 2017 | 53.785* | 15.260 | **.002** | 16.975 | 90.595 |
| 2016 | 2015 | 16.458* | 5.399 | .008 | 3.434 | 29.483 |
| | 2017 | 70.243* | 18.710 | **.001** | 25.110 | 115.376 |
| 2017 | 2015 | -53.785* | 15.260 | .002 | -90.595 | -16.975 |
| | 2016 | -70.243* | 18.710 | .001 | -115.376 | -25.110 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

**Tests of Between-Subjects Effects**

Measure: MEASURE_1

Transformed Variable: Average

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Intercept | 12381797.42 | 1 | 12381797.42 | 16.739 | .000 | .070 |
| Country | 6539630.511 | 2 | 3269815.255 | 4.421 | **.013** | .038 |
| Error | 164209635.1 | 222 | 739683.041 | | | |

**Pairwise Comparisons**

Measure: MEASURE_1

| (I) Country | (J) Country | Mean Difference (I-J) | Std. Error | Sig.[b] | 95% Confidence Interval for Difference[b] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| United Kingdom | United States | -276.859* | 97.634 | **.015** | -512.377 | -41.340 |
| | Other European countries | -147.727 | 73.280 | **.135** | -324.498 | 29.044 |
| United States | United Kingdom | 276.859* | 97.634 | .015 | 41.340 | 512.377 |
| | Other European countries | 129.131 | 93.886 | **.511** | -97.345 | 355.608 |
| Other European countries | United Kingdom | 147.727 | 73.280 | .135 | -29.044 | 324.498 |
| | United States | -129.131 | 93.886 | .511 | -355.608 | 97.345 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

# Appendix 4. Repeated measures ANOVA sector

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Time | Sphericity Assumed | 402443.570 | 2 | 201221.785 | 11.962 | .000 | .053 |
| | Greenhouse-Geisser | 402443.570 | 1.094 | 367934.867 | 11.962 | **.000** | .053 |
| | Huynh-Feldt | 402443.570 | 1.147 | 351010.857 | 11.962 | .000 | .053 |
| | Lower-bound | 402443.570 | 1.000 | 402443.570 | 11.962 | .001 | .053 |
| Interaction effect Time * Sector | Sphericity Assumed | 1552011.829 | 20 | 77600.591 | 4.613 | .000 | .177 |
| | Greenhouse-Geisser | 1552011.829 | 10.938 | 141893.003 | 4.613 | **.000** | .177 |
| | Huynh-Feldt | 1552011.829 | 11.465 | 135366.308 | 4.613 | .000 | .177 |
| | Lower-bound | 1552011.829 | 10.000 | 155201.183 | 4.613 | .000 | .177 |
| Error(Time) | Sphericity Assumed | 7199689.362 | 428 | 16821.704 | | | |
| | Greenhouse-Geisser | 7199689.362 | 234.071 | 30758.556 | | | |
| | Huynh-Feldt | 7199689.362 | 245.357 | 29343.745 | | | |
| | Lower-bound | 7199689.362 | 214.000 | 33643.408 | | | |

**Tests of Between-Subjects Effects**

Measure: MEASURE_1

Transformed Variable: Average

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Intercept | 10017992.46 | 1 | 10017992.46 | 16.018 | .000 | .070 |
| Sector | 36912693.10 | 10 | 3691269.310 | 5.902 | **.000** | .216 |
| Error | 133836572.6 | 214 | 625404.545 | | | |

**Pairwise Comparisons**

Measure: MEASURE_1

| (I) Sector | (J) Sector | Mean Difference (I-J) | Std. Error | Sig.[b] | 95% Confidence Interval for Difference[b] Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| Information Technology | Consumer Discretionary | 996.574* | 152.194 | .000 | 484.537 | 1508.611 |
| | Consumer Staples | 1036.065* | 162.592 | .000 | 489.046 | 1583.084 |
| | Energy | 1074.125* | 208.401 | .000 | 372.989 | 1775.261 |
| | Financials | 1085.355* | 162.592 | .000 | 538.336 | 1632.374 |
| | Health Care | 906.463* | 170.158 | .000 | 333.988 | 1478.938 |
| | Industrials | 997.788* | 146.224 | .000 | 505.839 | 1489.738 |
| | Materials | 985.355* | 162.592 | .000 | 438.336 | 1532.374 |
| | Real Estate | 1086.167* | 176.834 | .000 | 491.233 | 1681.100 |
| | Telecommunication Services | 1074.500* | 228.292 | .000 | 306.444 | 1842.556 |
| | Utilities | 1085.574* | 201.334 | .000 | 408.212 | 1762.936 |

# Appendix 5. Linear mixed model

**Model Dimension**[a]

| | | Number of Levels | Covariance Structure | Number of Parameters | Subject Variables | Number of Subjects |
|---|---|---|---|---|---|---|
| Fixed Effects | Intercept | **1** | | 1 | | |
| | Pollution | **1** | | 1 | | |
| | Firm_size | **1** | | 1 | | |
| | Customer_interaction | **1** | | 1 | | |
| | Interaction effect: pollution * customer_interaction | **1** | | 1 | | |
| | Interaction effect: pollution * firm_size | **1** | | 1 | | |
| | Sector | **11** | | 10 | | |
| | Country | **3** | | 2 | | |
| Random Effects | Intercept + Pollution + Firm size + Customer interaction | **4** | Variance Components | 4 | Firm | |
| Repeated Effects | Time | **3** | Compound Symmetry | 2 | Firm | **225** |
| Total | | 27 | | 24 | | |

a. Dependent Variable: Innovation_activity.

**Estimates of Fixed Effects**[a]

| Parameter | Estimate | Std. Error | df | t | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|
| Intercept | 318.739490 | 744.622214 | 230.948 | .428 | .669 | -1148.381460 | 1785.860440 |
| Pollution | **-.370495** | .168433 | 2129.199 | -2.200 | **.028** | -.700804 | -.040185 |
| Firm_size | .001212 | .001325 | 69.251 | .914 | .364 | -.001432 | .003856 |
| Customer_interaction | -.000753 | .436165 | 147.259 | -.002 | .999 | -.862704 | .861199 |
| Interaction effect: pollution * customer_interaction | **-2.441353E-5** | 7.315583E-6 | 7421.789 | -3.337 | **.001** | -3.875415E-5 | -1.007291E-5 |
| Interaction effect: pollution * firm_size | **2.524514E-6** | 2.528117E-6 | 951.652 | .999 | **.318** | -2.436815E-6 | 7.485842E-6 |
| Control variable sector: consumer discretionary | -118.845234 | 769.251985 | 238.048 | -.154 | .877 | -1634.255860 | 1396.565393 |
| Control variable sector: consumer staples | -202.829307 | 779.624692 | 217.431 | -.260 | .795 | -1739.418431 | 1333.759817 |
| Control variable sector: energy | -190.051235 | 975.202500 | 159.454 | -.195 | .846 | -2116.030455 | 1735.927986 |
| Control variable sector: financials | -338.411991 | 763.053045 | 209.333 | -.443 | .658 | -1842.665157 | 1165.841174 |
| Control variable sector: health care | -290.631255 | 784.131984 | 199.135 | -.371 | .711 | -1836.899055 | 1255.636544 |
| Control variable sector: Industrials | 5.380127 | 756.338614 | 228.361 | .007 | .994 | -1484.914438 | 1495.674692 |
| Control variable sector: Information technology | 1198.638746 | 800.963021 | 194.857 | 1.496 | .136 | -381.031010 | 2778.308503 |
| Control variable sector: materials | -190.989652 | 788.047644 | 181.551 | -.242 | .809 | -1745.899668 | 1363.920363 |
| Control variable sector: real estate | -170.095762 | 1528.639102 | 434.728 | -.111 | .911 | -3174.537876 | 2834.346353 |
| Control variable sector: telecommunication services | -243.607628 | 905.134220 | 112.672 | -.269 | .788 | -2036.898244 | 1549.682987 |
| Control variable sector: Utilities (reference group) | 0[b] | 0 | . | . | . | . | . |
| Control variable country: United Kingdom | -217.741679 | 265.845361 | 93.173 | -.819 | .415 | -745.644925 | 310.161567 |
| Control variable country: United States | -47.176057 | 252.973391 | 81.400 | -.186 | .853 | -550.476298 | 456.124184 |
| Control variable country: other European countries (reference group) | 0[b] | 0 | . | . | . | . | . |

a. Dependent Variable: Innovation_activity.

b. This parameter is set to zero because it is redundant.

**Estimates of Covariance Parameters**[a]

| Parameter | | Estimate | Std. Error | Wald Z | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|
| Repeated Measures | CS diagonal offset | 10200.8177[b] | .000000 | . | . | . | . |
| | CS covariance | -3400.27177[b] | .000000 | . | . | . | . |
| Intercept [subject = Firm] | Variance | 567364.3092 | 133807.8296 | 4.240 | .000 | 357366.3808 | 900762.5692 |
| Pollution [subject = Firm] | Variance | .000000[b] | .000000 | . | . | . | . |
| Firm_size [subject = Firm] | Variance | 5.505788E-5 | 1.802140E-5 | 3.055 | .002 | 2.898721E-5 | .000105 |
| Customer_interaction [subject = Firm] | Variance | 6015.203572 | 3.262732 | 1843.609 | .000 | 6008.812132 | 6021.601810 |

a. Dependent Variable: Innovation_activity.

b. This covariance parameter is redundant. The test statistic and confidence interval cannot be computed.

# Appendix 6. Robustness check linear regression

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .593[a] | .351 | .332 | 422.171 |

a. Predictors: (Constant), Twenty_sixteen, EU, Industrials, Firm_size, Utilities, Telecommunication_services, Energy, Customer_interaction, Health_care, Real_estate, Consumer_staples, Financials, Twenty_fifteen, US, Sustainability, Materials, Consumer_discretionary, Sustainability_X_firm_size_centered, Sustainability_X_customer_interaction_centered

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 63176771.44 | 19 | 3325093.234 | 18.656 | .000[b] |
| | Residual | 116739819.5 | 655 | 178228.732 | | |
| | Total | 179916591.0 | 674 | | | |

a. Dependent Variable: Innovation_activity

b. Predictors: (Constant), Twenty_sixteen, EU, Industrials, Firm_size, Utilities, Telecommunication_services, Energy, Customer_interaction, Health_care, Real_estate, Consumer_staples, Financials, Twenty_fifteen, US, Sustainability, Materials, Consumer_discretionary, Sustainability_X_firm_size_centered, Sustainability_X_customer_interaction_centered

**Bootstrap for Coefficients**

| Model | | B | Bootstrap[a] | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | BCa 95% Confidence Interval | |
| | | | Bias | Std. Error | Sig. (2-tailed) | Lower | Upper |
| 1 | (Constant) | 724.954 | 3.732 | 204.717 | .002 | 355.479 | 1136.803 |
| | Pollution | -.165 | .010 | .096 | **.039** | -.345 | .192 |
| | Firm_size | .001 | 6.963E-6 | .000 | **.001** | .000 | .001 |
| | Customer_interaction | .001 | .000 | .001 | **.017** | .001 | .004 |
| | Inteaction effects: pollution * customer_interaction | 2.358E-7 | 4.406E-7 | 3.187E-6 | .692 | -1.823E-6 | 6.949E-6 |
| | Interaction effect: pollution * firm_size | -2.804E-6 | 1.677E-8 | 1.675E-6 | **.098** | -6.861E-6 | 1.783E-7 |
| | Control variable sector: consumer discretionary | -803.999 | -4.701 | 213.611 | .004 | -1247.086 | -396.745 |
| | Control variable sector: consumer staples | -870.754 | -3.191 | 216.275 | .003 | -1312.606 | -467.854 |
| | Control variable sector: energy | -831.458 | -3.855 | 209.951 | .003 | -1257.107 | -445.276 |
| | Control variable sector: financials | -927.577 | -5.031 | 213.149 | .002 | -1358.550 | -540.447 |
| | Control variable sector: health care | -705.418 | -5.582 | 226.075 | .004 | -1162.998 | -267.002 |
| | Control variable sector: industrials | -768.086 | -4.739 | 213.142 | .002 | -1198.400 | -389.069 |
| | Control variable sector: materials | -685.901 | -5.039 | 210.166 | .003 | -1112.094 | -315.980 |
| | Control variable sector: real estate | -782.544 | -3.586 | 211.466 | .003 | -1212.909 | -402.023 |
| | Control variable sector: telecommunication services | -893.710 | -4.537 | 210.060 | .002 | -1307.411 | -512.791 |
| | Control variable sector: utilities | -752.610 | -4.756 | 208.546 | .002 | -1170.108 | -371.443 |
| | Control variable country: United States | 18.725 | -4.900 | 48.554 | .710 | -59.577 | 95.613 |
| | Control variable country: European countries | 143.484 | -1.857 | 28.609 | .002 | 87.938 | 198.464 |
| | Control variable year: 2015 | 48.839 | .324 | 36.478 | .196 | -18.067 | 123.158 |
| | Control variable year: 2016 | 55.611 | -2.382 | 36.723 | .134 | -6.422 | 118.925 |

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

# Appendix 7. Robustness check negative binominal regression

**Omnibus Test[a]**

| Likelihood Ratio Chi-Square | df | Sig. |
|---|---|---|
| 329.638 | 5 | **.000** |

Dependent Variable: Innovation_activity_2016
Model: (Intercept), Pollution_2015, Firm_size_2015, Customer_interaction_2015, Pollution * firm_size, Pollution * customer_interaction

a. Compares the fitted model against the intercept-only model.

**Parameter Estimates**

| | | | 95% Wald Confidence Interval | | Hypothesis Test | | | | 95% Wald Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | B | Std. Error | Lower | Upper | Wald Chi-Square | df | Sig. | Exp(B) | Lower | Upper |
| (Intercept) | 4.721 | .3650 | 4.005 | 5.436 | 167.251 | 1 | .000 | 112.259 | 54.891 | 229.582 |
| Pollution_2015 | -.007 | .0016 | -.011 | -.004 | 19.506 | 1 | **.000** | **.993** | .990 | .996 |
| Firm_size_2015 | 1.984E-5 | 1.9449E-6 | 1.603E-5 | 2.366E-5 | 104.107 | 1 | **.000** | **1.000** | 1.000 | 1.000 |
| Customer_interaction_2015 | -6.842E-5 | 1.7628E-5 | .000 | -3.387E-5 | 15.064 | 1 | **.000** | **1.000** | 1.000 | 1.000 |
| Interaction effect: pollution * firm_size | 3.487E-8 | 7.6034E-9 | 1.997E-8 | 4.978E-8 | 21.038 | 1 | **.000** | **1.000** | 1.000 | 1.000 |
| Interaction effect: pollution * customer_interaction | -4.366E-7 | 9.4171E-8 | -6.212E-7 | -2.520E-7 | 21.493 | 1 | **.000** | **1.000** | 1.000 | 1.000 |
| (Scale) | 1[a] | | | | | | | | | |
| (Negative binomial) | 1[a] | | | | | | | | | |

Dependent Variable: Innovation_activity_2016
Model: (Intercept), pollution_2015, Firm_size_2015, Customer_interaction_2015, pollution * firm_size, pollution * customer_interaction

a. Fixed at the displayed value.