The influence of green innovations on economic performance.

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Master thesis

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Chapter 1: Introduction

Humanity is on a collision course with the natural world (Ripple et al., 2017). Environmental degradation poses a major threat to the survival of the human race. Manifestations of environmental degradation have become painfully visible. With 18 of the 19 warmest years ever recorded having occurred since 2001 and a current average temperature anomaly of 0.8 °C, global climate change can no longer be disputed (NASA, 2019). For a large part, these rising temperatures are the result of increased atmospheric greenhouse gas levels. Regarding carbon dioxide, one of the most abundant greenhouse gases, pre-industrial levels had never exceeded 280 ppm. In 2017 the atmospheric CO_2 concentration reached 405.5 ppm with an average annual increase of 2.24 ppm over the last decade (WMO, 2018). Based on global emissions in 2010, the industrial sector is a considerable culprit responsible for 31% of global greenhouse gas emissions. This includes direct and indirect emissions that are associated with on- and offsite industrial energy production (IPCC, 2014, p. 8). The energy consumption by the industrial sector is higher than the energy consumption by all other end-use sectors combined and over the coming twenty years the amount of energy consumed by the industrial sector is only projected to grow (Capuano, 2018). It is evident that industry needs to shift toward a more environmentally sustainable way of doing business in which the needs of current and future generations are met, while preserving the health of the ecosystems required to do so (Morelli, 2011).

In an effort to address sustainability issues and reduce negative environmental externalities of industrial activity, green innovations could offer a solution. Green innovations "capture improvements in product design and manufacturing processes that save energy, reduce pollution, minimize waste and decrease a firm's negative impact on the environment" (Tang, Walsh, Lerner, Fitza, & Li, 2018, p. 40). This hints at a duality in the green potential of manufacturing firms. Not only does the manufacturing industry account for a sizeable portion of humankind's global energy consumption, it also has the ability to produce environmentally-friendly products. At the end of last century, the predominant business logic for corporate greening concentrated on the cost-saving potential, while largely ignoring the opportunities in other areas (Hart, 1997). In the last two decades, that logic has started to shift to a logic that acknowledges the opportunities that a focus on environmental sustainability holds for innovation (Dangelico, Pujari, & Pontrandolfo, 2017; Hansen, Grosse-Dunker, & Reichwald, 2009; Nidumolu, Prahalad, & Rangaswami, 2009). Conducting business in an environmentally sustainable way could simultaneously be a driver of value and a source of competitive advantage (Ambec & Lanoie, 2008; van Hoek, 1999; Wilkerson, 2005). Environmental considerations "can trigger innovations that lower the total cost of a product or improve its value" (Porter & van der Linde, 1995, p. 120). Accordingly, this thesis concentrates on the potential of green innovations to save costs and add value.

The realization that humanity needs to take into account the planetary environmental limits seems to have permeated into society, politics and business as there is an increasing awareness for environmental degradation and the urgency associated with the issue. In several European countries, students have held protest marches and called for action on climate change with expressions as "there is no planet B" and "human change, not climate change" (HLN, 2019; NRC, 2019). Internationally, governments have acknowledged the importance of combating climate change as illustrated by the 185 UNFCCC members ratifying the Paris Agreement (UNFCCC, n.d.). Principally, the agreement aims to keep the increase in global temperature below a maximum of 2 °C for this century (UNFCCC, 2018). The fact that environmental consciousness is gaining momentum on a global scale puts the business world under pressure to act environmentally responsible. The emergence of concepts like corporate social responsibility, corporate sustainability, and triple bottom line shows that the industrial sector recognizes that it should not exclusively strive for financially sound performance. Instead, industry needs to arrive at a sustainable equilibrium within the interaction between people, planet, and profit (Elkington, 1997).

Green innovations, in the prominent win-win proposition, provide a way to reach such a balanced interaction in which environmental benefits and increased competitiveness line up harmoniously (Bernauer, Engel, Kammerer, & Seijas, 2007). Green innovations raise competitiveness (Chen, Lai, & Wen, 2006) by unlocking resource efficiencies, unexplored market segments, and profitable opportunities (Porter & van der Linde, 1995). This is likely to have positive implications for the overall economic performance of firms by enabling cost reductions, revenue growth, and profitability improvements. The role of green innovations as potential catalyst of superior economic performance has sparked considerable scholarly interest. With regard to green product innovations and green product developments in relation to economic performance, academic literature denotes a positive relationship (Ar, 2012; Chan, Yee, Dai, & Lim, 2016; Lin, Tan, & Geng, 2013; Pujari, 2006). With respect to the link between green process innovations and economic performance, scientific work has spurred controversy. Hart and Ahuja (1996) suggest that the economic performance of firms benefits from efforts to reduce emissions by aiming to prevent pollution during the manufacturing process. Pons, Bikfalvi, Llach, and Palcic, (2013) are unable to substantiate that claim as they find no clear direct relationship between the application of energy- and material-saving technologies and economic performance. However, others do succeed in providing empirical evidence for positive profitability effects of energy and resource efficient process innovations (Ghisetti & Rennings, 2014).

The objective of this thesis is to investigate the influence of green product innovations and green process innovations on manufacturing firms' revenue growth and production cost growth. Additionally, this study aims to shed light on the role of energy consumption in the relationship between green process innovations and production costs. Green product innovations are understood as both improvements to existing products or the launch of entirely new products that lead to better environmental effects. Green process innovations represent energy- and resource-saving technologies applied in the manufacturing process. The study builds on research by Pons et al. (2013) by portraying whether green process innovations affect economic performance in the context of Dutch manufacturing firms. It offers a unique contribution by involving energy consumption in that relationship. Furthermore, the study adds to existing literature by exploring the effect of green product innovations on economic performance indicators of those manufacturing firms. \

Based on the foregoing, the thesis poses the following main research question: *'To what extent are green innovations related to economic performance in manufacturing firms and to what extent does energy consumption play a role?'*. Sub questions are formulated to unveil the underlying relationships and include: *'To what degree do green product innovations influence revenue growth and production cost growth?'*, *'To what degree do green process innovations influence production cost growth?'*, and *'To what degree do green process innovations influence production cost growth through their effect on energy consumption growth?'*. By thoroughly analyzing the business logic for Dutch manufacturing firms with regard to green innovations, this thesis contributes to the progression towards a world where society and business interact without adverse consequences for the environment. It attempts to invigorate the business case for corporate environmental sustainability by determining whether green innovation can be considered an attractive business strategy because of its cost-saving and value-adding potential. In the ensuing chapters, this paper will provide an overview of relevant literature, address the methodology used to collect data, present and interpret the outcomes, remark on the limitations, and ultimately discuss recommendations for practice and research.

Chapter 2: Literature review

The following section will present a theoretical background for the concepts of interest to this study. It starts with a foundation for the overarching concept of green innovation by discussing its origins, synonyms, and definitions. Subsequently, it specifies two forms of green innovations represented by green product innovations and green process innovations. Thereafter, this chapter provides a theoretical embedding for the direct effects of green product innovations and green process innovations. Finally, it formulates a theoretical grounding for the potential mediating effect of energy consumption before ending with a conceptual visualization of the hypothesized relationships.

Green innovation

Innovation, in its most general sense, describes the organizational multi-stage process whereby ideas are transformed into new or improved products, services or processes with the goal of increasing competitiveness and differentiability relative to others in the marketplace (Baregheh, Rowley, & Sambrook, 2009). Green innovation, as a distinct form of innovation, incorporates the environmental component by urging that such products, services or processes should "contribute to a reduction in environmental burdens" (Hellström, 2007, p. 148). The concept of green innovation originates from the broader notion of 'sustainable development', which in turn has its roots in the literature on 'corporate social responsibility'. The basic conception of corporate social responsibility (CSR) was introduced to the academic world as early as the 1950s (Carroll, 1999). CSR refers to the voluntary integration of social and environmental concerns in business operations as well as in firms' interaction with stakeholders (Commission of the European Communities, 2001). Sustainability, as one of CSR's key principles, suggests that firms "should operate in ways that secure long-term economic performance by avoiding short-term behavior that is socially detrimental or environmentally wasteful" (Porter & Kramer, 2006, p. 81). Sustainable development is interpreted as meeting the needs of the present in a way that does not compromise the ability of future generations to meet their needs (Brundtland Commission, 1987). The rather generic connotation of the concept of sustainable development has led researchers to investigate the notion of green innovation under different denominators. As a result, various alternatives to green innovation now circulate in academic literature that imply roughly the same (i.e., sustainable innovation, ecological innovation, environmental innovation) (Schiederig, Tietze, & Herstatt, 2012).

The existence of a plethora of terms and accompanying definitions for the concept of green innovation indicates that consensus has not been reached with regard to what exactly green innovation appertains to. Researchers generally concur that green innovative activities should reduce negative environmental externalities. However, some relate the process of green innovation to the development of a broad spectrum of both tangible and intangible outcomes (Hellström, 2007), while others only recognize tangible developments (Chen, Lai, & Wen, 2006). Additionally, some dichotomize the concept into a technological and an organizational dimension (Petruzzelli, Dangelico, Rotolo, & Albino, 2011). Still others emphasize that it is a process which contains multiple consecutive stages, from idea generation to actual value creation (Sarkar, 2013). In order to prevent spiralling into an endless debate on what belongs to green innovation, this thesis is exclusively concerned with the outcomes that arise out of the process. It focuses on green innovations as the result of innovative activities rather than the innovation process itself. Additionally, it concentrates solely on technological and tangible outcomes (i.e., products, processes and technologies) of green innovation and omits organizational and intangible outcomes (i.e., ideas and behaviour) for reasons of scope. Hence, this study interprets green innovations as new or modified products, processes and technologies that enable a firm to avoid or mitigate environmental harm (Kemp, 2000).

Porter and van der Linde (1995) make the renowned suggestion that reducing pollution coincides with improving productivity by completely, efficiently, and effectively using resources. This line of reasoning implies that green innovations may lead to increased revenues and reduced costs (Tsai & Liao, 2017), and thus to improved economic performance (Ar, 2012; Dangelico, 2016; Lee & Min, 2015; Lin et al., 2013). Revenues grow as a result of the increase in demand by environmentally conscious customers, while costs decrease through productivity and efficiency gains (King & Lenox, 2002; Reinhardt, 1999; Schmidheiny, 1992).[1]

Green product innovations

Green product innovations, constituting the first category of green innovations, relate to 'what' is manufactured. Green products are those that take the natural environment into account by conserving energy and/or resources as well as by reducing or eliminating toxic agents,

[1] Although this appears to be too good to be true from a business perspective, an environmental perspective urges caution. Economic efficiency improvements can provoke rebound effects. Rebound effects occur when improved production efficiency lowers associated production costs and prices of end-products, which ultimately elevates demand and related consumption of resources (Berkhout, Muskens, & Velthuijsen, 2000). The resulting overall economic growth could more than nullify the initial environmental gains generated by enhanced efficiency (Korhonen, Honkasalo, & Seppälä, 2018).

pollution, and waste (Ottman, Stafford, & Hartman, 2006). Dangelico and Pujari (2010) consider green products in relation to three different areas of environmental focus - material, energy, and pollution. These areas transgress multiple stages of the product life cycle and are accentuated for their considerable environmental impact. Devoting effort to various areas and life cycle stages as opposed to a single area or stage, for example by simultaneously reducing the energy consumption during use and improving recycling properties, can be assumed to yield more environmental benefits. Parallely, Dangelico and Pujari (2010) posit that addressing environmental sustainability across the different areas and product life cycle stages can bring product differentiation and deliver competitiveness. Therefore, when examining the relationship between green product innovations and economic performance, it is better to study their performance in terms of the amount of environmental effects they evoke than to merely study their presence. Accordingly, and similar to Chen, Lai, and Wen (2006), this thesis takes the performance of green product innovations into account by investigating the number of environmental effects they achieve.

The influence of the effectiveness of green product innovations on revenues

Regarding the potential of green product innovations to increase revenues, a dual effect merits discussion. Firstly, green product innovations can pave the way for tapping into new, unexplored markets. A market can be segmented according to the heterogeneity in demand that is inherently existent among consumers (Dickson & Ginter, 1987) and those various market segments can be served by distinctly positioned product offerings (Dibb & Simkin, 1991). A product offering, viewed as a bundle of characteristics (Rosen, 1974), occupies a specific position in the minds of consumers when it is perceived as different from competitive offerings on any physical or non-physical product characteristics (Dickson & Ginter, 1987). Regarding the environmental context, there is a large market segment that is interested in green products, for whom such products offer added value above and beyond the value offered by non-green products (Shrivastava, 1995). Through green product design and innovation, products can be realized that address environmental issues and enable access to the green consumer market (Chen, 2001). A Turkish study conducted among 540 consumers provides empirical support for the existence and attractiveness of the green consumer market by showing that green product features positively influence green purchasing behaviors of consumers (Boztepe, 2012). Related research among 887 Portuguese consumers endorses this by evincing that a green consumer segment can be differentiated and that some of those consumers are prepared to let their buying decisions depend on whether a product is environmentally harmful or not (do Paço & Raposo, 2010).

Secondly, firms that act as pioneers in the unexplored green market will experience first mover advantages, which grants them the ability to demand higher prices for green products (Hart, 1995; Peattie, 1992). Green consumers, those who consider environmental issues when making purchases, exhibit a higher willingness to spend more for green products (Laroche, Bergeron, & Barbaro-Forleo, 2001). Consequently, this allows for price premiums to be set for green products, which raises competitiveness (Porter & van der Linde, 1995) and drives the potential to yield higher revenues (Hojnik & Ruzzier, 2016). Ranging from the food to the wood sector, green products have been consistently shown to be positively related with willingness to pay (Loureiro, McCluskey, & Mittelhammer, 2002; Veisten, 2007; Vlosky, Ozanne, & Fontenot, 1999; Xu, Zeng, Fong, Lone, & Liu, 2012). In a Malaysian study of 250 consumers, a green consumer attitude turned out to be positively associated with willingness to pay for environmentally-friendly products (Tsen, Phang, Hasan, & Buncha, 2006). The rationale recounted above leads to the first hypothesis, which is formulated as follows.

H1. The higher the amount of environmental effects achieved by green product innovations, the higher the revenue growth.

The influence of the effectiveness of green product innovations on production costs

In relation to the ability of green product innovations to influence production costs, multiple aspects deserve attention. In terms of materials, green product innovations can lead to resource-savings at what Terzi, Bouras, Dutta, Garetti, and Kiritsis (2010) refer to as a product's beginning-of-life (BOL) and end-of-life (EOL) phase. At the BOL-phase, raw material inputs can be minimized by reducing the number of parts, the amount of different material types, and the absolute quantity of required materials in the product (Hellström, 2007). At the EOL-phase, improvements in recyclability can "make waste, ugly and useless, something nice and useful" (Dangelico & Pujari, 2010, p. 476). Conventional materials used in production can be substituted with recycled materials retrieved from end-of-life products, with apparent cost benefits. The resulting efficient use of raw materials translates into cost-savings for manufacturing firms (Ar, 2012; Schmidheiny, 1992; Young, 1991).

Additionally, environmental regulations imposed to limit or reduce pollution could paradoxically lead to lower costs. Becker (1968) proposes that, in the face of regulatory compliance or non-compliance, the option with the highest expected utility is chosen. Applied to the context of environmental regulations, this means that firms comply with a particular regulation when the benefits of compliance exceed the costs of compliance (Winter & May, 2001). At first sight, environmental regulations would appear to inflate costs by necessitating green product innovation or development. Empirical research conducted among 4188 facility managers in Canada, France, Germany, Hungary, Japan, Norway, and the US confirms that manufacturing firms incur costs because of environmental regulations, but also indicates that such costs can be completely neutralized when a firm's environmental harmfulness is reduced (Darnall, 2009). Porter and van der Linde (1995) go one step further by positing that appropriate environmental regulations can trigger innovations that might more than offset the compliance costs through their connection with productivity and efficiency gains. Andersen (2010) reinforces that production costs can be reduced through improved resource efficiency. However, the theorized positive relationship between environmental regulations and productivity gains remains empirically unsubstantiated. Whereas various studies in the US manufacturing industry reviewed by Jaffe, Peterson, Portney, and Stavins (1995) highlight a generally negative relationship, other research suggests that the opposite holds true (e.g., Alpay, Buccola, & Kerkvliet, 2002; Berman & Bui, 2001). Stringent environmental regulations are not always detrimental to productivity (Ambec & Lanoie, 2008). However, green product innovations spurred by environmental regulations do not all equally generate productivity and efficiency gains either. Some environmental regulations provoke incremental green product innovations that are introduced solely for the purpose of regulatory compliance (e.g., Smith & Crotty, 2008). This might suggest that the radicalness of green product innovations, in terms of how effective they are in addressing various sustainability challenges (Dangelico & Pujari, 2010), is tied to the productivity and efficiency gains they elicit, and thus to their ability to decrease production costs. Based on the foregoing, this study presents the second hypothesis as follows.

H2. The higher the amount of environmental effects achieved by green product development, the lower the production cost growth .

Green process innovations

Green process innovations, representing the second category of green innovations, are concerned with 'how' something is manufactured. At a fundamental level, green process innovation occurs "when a given amount of output can be produced with less input" (Rennings, 2000, p. 322). Compared to alternative production processes, green processes induce positive or less negative externalities with respect to the environment (Triguero, Moreno-Mondéjar, & Davia, 2013).

The influence of the use of green process innovations on production costs

Hart (1995) proposes the control approach and the prevention approach as the two primary methods for abating pollution. Where the control approach holds that "emissions and effluents are trapped, stored, treated, and disposed of using pollution-control equipment", the prevention approach pertains that "emissions and effluents are reduced, changed, or prevented through better housekeeping, material substitution, recycling, or process innovation" (p. 992). Therefore, green process innovations aimed at reducing or preventing pollution during the manufacturing process can be considered to belong to the prevention approach more than the control approach. Firms that direct their attention to preventing pollution, rather than relying on expensive, non-productive end-of-pipe pollution-control equipment, can realize considerable savings and establish cost advantages over competitors (Hart & Ahuja, 1996; Romm, 1994; Rusinko, 2007). The underlying logic is in accordance with the adage that 'prevention is better than cure', derived from the Kaizen approach to management (Imai, 1986). Introducing green innovations for the purpose of pollution prevention in the manufacturing process can generate savings by averting the costs associated with installing and operating pollution-control equipment (Dietmair & Verl, 2009; Hart, 1995).

Similarly, applying such innovations can reduce cycle times and decrease related costs through the ability to simplify production operations or eliminate unnecessary steps altogether (Hammer & Champy, 1993; Stalk & Hout, 1990). When investment portfolios are increasingly centered around pollution prevention technologies, manufacturing performance improves in terms of cost, speed and flexibility (Klassen & Whybark, 1999).

Analogous to the previous section discussing the linkage between environmental regulations and green product innovations, such regulations also have the potential to decrease costs with respect to green process innovations. Aiming to prevent pollution during the manufacturing process offers the potential to cut back emissions well below stipulated regulatory ceilings, leading to lower compliance costs (Rooney, 1993). Though realizing that efforts to reduce emissions throughout each and every individual stage of the manufacturing process may be a costly affair, Frosch and Gallopoulos (1989) advocate imposing of regulations in order to incentivize firms to change their manufacturing processes in a way that minimizes negative externalities for the environment. Hart and Ahuja (1996) suggest that high polluters, those with the highest emission levels, can stand to gain substantially from implementing environmental improvements. With regard to the early stages of pollution prevention, there is a considerable amount of "low hanging fruit" in terms of realizable environmental potential (Hart, 1995, p. 993). In these initial stages, simple and inexpensive innovations can bring about sizable emission reductions relative to costs. However, as corporate environmental performance improves, achieving additional emission reductions becomes increasingly challenging due to it requiring more demanding changes to production processes (Frosch & Gallopoulos, 1989). For reasons mentioned above, the third hypothesis is crafted as follows.

> *H3. The higher the amount of green process technologies applied, the lower the production cost growth.*

The influence of the use of green process innovations on production costs through its effect on energy consumption

Given that the industrial sector consumes roughly 54% of the energy generated worldwide (EIA, 2016), it is unsurprising that green process innovations and energy efficiency are often mentioned within the same breath. However, although investing in higher energy efficiency is mainly incentivized by the desire to save costs (Rennings & Rammer, 2009), the actual effect of green process innovations on energy efficiency and subsequent monetary outcomes remains underexplored. Rather than having been studied in conjunction, the performance of green process innovations in terms of energy-saving (e.g., Chen, Lai, & Wen, 2006) and the effect of environmental performance on economic performance (e.g., King & Lenox, 2001; Russo & Fouts, 1997) have been examined separately. In an attempt to fill that research gap, this thesis discusses the influence of the application of green process innovations on production costs through its effect on energy consumption. Energy consumption growth is used as a proxy for environmental performance to account for the actual potential of green process innovations to attain energy efficiency.

The academic world is divided on the subject of energy-efficient innovations and their influence on firms' economic performance. Where Ghisetti and Rennings (2014) find that energy-efficient process innovations engender positive profitability effects, Pons et al. (2013) are unable to prove a direct positive effect of energy-saving technologies on the sales profit of manufacturing firms. Interestingly, Pons et al. (2013) do indicate a significant link between energy-saving technologies and environmental performance. With regard to environmental performance, Al-Tuwaijri, Christensen, and Hughes Ii (2004) demonstrate that it is positively associated with economic performance. This suggests that green process innovations do not influence economic performance directly, but rather through their ability to accomplish environmental performance (e.g., by way of reducing energy consumption). It should be noted that there is at least some degree of controversy regarding the connection between environmental and economic performance. The relevant body of research has not exclusively arrived at the same conclusion. As an example, Link and Naveh (2006) have been unsuccessful in corroborating any relationship between environmental performance and economic performance. On the other hand, neither did their research show that improving environmental performance was harmful to economic performance. Part of the explanation for the existence of conflicting results is that previous studies used different definitions for the concept of environmental performance (Zeng, Meng, Yin, Tam, & Sun, 2010).

The astronomical energy demand of the manufacturing industry is accompanied by considerable costs. Currently, costs associated with energy generation from alternative, renewable sources have decreased to the point that they are level with or below the costs of energy generation from conventional, non-renewable sources (Lazard, 2018). This implies that manufacturing firms could benefit from using renewable energy as opposed to more expensive non-renewable energy. However, regardless of whether energy is renewable or not, energy consumption remains inseparable from costs. Therefore, reducing the overall energy consumption is most beneficial. Logic dictates that using a lower amount of energy to produce the same level of output will result in superior economic performance by decreasing costs while maintaining the sales volume. Lower energy consumption levels can be achieved by operating energy-efficient production mechanisms, embodied by green process innovations (Chen et al., 2006). The previous discussion provides the foundation for the fourth hypothesis, which is phrased as follows.

H4. The higher the amount of green process technologies applied, the lower the energy consumption growth, and subsequently the lower the production cost growth.

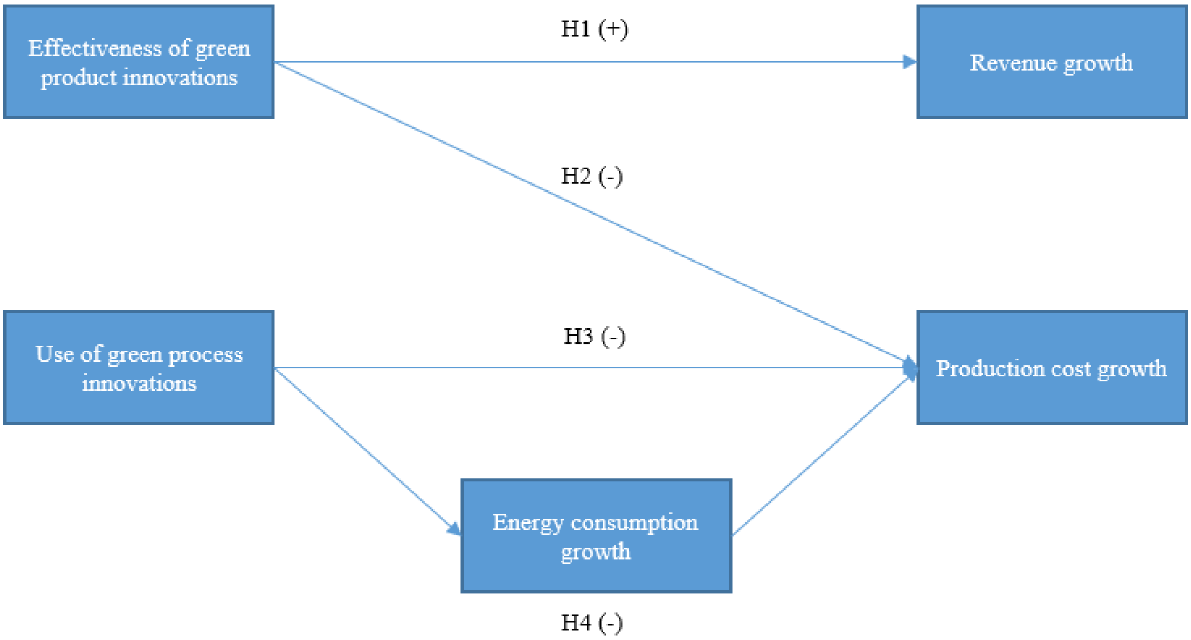

Figure 1: Conceptual model

Chapter 3: Methodology

This chapter will elaborate on the methodological considerations of the study. It first addresses the research design and provides details on the process of data collection. Subsequently, it touches upon the operationalization of the concepts studied, which is depicted in table-form as well. Lastly, it reports on the validity and reliability of the study as well as the research ethics.

Research design

As graphically displayed by the conceptual model (Figure 1), this study investigates how the effectiveness of green product innovations influences revenue growth and production cost growth as well as how the use of green process innovations affects production cost growth. It also probes the possible mediating role of energy consumption growth in the relationship between the use of green process innovations and production cost growth. A quantitative research, involving numbers as primary data (Field, 2013), was conducted to examine the posed hypotheses. More specifically, a survey was presented to a large group of respondents with the ultimate goal of "describing, predicting, and explaining" the conceptualized phenomena ('t Hart, Boeije, & Hox, 2009, p. 215). Qualitative research methods were deemed unsuitable as they are unable to prove causal relationships. Furthermore, an experimental research design was considered unfitting as the objective was not to compare two or more groups by manipulating a variable, but to study relationships between variables in reality for ungrouped manufacturing firms of diverse sizes and industries.

Data collection and sample

Information was acquired through a recent (2015) edition of the 'European Manufacturing Survey' (EMS). The purpose of the EMS is to gain insight into the efforts of European manufacturing firms to modernize their production (see Appendix A). It was applied to the context of Dutch manufacturing firms and was organized by the Institute for Management Research at the Radboud University in Nijmegen. The complete survey included questions regarding the application of organizational concepts and technologies in production, employee details and activities, environmental considerations, innovation approaches, and performance figures. Survey responses were gathered within the period of October 2015 to December 2015. The target population was contacted through a letter and two reminders. Data entries were admitted to the sample if the responding firm was economically active, had 10 or more employees, and belonged to one of the predetermined industrial sectors.

Operationalization

As depicted in the conceptual model (Figure 1), this study contains two independent variables and three dependent variables. It also controls for three potentially distortive variables. Table 1 provides an overview of the variables, their measurement methods, the answer possibilities, and the corresponding question number in the survey.

Independent variables

Regarding the first independent variable, survey question 9.2 serves as the basis for information. The five specific environmental effects of green product innovations encompass (a) 'product life extension'; (b) 'reduction of energy consumption during use'; (c) 'reduction of environmental pollution during use'; (d) 'simplification of maintenance or repair'; and (e) 'improved recycling, recovery, or removal properties' (see Appendix A). Scores for effectiveness of green product innovations are calculated by summing the number of environmental effects achieved by product improvements and new product development. 'Reduction of health risks during use', which is also available as an answer option to question 9.2, is omitted as it is beyond the scope of this study. The present research is solely concerned with planetary environmental effects and disregards the significance that green innovations might have for human health.

Survey questions 8.1 and 8.2 act as the source for data with respect to the second independent variable. The energy saving technologies measuring the use of green process innovations include (a) 'control systems that shut down machines in off-peak periods'; (b) 'automated control systems for energy efficient production'; (c) 'systems for the recuperation of kinetic and process energy'; (d) 'technologies for energy and/or heat generation by means of solar power, wind power, hydro power, biomass or geothermal energy'; and (e) 'technological improvements of existing machinery or installations' (see Appendix A). Scores for the use of green process innovations are computed by adding up the number of applied energy saving technologies. Two items of question 8.2 are not incorporated in the variable. The item of 'shutdown systems for parts, machines or installations when not in use' overlaps for too large a part with the item of 'control systems that shut down machines in off-peak periods', which is already taken up in the variable. Furthermore, 'premature replacement of existing machines or installation by new machines or installations' is excluded because it is considered more of an organizational instrument than a process technology.

Table 1: Operationalization of studied concepts

Variable type	Concept	Measurement	Lower answer boundary	Upper answer boundary	Survey question
Independent	**Effectiveness of green product innovations**	# Achieved environmental effects of product developments	0	5	9.2
	Use of green process innovations	# Applied energy- and resource-saving technologies	0	5	8.1 & 8.2
Dependent	**Revenue growth**	(Δ Annual revenue / annual revenue 2012) * 100%	-∞%	∞%	21
	Production cost growth	Δ Production costs / # units produced	≤ -10%	≥ 10%	12
	Energy consumption growth	(Δ Electricity consumption + Δ oil- and gas consumption) / 2	≤ -10%	≥ 10%	22.2 & 22.3
Control	**Firm size**	# Employees	1	∞	21
	Industry	Industry type	-	-	1.2
	Use of other process innovations	# Applied process technologies	0	19	8.1

Dependent variables

With regard to the dependent concepts, trend variables (e.g., revenue growth) are opted for in favor of fixed variables (e.g., revenue). Trend variables are preferred over fixed variables as there may be various potentially disruptive factors to be of influence to fixed variables.

Therefore, it is better to compare development rates of firms over a period of time instead of absolute figures at a fixed point in time.

Revenue growth, as first dependent variable, is operationalized by taking the difference between the 2014 annual revenue and the 2012 annual revenue, dividing that by the 2012 annual revenue, and multiplying that by 100%. The growth in production costs, forming the second dependent variable, is examined over 2014. It contains seven answer categories that represent values ranging from a decrease of 10% or more to an increase of 10% or more. Energy consumption growth, representing the third and final dependent variable, is constructed by taking the average of the growth in electricity consumption and the growth in oil- and gas consumption over 2014. It has the same seven answer categories as the variable of production cost growth.

Control variables

With respect to the control variables, firm size, industry type, and use of other process innovations are included. Firstly, firm size is incorporated as it is associated with both economic performance indicators (King & Lenox, 2001) and innovative behavior (Cuerva, Triguero-Cano, & Córcoles, 2014). Firm size is operationalized by the number of employees, which is a customary measure for the concept (Doğan, 2013).

Secondly, sectoral differences are controlled for by employing industry type as a control variable. Diversity of industries goes hand in hand with diversity of manufacturing processes. These manufacturing processes require various amounts of energy. Building on this reasoning, industry type is included as it can be expected to have a distorting effect in the hypothesized relationships. Based on the type of economic activity, represented by NACE codes in the range of C10 to C33 (European Commission, 2010), firms are classified into seven industries. The industries comprise (1) metals and metal products; (2) food, beverages and tobacco; (3) textiles, apparel, leather, paper and board; (4) construction and furniture; (5) chemicals; (6) machinery, equipment and transport equipment; and (7) electrical and optical equipment (see Appendix B). The corresponding numbers are used as answer categories to distinguish between the different industries in a quantitative way.

Thirdly, in order to isolate the effect of the use of green process innovations on production cost growth, this study controls for the use of other process innovations. These other process innovations relate to (a) automation and robotization; (b) new materials; (c) additive production methods; and (d) IT (Appendix A).

Validity and reliability

Methodological decisions were carefully considered in terms of validity and reliability to safeguard the quality of the measurement method. Substantial efforts were made for the purpose of establishing internal and external validity. Internal validity is understood as the degree to which what is actually measured by a scale accords with what was intended to be measured (Bannigan & Watson, 2009). The phrasing of the survey questions was based on discussions held with representatives of 15 countries at international manufacturing conferences. As a result, detailed survey items could be composed. Additionally, the survey was pre-tested through trial versions before it was finalized and disseminated. External validity, as counterpart to internal validity, describes the extent to which the outcomes of a study are generalizable to and across other contexts, stimuli, populations, and times (Aronson, Wilson, Akert, & Fehr, 2007; Mitchell & Jolley, 2001). External validity was secured by including firms of different sizes and diverse industries in the sample. Therefore, the results of the study are applicable to a wide array of manufacturing firms involved in various types of economic activity. As a final aspect of measurement quality, methodological choices were subject to reliability deliberations. The reliability concept refers to the consistency of a measurement in comparable conditions (Trochim, 2006). Reliability was assured by collecting objective data in the form of practices, facts, investments, and performance indicators, rather than asking for subjective opinions.

Research ethics

Research ethics are discussed on the basis of four principles specific to management research. The principles appertain to (a) conflict of interest and affiliation bias; (b) informed consent; (c) harm, wrongdoing and risk; and (d) confidentiality and anonymity (Bell & Bryman, 2007). Regarding the first principle, conflict of interest and affiliation bias were prevented by the fact that researchers and responding firms were in no way connected other than through this study. For that reason, undistorted presentation of research findings could be guaranteed. With respect to the principle of informed consent, respondents were provided with details of the study before they were asked for permission to collect and process their responses. Details of the study comprised information on the research subject, the respondents' role, and the possible consequences of participation. Harm, wrongdoing and risk were taken into account by treating respondents in a respectable way, rather than as a means to an end. This is evidenced by the respondents being awarded a free benchmark report for their participation. Such a benchmark report offered the respondents a way of comparison against other manufacturing firms for relevant indicators. Finally, confidentiality and anonymity were assured by exclusively demanding non-identifiable firm information. In this way, the privacy of respondents was protected in case their responses and sensitive information were to fall victim to potentially maleficent parties.

Chapter 4: Results

The results segment of this study will describe the outcomes of the analyses. It opens by reporting on the response figures. Thereafter, it presents the univariate analysis and belonging statistics as well as the bivariate analysis and accompanying statistics. It ends with a discussion on the multivariate analyses conducted for the evaluation of the hypotheses.

Response

From the total of 8195 Dutch organizations registered in the Chamber of Commerce database, 6146 were contacted by letter and two reminders. Of those contacted, 502 (8.17%) started the online survey, 345 (5.61%) provided information regarding the industry in which they operate, and 194 (3.16%) provided information regarding firm size. Ultimately, the sample included 174 (2.83%) valid cases of firms that presented information with respect to both industry and size. After careful inspection of the data, four outliers were identified and removed yielding a definitive dataset of 170 firms.

Univariate analysis

Table 2 presents an overview of the univariate statistics for the concepts of interest to this study, except for the non-metric variable of industry type. The composition of the sample regarding industry type is displayed in Appendix B. Sample sizes for the different dependent variables vary based on missing values of underlying items.

The data indicate that green innovations in manufacturing firms can be considered the exception rather than the rule. A clear minority indicated to be achieving any environmental effects with green product innovations. Similarly, green process innovations are only limitedly applied. This explains the occurrence of relatively many zero scores and relatively few high scores with respect to the independent variables. For the variable measuring the effectiveness of green product innovations, this caused violation of the threshold for skewness and kurtosis. In order to prove normality of a univariate distribution, values for kurtosis and skewness are required to be in the range of -2 to +2 (George & Mallery, 2010). In response, a logarithmic transformation (log10) was applied to the original variable of effectiveness of green product innovations. Such a transformation deals with positively skewed and leptokurtic data and is often performed to approach univariate normality (Field, 2013, p. 203). After transformation, the variable remained slightly non-normally distributed. However, this was not deemed problematic as the values were not extremely remote from normality parameters. With the objective of attaining univariate normality, the same transformation was carried out for firm size. Post-transformation, firm size fell well below the skewness and kurtosis limits. Hence, normality could be assumed.

On average, manufacturing firms in the sample reported an almost 10% increase in revenues from 2012 to 2014, $\mu = 9.79$, $n = 139$. In terms of production cost growth and energy consumption growth, firms noted averages between the third and fourth answer category, $\mu = 3.87$, $n = 170$ and $\mu = 3.82$, $n = 141$, respectively. This implies that, on average, firms experienced a decrease in production costs and energy consumption of between 0% and 5% in 2014.

Table 2: Univariate statistics

Variable type	Concept	N	Mean	Median	St. dev.	Min. - Max.	Skew.	Kurt.
Independent	**Effectiveness of green product innovations***	170	.09	0	.2	0 - .78	1.93	2.31
	Use of green process innovations	170	.79	1	.93	0 - 4	1.05	.63
Dependent	**Revenue growth**	139	9.79	10	18.96	-41.18 - 71.3	.3	.99
	Production cost growth	170	3.87	4	1.28	1 - 7	-.01	-.38
	Energy consumption growth	141	3.82	4	.96	1 - 7	-.22	.81
Control	**Firm size***	170	1.57	1.57	.33	1 - 2.34	.25	-.7
	Use of other process innovations	170	4.02	4	2.76	0 - 14	.95	.92

* transformed.

Bivariate analysis

Table 3 reports statistics for the bivariate relationships between studied concepts. As could be expected, a significant positive relationship was found between the effectiveness of green product innovations and the use of green process innovations, $r = .2$, $n = 170$, $p = .009$. Firms that achieve more environmental effects with their product innovations also use more green process innovations and vice versa. Rather than focussing on either the product or the process dimension, firms seem to develop and implement both or neither types of innovations. This suggests that when firms take to a green innovation strategy, they commit to it in a comprehensive fashion. Adhering to such a comprehensive green innovation strategy might hint at firms' growing desire to become green (Esty & Winston, 2006). Instead of limitedly reaping the benefits of green product or green process innovations, firms might be interested in developing green core competence by acquiring knowledge and capabilities about green innovations as a whole (Chen, 2008).

Another notable observation is that the use of other process innovations is also positively correlated with both the effectiveness of green product innovations, $r = .27$, $n = 170$, $p = .000$, and the use of green process innovations, $r = .33$, $n = 170$, $p = .000$. These findings are unsurprising and can be explained by firms' overall level of innovativeness. Logic dictates that firms net more environmental effects with product innovations and have more technologically advanced operating processes when they are more innovative in nature.

In the line of expectation, the use of green process innovations was shown to be negatively correlated with energy consumption growth, $r = -.17$, $n = 141$, $p = .043$. Firms that apply a greater number of green process innovations experience lower energy consumption growth. Similarly, the use of other process innovations was indicated to be negatively correlated with energy consumption growth, $r = -.25$, $n = 141$, $p = .003$. It appears that firms with more advanced manufacturing processes report lower energy consumption growth.

Finally, the various significant correlations of firm size are noteworthy. Firm size correlates positively with the three innovations-related variables. This accords with a central tenet of the Schumpeterian hypothesis - that there is a positive influence of firm size on innovation (Acs & Audretsch, 1987; Schumpeter, 1942). Specific to this study, it implies that larger firms achieve more environmental effects with their product innovations and have more technologically advanced operating processes. The aforementioned is in line with empirical research on innovation, which demonstrates that firm size has a positive effect on green product innovations (Rehfeld, Rennings, & Ziegler, 2007) and that the use of advanced manufacturing technologies is higher in larger firms than in smaller firms (Swamidass & Kotha, 1998).

Table 3: Bivariate statistics

Concept		EGPI	UGPI	RG	PCG	ECG	FS	UOPI
Effectiveness of green product innovations (EGPI)	r	1						
	N	170						
Use of green process innovations (UGPI)	r	.2**	1					
	N	170	170					
Revenue growth (RG)	r	-.13	-.12	1				
	N	139	139	139				
Production cost growth (PCG)	r	-.02	-.06	0	1			
	N	170	170	139	170			
Energy consumption growth (ECG)	r	-.11	-.17*	.27**	-.02	1		
	N	141	141	119	141	141		
Firm size (FS)	r	.17*	.28**	-.07	-.03	-.12	1	
	N	170	170	139	170	141	170	
Use of other process innovations (UOPI)	r	.27**	.33**	-.06	.01	-.25**	.43**	1
	N	170	170	139	170	141	170	170

* significant at $p < .05$; ** significant at $p < .01$.

Multivariate analyses

Multiple regression analysis was used as statistical technique to model the hypothesized relationships. Regression analysis is one of the most frequently applied analytical methods in business research and provides the foundation for a wide range of business forecasting models (Hair, Black, Babin, & Anderson, 2014). The objective of multiple regression analysis is to predict a specific dependent variable by means of two or more independent variables weighted for their relative contribution to the overall prediction (Hair et al., 2014). The resulting regression variate, which contains a particular combination of weighted independent variables, optimally predicts the dependent variable (Hair et al., 2014). In order for regression analysis to be allowed, data needs to be metric or appropriately transformed through dummy variable coding (Hair et al., 2014). To comply with this requirement, industry type was dummified by converting the nominal industry information into metric categories. With respect to this dummy variable, a theoretical argument for using one particular industry type as the reference category was lacking. Therefore, the metal industry, for the simple reason of it being the first category, was used as the reference category.

Before commencing with the analyses, a set of assumptions specific to regression analysis had to be evaluated. Hair et al. (2014, pp. 179-181) describe four assumptions: (1) normality of the error term distribution, (2) constant variance of the error terms, (3) linearity of the phenomenon measured, and (4) independence of the error terms. Normality of the error term distribution was assessed through inspection of the normal probability plots. The normal probability plots demonstrate that the residuals did not drastically deviate from the normality diagonal (Appendix C, Appendix D, Appendix E). For that reason, normality could be assumed. With regard to the second and third assumption, homoscedasticity and linearity were confirmed after observing the scatter plots of the residuals. The data do not constitute a discernible curvilinear pattern and are evenly dispersed around zero on both the X-axis and the Y-axis (Appendix C, Appendix D, Appendix E). Finally, independence of the error terms was examined. This assumption is concerned with multicollinearity, which "exists when there is a strong correlation between two or more predictors" (Field, 2013, p. 324). Absence of multicollinearity indicates indepence of the error terms. Independence was evinced based on the values for the variance inflation factors remaining below 10 and the tolerance statistics remaining above .2 (Appendix F, Appendix G, Appendix H), signalling that the assumption was not violated (Field, 2013, p. 325).

Testing hypothesis 1

The first regression analysis showed that the proposed models were incapable of predicting the dependent variable of revenue growth (Appendix F). Although the amount of variance explained increased as more regressors were added to the model, the adjusted coefficient of determination decreased and even dropped below zero, $R^2_{adj} = -.01$, $F(8, 130) = .88$, $p = .532$. This means that, when corrected for the sheer amount of included terms, the model was a poor fit for the data. In the final model, the effectiveness of green product innovations proved to be a non-significant predictor of revenue growth when controlling for firm size and industry type, $B = -12.71$, $t(130) = -1.52$, $p = .131$. Besides that, its unstandardized coefficient also went in an unexpected direction, hinting at a negative rather than a positive relationship with revenue growth. As a result, hypothesis 1 was rejected. The amount of environmental effects achieved by green product innovations is of non-significant influence to revenue growth.

Testing hypotheses 2 and 3

The second regression analysis indicated that the suggested models were unable to explain a significant amount of variance in the dependent variable of production cost growth (Appendix G). Again, the adjusted determination coefficient reported a negative non-significant value, symptomatic for weak explanatory power, $R^2_{adj} = -.03$, $F(11, 129) = .61$, $p = .821$. The effectiveness of green product innovations and the use of green process innovations were both found to be non-significant predictors of production cost growth when controlling for each other and all other variables, $B = -.36$, $t(129) = -.61$, $p = .546$ and $B = -.04$, $t(129) = -.28$ $p = .779$, respectively. Therefore, hypotheses 2 and 3 were rejected. The amount of environmental effects achieved by green product innovations and the amount of green process innovations applied are non-significantly able to explain production cost growth.

Testing hypothesis 4

In order to examine the mediating effect positted in hypothesis 4, the Sobel test was conducted (Preacher & Leonardelli, n.d.). Necessary inputs were obtained from a regression analysis with the independent variable predicting the mediator and a subsequent regression analysis with the independent variable as well as the mediator predicting the dependent variable. The first regression analysis delivered the unstandardized regression coefficient (a) along with its standard error (s_a) for the link between the use of green process innovations and energy consumption growth. The second regression analysis provided the unstandardized regression coefficient (*b*) together with its standard error (s_b) for the relationship between energy consumption growth and production cost growth. The test indicated that there was no significant change in the effect of the use of green process innovations on production cost growth after inclusion of energy consumption growth as a mediator, $p = .757$ (Appendix I). Partial mediation could not be proven, thus providing argumentation for the rejection of hypothesis 4. The effect of energy consumption growth on production cost growth brought about by the use of green process innovations is non-significant.

A follow-up regression analysis was performed to examine the mediation-hypothesis in more detail. It assessed whether the application of green process innovations had significant predictive power in terms of energy consumption growth (Appendix H). Interestingly, although it was able to explain only a relatively low portion of the variance, the designed model was shown to be significant, $R^2_{adj} = .07$, $F(9, 131) = 2.12$, $p = .032$. However, in that model, the use of green process innovations was indicated a non-significant predictor of energy consumption growth, $B = -.13$, $t(131) = -1.35$, $p = .180$. With respect to the first part of the mediation-hypothesis, the use of green process innovations was unable to significantly influence energy consumption growth.

Chapter 5: Discussion & conclusion

The fifth and final chapter of this study interprets the research outcomes and provides a conclusion. It sets out by giving a succinct summary of the study and answering the research question. Thereafter, it reflects on the outcomes in relation to the underlying theoretical arguments used to arrive at the hypotheses. Subsequently, it discusses limitations of the study before ending by making recommendations for practice and research.

<ins>Summary</ins>

This thesis has attempted to answer the following research question: *'To what extent are green innovations related to economic performance in manufacturing firms and to what extent does energy consumption play a role?'.* More specifically, the objective was to investigate the influence of the effectiveness of green product innovations and the use of green process innovations on manufacturing firms' revenue growth and production cost growth. In the relationship between the use of green process innovations and production costs special attention was paid to the role of energy consumption.

The study hypothesized that the effectiveness of green product innovations would be positively related to revenue growth (H1) on account of there being a green consumer market willing to pay price premiums for green products. Additionally, it hypothesized that the effectiveness of green product innovations would be negatively related to production cost growth (H2) for reasons of material-saving as well as productivity and efficiency gains. Thirdly, the study posited that the use of green process innovations would be negatively related to production cost growth (H3) because costs associated with pollution-control equipment could be averted and compliance costs could be reduced. Lastly, the study expected that the use of green process innovations would negatively affect production cost growth through a negative relationship with energy consumption growth (H4) based on their potential to increase energy efficiency as well as enable the use of cheaper renewable energy.

Quantitative research was conducted to investigate the hypothesized relationships. A survey was disseminated among Dutch manufacturing firms of which responses were collected between October 2015 and December 2015, ultimately yielding a definitive dataset of 170 firms. Analysis of the data provided no support for any of the hypotheses. Responding to the research question, green innovations appear to be unrelated to economic performance in manufacturing firms and energy consumption does not seem to play a role.

Interpretation of the results

The first hypothesis postulated a positive influence of the effectiveness of green product innovations on revenue growth. The higher the amount of environmental effects achieved by green product innovations, the higher the revenue growth. After analyzing the data, no support was found for this hypothesis. The amount of environmental effects achieved by green product innovations was of non-significant influence to revenue growth. Several reasons could explain why this result was found. Firstly, the fact that green product innovations were measured in terms of their ability to achieve different environmental effects deserves attention. The argumentation for the revenue-elevating effect of green product innovations rests on the existence of an unexplored market of green consumers exhibiting a higher willingness to pay more for green products. However, consumers may not always be equally able to discern the different environmental effects of products. Sønderskov and Daugbjerg (2011) indicate that is often difficult for consumers to ascertain the environmental friendliness of a product, even after purchase. As a result, they might not always be capable of distinguishing green products from conventional products. Consumers' green perceived value of products (e.g., the amount of recognized environmental benefits) positively affects their purchase intention (Chen & Chang, 2012; Kong, Harun, Sulong, & Lily, 2014). It stands to reason that when consumers are unable to recognize environmental effects of a product, they do not perceive that product to be green, which results in a lower purchase intention and ultimately translates into unchanged revenue levels for manufacturers of such products. A second possible reason is offered by the dissimilarity of the B2C- and B2B-sector. For this study, no distinction was made between manufacturing firms that operate in B2C-contexts and B2B-contexts. Where manufacturers in the B2C-sector produce final products to be marketed at end-consumers, manufacturers in the B2B-sector produce intermediate products aimed at other manufacturers (Zhu & Geng, 2001). While the rise of a green market has been observed on the consumer-side of the spectrum (do Paço, Raposo, & Leal Filho, 2009), it is unsure whether there is a comparable green supplier-market. Although recently there has been an increasing amount of interest for the potential of green supply chain management (Rao & Holt, 2005) and green supplier selection (Lee, Kang, Hsu, & Hung, 2009), it remains unclear whether it is economically beneficial to be a green supplier. The fact that a positive influence of the effectiveness of green product innovations on revenues is less evident for B2B-manufacturers may have suppressed or even cancelled out the same effect for B2C-manufacturers. In the end, the abovementioned may explain why the amount of environmental effects achieved by green product innovations was found to be of non-significant influence to revenue growth.

The second hypothesis posited a negative influence of the effectiveness of green product innovations on production cost growth. The higher the amount of environmental effects achieved by green product innovations, the lower the production cost growth. The data proved unsupportive of this hypothesis. The amount of environmental effects achieved by green product innovations turned out to be of non-significant explanatory value to production cost growth. Two logics offer possible explanations for this finding. Firstly, the possibility of a lagged effect warrants consideration. The impact of green product innovations in reducing production costs is not necessarily visible instantaneously. Porter and van der Linde (1995) argue that green innovations can reduce resource inefficiencies, which can eventually lower costs. However, with regard to improvements in economic performance, "this effect could require time to materialize" (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013, p. 379). Although this study took into account the possibility of a delayed effect on production costs by monitoring the development in production costs over 2014, the measurement of green product innovations might have been suboptimal. The survey question on green product innovations asked respondents about the effects of green product developments and introductions since 2012. This means that there was a mismatch in terms of measurement periods. Green product innovations could have been introduced two years before the start of production costs measurement. Keeping this in mind, changes in production costs as a consequence of green product innovations could have crystallized in the time span prior to its measurement. A second possible explanation is offered by unforeseen costs of green product innovations countering their cost-reducing effect. Firms that bring green product innovations could incur additional costs as a result of "verification procedures" (D'Souza, Taghian, Lamb, & Peretiatkos, 2006, p. 147). Verification costs refer to the costs related to monitoring the environmental impact of final products, which requires appropriate equipment and knowhow (Gaviria, 1995). Besides such verification costs, firms that use more environmentally sustainable materials in manufacturing could experience higher production costs. Replacement of conventional materials with more environmentally sustainable materials could raise production costs for the simple reason that in some cases such materials have "higher upfront costs" (EPA, n.d.). Illustratively, most bioplastics cannot compete economically with petroleum-based plastics that currently dominate the market (Mohanty, Misra, & Drzal, 2002). The designated arguments could have negated the hypothesized productivity and resource efficiency gains, thus explaining why a non-significant effect of green product innovations on production cost growth was found.

The third hypothesis suggested a negative influence of the use of green process innovations on production cost growth. The higher the amount of green process innovations applied, the lower the production cost growth. The data were unable to provide empirical evidence for such a relationship. With respect to its effect on production costs, the amount of green process innovations applied in manufacturing was non-significant. A reason for this finding is that this study did not sufficiently take into account the moment of implementation. Logically, changes in production costs are most noticeable in the year following implementation of a certain green process technology. However, it is naive to assume that all green process innovations were implemented in the year before survey responses were gathered. If such innovations were implemented longer ago, it is likely that production costs have since stabilized. Another conceivable explanation is provided by the fact that production costs are fundamentally volatile. Production costs are composed of labor costs, material costs, and overhead costs. This means that adjustments to collective labor agreements regarding wages, contractual alterations with suppliers, or even changes in rent for buildings could trigger production cost fluctuations. Although the application of green process technologies could have averted costs associated with installing and operating end-of-pipe pollution control equipment, resulting production cost reductions could have been masked by other factors having adverse consequences for production costs.

Finally, the fourth hypothesis proposed a negative influence of the use of green process innovations on production cost growth through its effect on energy consumption growth. The higher the amount of green process technologies applied, the lower the energy consumption growth, and subsequently the lower the production cost growth. Running the Sobel test for mediation did not deliver substantiation. As a result, the hypothesis was rejected. The follow-up regression with energy consumption growth as a dependent variable enabled a more detailed examination. It demonstrated that the use of green process innovations was non-significantly related to energy consumption growth. However, despite a lack of significance, the relationship did go in the expected negative direction. When interpreting these findings, measurement details merit discussion. The survey measured the development in energy consumption over a year, but left differences in output unconsidered. Not measuring energy consumption relative to the amount of units produced might have distorted the effect of the use of green process innovations on energy consumption. Ceteris paribus, increasing production raises energy consumption. Therefore, it was impossible to attribute differences in energy consumption solely to the use of green process innovations, which might explain the non-significant outcome.

Limitations

First and foremost, the sample size of this study forms a limitation. The negative adjusted coefficients of determination denoted in the regression analyses point to weak explanatory ability of the models. This implies that there was insufficient statistical power to base empirical conclusions on. Such statistical strength can be improved by increasing sample size.

Secondly, as indicated before, a number of operationalization issues appeared. The dependent variable of revenue growth was measured between 2012 and 2014, which hampered comparability with other dependent variables, as these were measured over 2014. Furthermore, whereas revenue growth was calculated precisely by means of actual figures, the other dependent variables only approximated reality by using predetermined answer categories. Results might be improved by relying on true numbers for all dependent variables. In addition, only the variable of cost production growth was measured relative to the amount of units produced. It would have been preferable to evaluate energy consumption growth and revenue growth relative to the amount of products produced and sold to account for production and sales volume differences. Moreover, merely adding up the number of green process innovations used in manufacturing may have been too simplistic. The study did not adequately account for the applied potential of such innovations, which is likely to be related to their actual ability to achieve energy efficiency effects.

Recommendations

Although this study did not succeed in invigorating the business case for implementing green innovations, neither did it indicate inferior economic performance. Therefore, given the rising attention for green issues in society, implementing green innovations can still be considered an appealing business strategy for its marketing potential. Arguably, that marketing potential is lower for green process innovations as they are less visible to the outside. For that reason, compared to green product innovations, managers should devote more attention to the advantageousness of green process innovations in terms of their capability to directly influence economic performance. In general, management practitioners should be wary of the temporal distance between implementation of green innovations and measurability of their performance effects as economic consequences may only become visible after a while.

As agenda for future research, four recommendations are directed at the academic world. First of all, it would be interesting to distinguish between green process innovations from the inside, that are developed by the organization itself, and innovations from the outside, that are developed by others. Green process innovations from the inside might be better adjusted to the specifics of the manufacturing process. When such innovations are seamlessly integrated, they can be expected to engender superior results. Secondly, it would be useful to investigate how quickly effects of green innovations stabilize in terms of revenues and costs. Gaining an understanding about how long effects are noticeable could contribute to the development of appropriate measurement methods. Additionally, it would be valuable to know whether green product innovations differ from green process innovations with regard to the time that elapses between implementation and financial consequences. It stands to reason that green process innovations would have a rather immediate effect in terms of cost reductions for their instantaneous ability to lowering energy consumption levels. Comparatively, it might take longer for green product innovations to bring about changes in revenues as consumer demand can be expected to be less responsive. Thirdly, an attractive avenue for academic effort would be to determine the degree to which consumers are able to recognize environmental effects of product innovations. Doing so would require interaction between the research fields of marketing and innovation. Lastly, future research could append the effect of energy consumption on actual energy costs in the model to enable an improved translation from environmental performance to economic performance.

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Appendices

Appendix A: modernization of the production - survey 2015

Radboud Universiteit Nijmegen
Institute for Management Research

Modernisering van de productie
Enquête 2015

Deze vragenlijst heeft als doel inzicht te krijgen in de inspanningen van industriële bedrijven in Nederland om hun productie en bedrijfsprocessen te moderniseren. Het onderzoek richt zich op productiebedrijven met een omvang van tenminste 10 werknemers. Bij ondernemingen met meerdere vestigingen hebben de vragen betrekking op de aangeschreven vestiging en niet op de totale onderneming.

Voor het onderzoek is beantwoording van alle vragen van belang. Ook als niet alle genoemde technologieën of organisatieconcepten van toepassing zijn op uw bedrijfsvestiging, verzoeken wij u vriendelijk de vragenlijst toch volledig in te vullen.

Voor vragen kunt u terecht bij. dr. Peter Vaessen E-Mail: P.Vaessen @ fm.ru.nl Tel.: 024 3611266 Fax: 024 3611933

1.1 Is uw bedrijfsvestiging (kruis slechts één optie aan):

- Het hoofdkantoor van een onderneming/groep met ook buitenlandse vestigingen ☐
- Een dochter/divisie van een buitenlandse onderneming/groep ☐
- Het hoofdkantoor van een onderneming/groep met alleen binnenlandse vestigingen ☐
- Een dochter/divisie van een onderneming/groep met alleen binnenlandse vestigingen ☐
- Een zelfstandige onderneming ☐

1.2 Bedrijfstak (bijv. textiel, chemische industrie, machinebouw, enz.): ________ hoofdproductgroep ________ aandeel van hoofdproduct (groep) in omzet ca. ____ %

1.3 Is uw bedrijfsvestiging gelet op uw hoofdproduct(groep) leverancier van eindfabricaten of een toeleverancier van onderdelen/ materialen of bewerkingen? (Kruis slechts één optie aan)

producent van eindfabricaten: ☐ voor consumenten ☐ voor bedrijven
toeleverancier: ☐ van systemen/ installaties ☐ van halffabricaten/ onderdelen
aanbieder van bewerkingen: ☐ aanbieder van bewerkingen (draaien, coaten, lassen, vermalen, e.a.)

1.4 Als u uw hoofdproduct(groep) levert aan andere bedrijven (als eindfabrikant of toeleverancier), aan welke bedrijfstak levert u dan hoofdzakelijk? (Kruis slechts één optie aan)

Machinebouw ☐ Chemische industrie ☐ Automotive industrie ☐ Elektro- techniek ☐ andere bedrijfstak, nl.: ________

1.5 In hoeverre voert uw bedrijfsvestiging voor het hoofdproduct de volgende activiteiten uit van het waardecreatieproces?
Kruis voor elke activiteit aan in welke mate die in uw eigen bedrijfsvestiging dan wel elders wordt uitgevoerd.
Kruis ook aan of een activiteit in het geheel geen deel uitmaakt van het waardecreatieproces

Waardecreatie-activiteiten

	Onderzoek en Ontwikkeling	Ontwerp/ Vormgeving	Productie/ Verwerking/Recycling	Assemblage	Onderhoud/ Dienstverlening	Verpakken/ Distributie
grotendeels intern > 85%	☐	☐	☐	☐	☐	☐
relevant deel intern (25%-85%)	☐	☐	☐	☐	☐	☐
klein deel intern (<25%)	☐	☐	☐	☐	☐	☐
niet nodig voor vervaardiging van het hoofdproduct	☐	☐	☐	☐	☐	☐

2 Hoe belangrijk zijn de volgende factoren voor de concurrentiepositie van uw bedrijfsvestiging? (geef de volgorde van belangrijkheid aan met een score van 1 tot 6; 1 is het belangrijkst, gebruik elke score slechts één keer)

productprijs	productkwaliteit	innovatieve producten	aanpassing producten aan klantenwensen	tijdige levering/ korte levertijden	dienstverlening en service
☐	☐	☐	☐	☐	☐

3 Welke van de volgende organisatieconcepten en werkwijzen worden momenteel in uw bedrijfsvestiging toegepast?

Toepassing gepland voor 2018	Nee	Organisatieconcepten	Ja	Voor het eerst toegepast[1]	Omvang van het toegepaste potentieel [2]
		Organisatie van het werk			
☐	☐	Gedetailleerde voorschriften voor de werkplekinrichting van apparatuur en opslag van tussenproducten (bijv. 5-S methode)	☐	19/20 ☐	g m h
☐	☐	Gestandaardiseerde en gedetailleerde werkinstructies	☐	19/20 ☐	g m h
☐	☐	Taakverrijking productiemedewerker (integratie van planning, uitvoering of controle)	☐	19/20 ☐	g m h
		Organisatie van de productie			
☐	☐	Maatregelen ter verbetering van de interne logistiek (Value Stream Mapping/Design, ruimtelijke inrichting van productiestappen)	☐	19/20 ☐	g m h
☐	☐	Klant- of productgeoriënteerde inrichting van productie-eenheden (i.t.t. functionele indeling)	☐	19/20 ☐	g m h
☐	☐	Vraaggestuurde productie (bijv. KANBAN, afschaffen van tussenvoorraden)	☐	19/20 ☐	g m h
☐	☐	Voorgeschreven methoden voor het verkorten van omstel- en aanlooptijden bij productwisseling (bijv. Single Minute Exchange of Die; Quick Change Over)	☐	19/20 ☐	g m h
		Productiemanagement/ -beheersing			
☐	☐	Grafische weergave werkprocessen en -status (Visual Management; dashboard)	☐	19/20 ☐	g m h
☐	☐	Kwaliteitsmanagement (bijv. preventieve onderhoud, total quality management/TQM, total productie-onderhoud/TPM)	☐	19/20 ☐	g m h
☐	☐	Methoden voor operation management o.b.v. wiskundige analyse van productie (bijv. Six Sigma methode)	☐	19/20 ☐	g m h
☐	☐	Methoden van continu verbeteren (Kaizen, kwaliteitscirkels e.d.)	☐	19/20 ☐	g m h
		Energie- en milieubeheersing			
☐	☐	Gecertificeerd energie-management systeem volgens ISO 50001, voorheen: EN 16001	☐	19/20 ☐	g m h
☐	☐	Instrumenten voor productlevenscyclus-analyse (bijv. EU Ecolabel, Cradle-to-Cradle certificaat, ISO-14020)	☐	19/20 ☐	g m h
☐	☐	Het opnemen van sociale en duurzaamheidseffecten in het vaststellen van bedrijfsprestaties	☐	19/20 ☐	g m h
		Human resource management			
☐	☐	Maatregelen voor het behoud van oudere werknemers of hun kennis voor uw bedrijfsvestiging (bijv. teams met verschillende leeftijdsgroepen, begeleidingsprogramma's, senior-junior tandems)	☐	19/20 ☐	g m h
☐	☐	Instrumenten ter bevordering van werknemersbetrokkenheid (bijv. gratis kantine, ondersteuning kinderopvang, gezinsvriendelijke werktijden)	☐	19/20 ☐	g m h
☐	☐	Gestandaardiseerde methoden van functie-ontwerp ter verbetering van gezondheids- en veiligheidsomstandigheden op het werk (bijv. Methods-time measurement (MTM))	☐	19/20 ☐	g m h
☐	☐	Financiële participatie toegankelijk voor alle werknemersgroepen (bijv. winstdelingsregelingen, aandelen(optie)plannen, enz.)	☐	19/20 ☐	g m h

Toelichting:

1 Het jaar waarin deze technologie voor het eerst werd toegepast in uw bedrijfsvestiging (maak een schatting indien u onzeker bent over het exacte jaar)

2 Daadwerkelijke toepassing ten opzichte van maximaal zinvolle toepassingsmogelijkheden: omvang van het gebruikte potentieel is "gering" bij eerste aanzetten, "midden" bij gedeeltelijke toepassing en "hoog" bij omvangrijke toepassing

4.1 Welke van de volgende activiteiten worden uitgevoerd voor uw productiepersoneel in uw bedrijfsvestiging?

Aanwezige competenties van productiewerknemers worden systematisch vastgelegd?	☐ nee	☐ ja
Functiebeschrijvingen zijn ontwikkeld voor specifieke functiegebieden in de productie?	☐ nee	☐ ja
Er bestaan specifieke competentieprogramma's for bepaalde functies	☐ nee	☐ ja

4.2 Bij welke personeelsgroepen worden deze instrumenten gebruikt?

☐ LBO of ongeschoold personeel ☐ MBO geschoold personeel ☐ Hooggeschoold personeel (HBO+WO)

4.3 Bestaat er afzonderlijk beleid voor competentie-ontwikkeling en training van productiepersoneel?

☐ nee ☐ ja → Is er in uw bedrijf voor dit beleid een vast jaarlijks budget beschikbaar? ☐ nee ☐ ja

5.1 **Is er een vastgesteld aantal dagen per jaar voor verdere kwalificatie, training en ontwikkeling van het productiepersoneel?**

☐ **nee** ☐ **ja** → **Hoeveel dagen per jaar is er per persoon vastgesteld?** ca. ☐ dagen per jaar

5.2 **Zijn de volgende activiteiten voor verdere kwalificatie, training en ontwikkeling toegepast voor het productiepersoneel in uw bedrijfsvestiging?**

In aanmerking komen de volgende groepen van productiepersoneel:

	nee	ja	LBO of ongeschoold	MBO technisch geschoold	Hooggeschoold (WO+HBO)
Training voor specifieke vaardigheden (bijv. machine-onderhoud)	☐	☐ →	☐	☐	☐
Training met interdisciplinair oogmerk (bijv. taalcursussen, leiderschapstraining)	☐	☐ →	☐	☐	☐
Digitale zelfscholingprogramma's (e-learning)	☐	☐ →	☐	☐	☐
On-the-job training (bijv. taakrotatie, werkplekinstructie, georganiseerde ervaringsuitwisseling met collega's)	☐	☐ →	☐	☐	☐
Informatie-aanbod (bijv. bedrijfstak specifieke beurzen, externe databases)	☐	☐ →	☐	☐	☐
Deelname aan activiteiten voor continue kwaliteitsverbetering (bijv. kwaliteitscirkels, Kaizen)	☐	☐ →	☐	☐	☐

6.1 **Werkt uw bedrijfsvestiging samen met andere bedrijven op de volgende terreinen?**
(samenwerking = vrijwillige samenwerking die verder gaat dan eenmalige transacties tussen bedrijven)

			Locatie van de partners		
	nee	**ja**	**regionaal (< 50km)**	**nationaal (> 50km)**	**buiten-land**
Samenwerking in inkoop	☐	☐ →	☐	☐	☐
Samenwerking in de productie (voor gezamenlijke systeemleveringen of capaciteitsuitbreiding)	☐	☐ →	☐	☐	☐
Samenwerking in distributie/verkoop	☐	☐ →	☐	☐	☐
Samenwerking in service	☐	☐ →	☐	☐	☐
Samenwerking in onderzoek en ontwikkeling met afnemers of leveranciers	☐	☐ →	☐	☐	☐
Samenwerking in onderzoek & ontwikkeling (O&O) met onderzoeksinstituten (bijv. universiteiten, TNO)	☐	☐ →	☐	☐	☐

6.2 **Indien uw bedrijfsvestiging voor onderzoek en ontwikkeling samenwerkt met andere bedrijven, zijn daarbij bedrijven actief op het gebied van nanotechnologie, micro-elektronica, photonen, nieuwe materialen, of biotechnologie?**

☐ **nee** ☐ **ja** → ☐ nanotechnologie ☐ micro-elektronica ☐ photonen ☐ nieuwe materialen ☐ biotechnologie

7.1 **Welke van de volgende maatregelen zijn genomen om het risico van industriële spionage te vermijden in uw bedrijfsvestiging?**
Sinds wanneer zijn deze ingevoerd?

	nee	**ja**	**sinds wanneer?**
Speciale IT-veiligheidsmaatregelen (bijv. geen gebruik cloud computing, versleutelen van documenten, algemeen verbod op gebruik van draagbare data media)	☐	☐ →	19/20 ☐
Werknemerstrainingen en verhoging van waakzaamheid voor het gevaar van industriële spionage	☐	☐ →	19/20 ☐
Veiligheidsmaatregelen voor toegang tot terrein, gebouwen of kamers	☐	☐ →	19/20 ☐
Veiligheidsinstructies over illegale verspreiding van informatie (bijv. regelingen voor omgaan met gevoelige gegevens in relatie tot derde partijen)	☐	☐ →	19/20 ☐

7.2 **Heeft uw bedrijfsvestiging te maken gehad met spionage door andere bedrijven, buitenlandse overheidsorganisaties of met verdachte gevallen in de laatste vijf jaar?**

concre(e)t(e) geval(len) ☐ **nee** ☐ **ja** → ☐ ander bedrijf ☐ buitenlandse overheidsorganisatie ☐ onbekend

verdacht(e) geval(len) ☐ **nee** ☐ **ja** → ☐ ander bedrijf ☐ buitenlandse overheidsorganisatie ☐ onbekend

7.3 **Indien er sprake was van een verdacht of concreet geval, welke informatie was het doelwit van industriële spionage?**

Informatie over....

☐ Producten (bijv. ideeën, studies, ontwikkeling, ontwerp) ☐ Productie- of fabricageprocessen ☐ Klanten/toeleveranciers (bijv. contracten, prijzen) ☐ Bedrijfsstrategie (bijv. investeringsplannen)

8.1 **Welke van de volgende technologieën worden momenteel in uw bedrijfsvestiging toegepast?**

Toepassing gepland voor 2018	Nee	Technologieën	Ja	Voor het eerst gebruikt (Jaar)[1]	upgrade sinds 2012: Ja	upgrade sinds 2012: Nee	Omvang van het toegepaste potentieel[2]
		Automatisering en robotisering					
		Industriële robots voor bewerking en fabricage (bijv. lassen, coaten, snijden)		19/20			g m h
		Industriële robots voor hanteren van gereedschap en werkstukken in productie (bijv. verplaatsen, assemblage, sorteren, verpakken)		19/20			g m h
		Energie- en grondstoffenbesparing					
		Controlesystemen die machines stilleggen bij onderbenutting (bijv. PROFI-energy)		19/20			g m h
		Geautomatiseerde beheerssystemen voor energie efficiënte productie		19/20			g m h
		Systemen t.b.v. terugwinning van kinetische en procesenergie (bijv. terugwinnen afvalwarmte)		19/20			g m h
		Technologieën voor energie- en/of warmteopwekking door middel van zon-, wind-, waterkracht, biomassa of geothermische energie		19/20			g m h
		Bewerkingstechnologieën voor nieuwe materialen					
		Productietechnologieën voor micromechanische componenten (micromachinale bewerking, lithografie, micro-injectie e.d.)		19/20			g m h
		Nanotechnologische productieprocessen (bijv. oppervlaktebewerking)		19/20			g m h
		Technieken voor verwerking van composietmateralen (bijv. carbonvezel, glasvezel)		19/20			g m h
		Bio- en gentechnologie in fabricageprocessen (bijv. catalysatoren, bioreactoren)		19/20			g m h
		Technieken voor verwerking van legeringen (aluminium-, magnesium-, titaniumlegeringen, enz.)		19/20			g m h
		Additieve productietechnologieën					
		Additive productietechnologie voor maken van prototypes (bijv. 3D printing, rapid prototyping; Selective Laser Sintering; Stereolithografie, Laser Beam Melting)		19/20			g m h
		Productie met additieve productietechnologie (incl. enkelstuksproductie; kleine productieseries; reserveonderdelen)		19/20			g m h
		Systemen voor Machine2Machine communicatie, Multi-agent systemen		19/20			g m h
		Systemen voor Cyber-Physical systems, cloud-computing		19/20			g m h
		Digitale fabriek / IT netwerken					
		Digitale productieplanning en roostering (bijv. ERP-systeem)		19/20			g m h
		Bijna real-time productiebeheersingssystemen (bijv. systemen voor gecentraliseerde aansturing en machinegegevensverwerking		19/20			g m h
		Digitale uitwisseling van productieplanningsgegevens met toeleveranciers en/of klanten (supply chain management)		19/20			g m h
		Systemen voor geautomatiseerd management van interne logistiek en orderverzameling (e.g. RFID, warehouse management system)		19/20			g m h
		Mobiele/draadloze apparaten voor programmering en bediening van installaties en machines (e.g. tablets)		19/20			g m h
		Product Lifecycle Management (PLM) systemen of Product/Productieproces datamanagement		19/20			g m h
		Technologieën voor veilige mens-machine interactie (bijv. coöperatieve robots, open werkstations e.d.)		19/20			g m h
		Digitale oplossingen voor het direct beschikbaar maken van tekeningen, werkschemas en -instructies op de werkvloer (e.g. tablets, smartphones)		19/20			g m h

Toelichting:

1 Het jaar waarin deze technologie voor het eerst werd toegepast in uw bedrijfsvestiging (maak een schatting indien u onzeker bent over het exacte jaar)

2 Daadwerkelijke toepassing ten opzichte van maximaal zinvolle toepassingsmogelijkheden: omvang van het gebruikte potentieel is "gering" bij eerste aanzetten, "midden" bij gedeeltelijke toepassing en "hoog" bij omvangrijke toepassing

8.2 Welke van de volgende maatregelen nam uw bedrijfsvestiging om energieverbruik te verminderen?

	Toepassing gepland voor 2018	nee	ja
Afschakelsystemen voor onderdelen, machines of installaties indien niet in gebruik (bijv. afschakeling luchttoevoer, aangepaste verlichtingssensoren)	☐	← ☐	☐
Verbeteren van bestaande machines of installaties (bijv. hoogefficiënte motoren (IE3), aanbrengen isolatie, warmtewisselaar)	☐	← ☐	☐
Voortijdige vervanging van bestaande machines of installaties door nieuwe machines of installaties	☐	← ☐	☐

8.3 Welke van de volgende redenen en welke van de genoemde barrières zijn van doorslaggevende betekenis voor het wel of niet invoeren van energie en warmte opwekkende technologieën op basis van hernieuwbare energie in uw vestiging?

Redenen voor invoering	Energie	Warmte
Verwachte ontwikkeling van de energieprijzen	☐	☐
Strategische redenen (bijv. "groen imago")	☐	☐
Terugdringen broeikasgassen	☐	☐
Eigen energie-opwekking ter vergroting aantal energiebronnen	☐	☐
Politieke of wettelijke bepalingen	☐	☐

Belangrijke barrières	Energie	Warmte
Te grote investeringen of voordelen ontbreken	☐	☐
Administratieve last (bijv. goedkeuringsprocedures)	☐	☐
Niet van toepassing in deze bedrijfsvestiging	☐	☐
Vooralsnog geen relevant onderwerp in deze vestiging	☐	☐
Andere barrières	☐	☐

9.1 Heeft uw bedrijf sinds 2012 producten geïntroduceerd die nieuw waren voor uw bedrijf of die technisch ingrijpend zijn vernieuwd?
(Bijv. door nieuwe grondstoffen of materialen te gebruiken, veranderingen in productiefuncties of werking e.d.)

☐ nee ☐ ja → Hoe groot was het aandeel van deze producten in de omzet van het jaar 2014? ca. ____ %

→ Hoe lang duurde gemiddeld genomen de ontwikkeling van zo'n product? (van productidee tot en met lancering) ca. ____ maanden

9.2 Hebben deze productvernieuwingen ook geleid tot betere milieu-effecten bij gebruik of verwijderen van deze nieuwe producten?

☐ nee ☐ ja → Welke verbeteringen in de milieu-effecten zijn met deze producten bereikt? (Kruis aan wat van toepassing is)

- ☐ Vermindering van gezondheidsrisico's bij gebruik
- ☐ Vermindering van energieverbruik bij gebruik
- ☐ Vereenvoudiging van onderhoud of herstel
- ☐ Verlenging productlevensduur
- ☐ Vermindering van milieuvervuiling bij gebruik (van grond, water, lucht, of geluid)
- ☐ Verbeterde recycling, terugwinning of verwijderingseigenschappen

9.3 Bevonden zich bij deze nieuwe producten (nieuw sinds 2012) ook producten, die <u>nieuw-voor-de-markt</u> waren en die uw bedrijfsvestiging als eerste op de markt introduceerde?

☐ nee ☐ ja → Wat was hun aandeel in de omzet van 2014? ca. ____ %

→ Zijn deze producten speciaal ontwikkeld vooral voor (kruis slechts één optie aan):

- ☐ bestaande klanten binnen uw huidige markt
- ☐ aantrekken van nieuwe klanten binnen uw huidige markt
- ☐ toetreding tot markten nieuw voor *uw bedrijfsvestiging*
- ☐ het ontwikkelen van geheel nieuwe markten

9.4 Heeft uw bedrijfsvestiging producten in het programma die u <u>al langer dan 10 jaar</u> aanbiedt?

☐ nee ☐ ja → Welk percentage van de omzet hadden deze producten in 2014? ca. ____ %

10.1 Welke van de volgende productgerelateerde diensten biedt u uw klanten aan?
Als uw bedrijfsvestiging dergelijke diensten aanbiedt, worden zij dan ook aangeboden voor producten van andere bedrijven?

	nee	ja	Voor producten van andere bedrijven
Installatie, inbedrijfstelling	☐	☐ →	☐
Onderhoud en reparatie	☐	☐ →	☐
Training	☐	☐ →	☐
Ontwerp, technisch advies (incl. testen, simulaties, O&O voor klanten)	☐	☐ →	☐
Software-ontwikkeling (bijv. software-aanpassing)	☐	☐ →	☐
Klantondersteuning op afstand (helpdesk, service hotline, website)	☐	☐ →	☐
Reviseren, vernieuwen (incl. functie opwaardering of software-uitbreidingen)	☐	☐ →	☐
End-of-life dienstverlening (bijv. recycling, opheffen, terugname)	☐	☐ →	☐

10.2 Indien u productgerelateerde diensten aanbiedt, hoe hoog schat u het aandeel daarvan in de totale omzet van 2014?
► In geval van geen omzet, vul in „0".

Aandeel in totale omzet van diensten die u in 2014 direct, d.w.z. apart, in rekening heeft gebracht ca. ☐ %

Aandeel van diensten die u in 2014 indirect in rekening heeft gebracht (via de productprijs) ca. ☐ %

10.3 Heeft uw bedrijfsvestiging vanaf 2012 nieuwe productgerelateerde diensten aangeboden, die geheel nieuw zijn voor uw bedrijfsvestiging of belangrijke verbeteringen bevatten?

☐ nee ☐ ja ➔ Hoe groot was het aandeel in de omzet van 2014 van deze sinds 2012 nieuw aangeboden productgerelateerde diensten, die uw bedrijfsvestiging direct of indirect in rekening heeft gebracht? ca. ☐ %

11 Hoe vaak heeft uw organisatie vanaf 2012 de volgende activiteiten verricht? (0=niet; 1=1 keer; 2=vaker)

Spin-offs	Opstarten van nieuwe organisaties of activiteiten buiten de onderneming	0	1	2
Uitgaand intellectueel eigendom	Verkopen, of aanbieden van licenties/patenten aan andere organisaties	0	1	2
Werknemer-betrokkenheid	Benutten van kennis en initiatieven van niet-O&O medewerkers bij het realiseren van innovaties	0	1	2
Klantbetrokkenheid	Direct betrekken van klanten in uw innovatieprocessen	0	1	2
Extern netwerken	Het samenwerken met andere organisaties (niet klanten) voor innovatie	0	1	2
Externe participatie	Deelnemen (met bijv. vermogen, kennis) in ondernemingen om toegang te krijgen tot hun kennis of om andere synergieën te creëren?	0	1	2
Uitbesteden van O&O	Uitbesteden van O&O (diensten) aan andere organisaties, zoals universiteiten, publieke onderzoeksinstellingen, commerciële ingenieurs of leveranciers?	0	1	2
Inkomend intellectueel eigendom	Kopen of in licentie nemen van intellectueel eigendom van andere organisaties	0	1	2

12. Hoe hebben zich in uw bedrijfsvestiging de productiekosten per eenheid product (eenheidskosten) ontwikkeld in 2014?

Gedaald met 10% of meer	Gedaald 5 - < 10%	Gedaald 0 - < 5%	Gelijk gebleven	Gestegen 0 - < 5%	Gestegen 5 - < 10%	Gestegen met 10% of meer
☐	☐	☐	☐	☐	☐	☐

13 In de voorafgaande vragen heeft u informatie gegeven over verschillende velden van innovatie. Rangorden deze innovatievelden naar mate van belangrijkheid voor uw bedrijfsvestiging.
Geef met een score van 1 tot 4 de volgorde van belangrijkheid aan met 1 als het belangrijkst; gebruik elke score slechts één keer.

Toevoegen van diensten aan uw producten	Organisatie-vernieuwing	Technische vernieuwing in het productieproces	Ontwikkeling van nieuwe producten
◯	◯	◯	◯

14 Welke van de onderstaande informatiebronnen zijn het meest relevant voor belangrijke innovatie-impulsen/ideeën in uw bedrijfsvestiging op de volgende gebieden? (Kruis maximaal drie informatiebronnen aan voor elk gebied van innovatie)

	intern				extern			
	O&O, engineering	productie-afdeling	Klanten-service	Leiding bedrijfsvestiging	Klant of gebruiker	Leverancier	Onderzoeks-instellingen, universiteiten	Conferenties, beurzen
Nieuwe producten	☐	☐	☐	☐	☐	☐	☐	☐
Nieuwe proces-technologieën	☐	☐	☐	☐	☐	☐	☐	☐
Nieuwe diensten	☐	☐	☐	☐	☐	☐	☐	☐
Nieuwe organisatie-concepten	☐	☐	☐	☐	☐	☐	☐	☐

15.1 Wat is het opleidingsniveau van het personeel van uw bedrijfsvestiging?

Hoger onderwijs (HBO+WO)	ca. ☐ %	=100%
MBO technische opleiding	ca. ☐ %	
MBO adminstratieve en commerciële opleiding	ca. ☐ %	
LBO of ongeschoold	ca. ☐ %	
Personeel in opleiding (leerlingen, stagiaires)	ca. ☐ %	

15.2 Hoe is het personeel in uw bedrijfsvestiging verdeeld over de volgende werkterreinen:

Onderzoek en ontwikkeling	ca. ☐ %	=100%
Ideevorming, ontwerp en vormgeving	ca. ☐ %	
Fabricage en montage	ca. ☐ %	
Klantenservice	ca. ☐ %	
Overige (administratie, inkoop, logistiek/distributie, onderhoud, productieplanning enz.)	ca. ☐ %	

16 **Heeft uw bedrijfsvestiging in de afgelopen twee jaar delen van de productie of delen van onderzoek en ontwikkeling (O&O) overgeheveld naar andere bedrijven (uitbesteding) of eigen vestigingen in het buitenland (verplaatsing) danwel vestigingen vanuit het buitenland teruggeplaatst?**

Overheveling:

nee | **Ja:** (meerdere opties mogelijk): Naar andere bedrijven in Nederland / Naar andere bedrijven in het buitenland / naar eigen vestigingen in het buitenland | Naar welk land (landen)?

Redenen: (meerdere opties mogelijk): Arbeidskosten / Ontsluiting nieuwe markten / Nabijheid belangrijke klanten / Toegang tot nieuwe kennis technologieën/clusters / Belasting, heffingen, subsidies / Gebrek aan gekwalificeerd personeel in eigen land / Importbeperkingen / Nabijheid van O&O of productie die reeds is overgeheveld / Toegang tot natuurlijke hulpbronnen leveranciers / Aanwezigheid van concurrenten

Overheveling van **productie-activiteiten** sinds 2013

Verplaatsing **onderzoeks- en ontwikkelingsactiviteiten** sinds 2013

Terugplaatsing (repatriëring) vanuit het buitenland naar het thuisland

Nee | **Ja**: Vanuit andere bedrijven in het buitenland / Vanuit eigen vestigingen in het buitenland | Uit welk land/landen

Kwaliteit / Flexibiliteit, leversnelheid / Capaciteitsbenutting / Beschikbaarheid gekwalificeerd personeel / Arbeidskosten / Transportkosten/ logistieke kosten / Kosten van coördinatie en toezicht / Nabijheid van binnenlandse O&O / Verlies van kennis/ -kopiëren/piraterij / Infrastructuur

Terugplaatsing van (delen van) de **productie** sinds 2013

17 **Geef a.u.b. de herkomst van uw toeleveringen (inputs) en de bestemming van uw producten in 2014.**
► Toeleveringen zijn gekochte onderdelen, (ruwe) materialen, productiemiddelen en diensten. Geef alleen het aandeel aan van producten gemaakt in uw bedrijfsvestiging.

Toeleveringen afkomstig uit:
- binnenland ca ____ %
- buitenland ca ____ %

=100% van de inkoopwaarde

Producten verkocht in:
- binnenland ca ____ %
- buitenland ca ____ %

=100% van de omzet

18.1 **Heeft uw bedrijfsvestiging onderzoek en ontwikkelingsactiviteiten (O&O) uitgevoerd of laten uitvoeren door externe partners in 2014?**

☐ nee ☐ ja ➔ O&O-uitgaven in procenten van de omzet in 2014 ca. ____ %

18.2 **Heeft uw bedrijfsvestiging sinds 2012 continu O&O uitgevoerd of laten uitvoeren door externe partners?**

☐ nee ☐ ja

19 **Welk van de volgende kenmerken zijn het meest van toepassing op uw hoofdproduct(groep)?**

Productontwikkeling (kruis slechts één optie aan)
- Op specificatie van klant ☐
- Voor een standaardprogramma waarbinnen klantspecifieke wensen gerealiseerd kunnen worden ☐
- Voor een standaardprogramma, waaruit de klant kan kiezen ☐
- Niet aanwezig in deze bedrijfsvestiging ☐

Seriegrootte (kruis slechts één optie aan)
- Enkelstuksproductie ☐
- Kleine of middelgrote series (20-1.000 stuks per maand) ☐
- Grote series (meer dan 1.000 stuks per maand) ☐
- Geen discrete productie (procesindustrie) ☐

Fabricage/montage (kruis slechts één optie aan)
- Na binnenkomst klantorder (make-to-order) ☐
- Eindmontage van het product wordt uitgevoerd na binnenkomst klantorder (assemble-to-order) ☐
- Op voorraad (make-to-stock) ☐
- Niet aanwezig in deze bedrijfsvestiging ☐

Productcomplexiteit (kruis slechts één optie aan)
- Eenvoudige producten ☐
- Producten van middelgrote complexiteit ☐
- Complexe producten ☐

20 **Beantwoordt u de volgende vragen over uw hoofdproduct(groep).**

Wat is de gemiddelde productietijd van uw hoofdproduct(groep)? (doorlooptijd vanaf moment dat opdracht binnenkomt bij productie tot product klaar is voor levering) ca. [ ] werk-dagen of [ ] uren

Hoeveel procent van de orders wordt op tijd afgeleverd? ca. [ ] %

Hoeveel procent van uw productie moet na kwaliteitscontrole nabewerking ondergaan of geheel worden afgekeurd? ca. [ ] %

Welk percentage van de geleverde bestellingen heeft klachten van klanten opgeleverd vanwege kwaliteitsproblemen? ca. [ ] %

21 **Hier worden enkele gegevens over uw bedrijfsvestiging gevraagd:**

Jaaromzet 2014 [ ] miljoen € 2012 [ ] miljoen €

Aantal werknemers (excl. uitzendkrachten) 2014 [ ] aantal

Aantal werknemers dat is afgevloeid in 2014 2014 [ ] aantal

Had uw bedrijfsvestiging uitzendkrachten in dienst in 2014? [ ] nee [ ] ja ➔ Hoeveel uitzendkrachten waren in 2014 gemiddeld in dienst bij uw bedrijfsvestiging? ca. [ ] aantal

Inkoop 2014 (ingekochte onderdelen, materialen en diensten) [ ] miljoen €

Afschrijvingen op machines en installaties 2014 (zonder grond en gebouwen) [ ] miljoen €

Investeringen in machines en installaties 2014 [ ] miljoen €

Personeelskosten als percentage van de omzet in 2014 (incl. loonnevenkosten) [ ] %

Graad van capaciteitsbenutting (gemiddeld in 2014) [ ] %

Totale energiekosten als percentage omzet 2014 [ ] %

Rendement op de omzet (vóór belasting in 2014) [ ] negatief [ ] 0 tot 2% [ ] > 2 tot 5% [ ] > 5 tot 10% [ ] > 10%

Jaar van oprichting, c.q. inschrijving bij de Kamer van Koophandel jaar: [ ]

Heeft uw bedrijfsvestiging een ondernemingsraad? [ ] nee [ ] ja

22.1 **Geef uw energieverbruik aan als volgt:**

Wat was het aandeel groene stroom in het totale stroomverbruik van uw bedrijfsvestiging in 2014? ca. [ ] %

Hoe groot is de te verwarmen oppervlakte van uw bedrijfsvestiging? ca. [ ] m²

22.2 **Hoe heeft het stroomverbruik van uw bedrijfsvestiging zich ontwikkeld in 2014?**

Gedaald met 10% of meer	Gedaald 5 - < 10%	Gedaald 0 - < 5%	Gelijk gebleven	Gestegen 0 - < 5%	Gestegen 5 - < 10%	Gestegen met 10% of meer
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

22.3 **Hoe heeft het olie- en gasverbruik van uw bedrijfsvestiging zich ontwikkeld in 2014?**

Gedaald met 10% of meer	Gedaald 5 - < 10%	Gedaald 0 - < 5%	Gelijk gebleven	Gestegen 0 - < 5%	Gestegen 5 - < 10%	Gestegen met 10% of meer
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

23 **Wie is in meerderheid of exclusief eigenaar van het bedrijf waartoe uw bedrijfsvestiging behoort?**

[ ] Private eigenaar/ familie [ ] Financiële investeerder (bijv durfkapitaal) [ ] Ander bedrijf (bijv. niet-financiële investeerder) [ ] stichting [ ] overige eigenaren [ ] Geen meerderheidseigenaar

➔ Is de familie actief in het management? [ ] Nee [ ] Ja

Hartelijk dank voor uw bijdrage aan dit onderzoek.

Wij verzoeken u de ingevulde vragenlijst terug te sturen per e-mail naar: P.Vaessen@fm.ru.nl

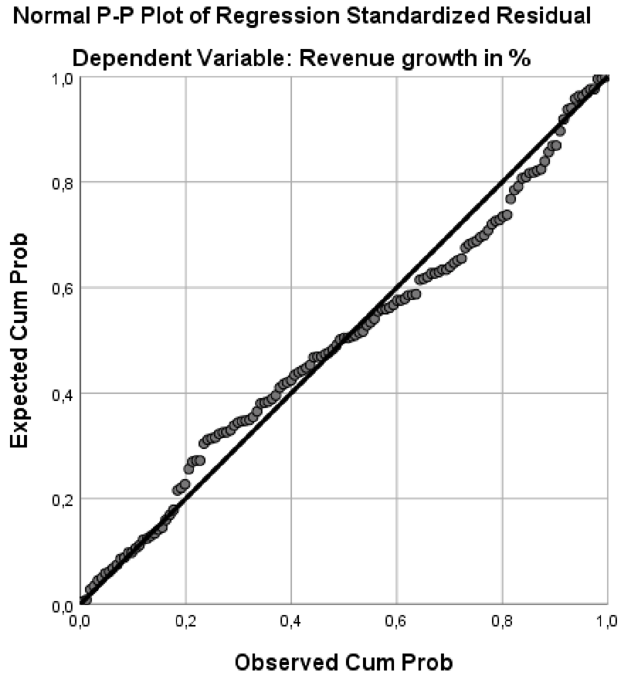
of per post naar:

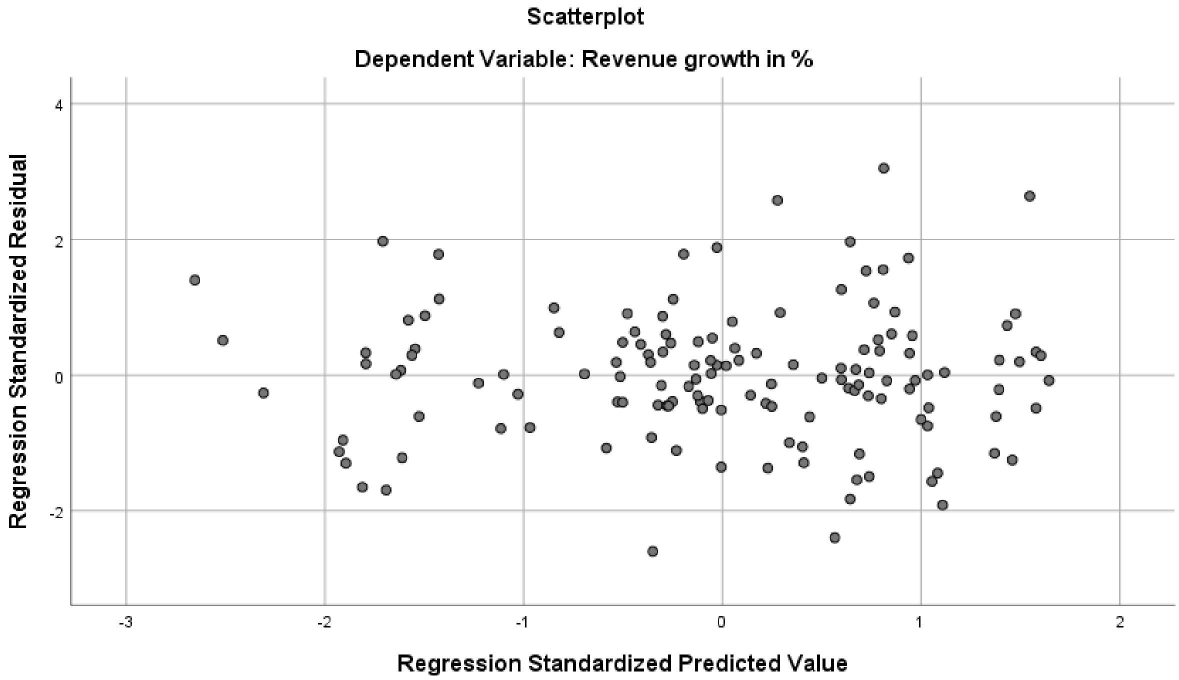
Radboud Universiteit Nijmegen, t.a.v Dr P.Vaessen, Antwoordnummer 1908, 6500 VC Nijmegen

Appendix B: Sample distribution for industry type

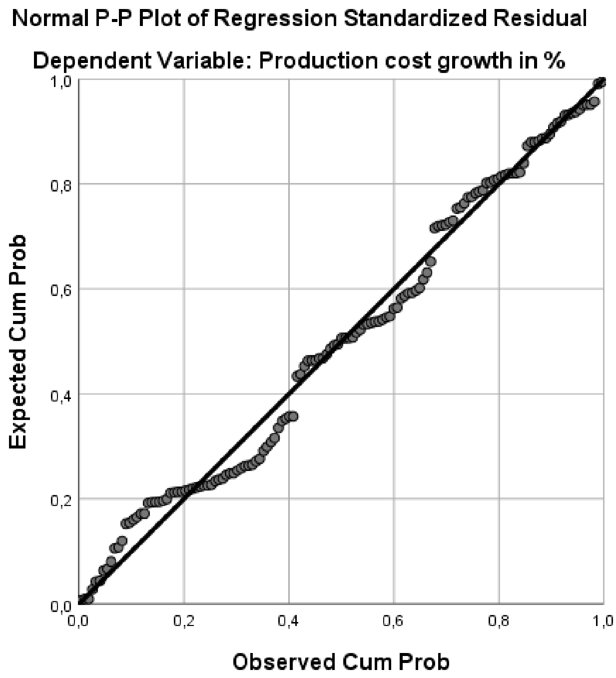
Industry type	**Frequency**
Metals and metal products	36
Food, beverages and tobacco	16
Textiles, apparel, leather, paper and board	22
Construction and furniture	13
Chemicals	22
Machinery, equipment and transport equipment	30
Electrical and optical equipment	31
Total	170

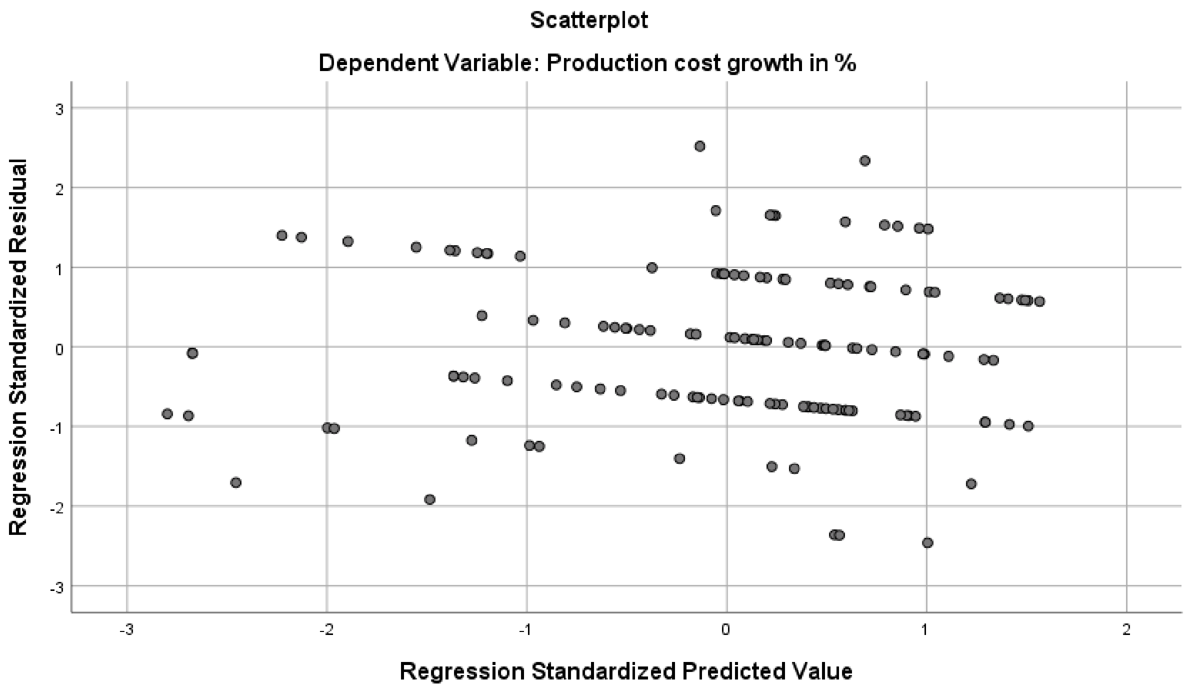
Appendix C: Normal probability plot and scatter plot for revenue growth regression



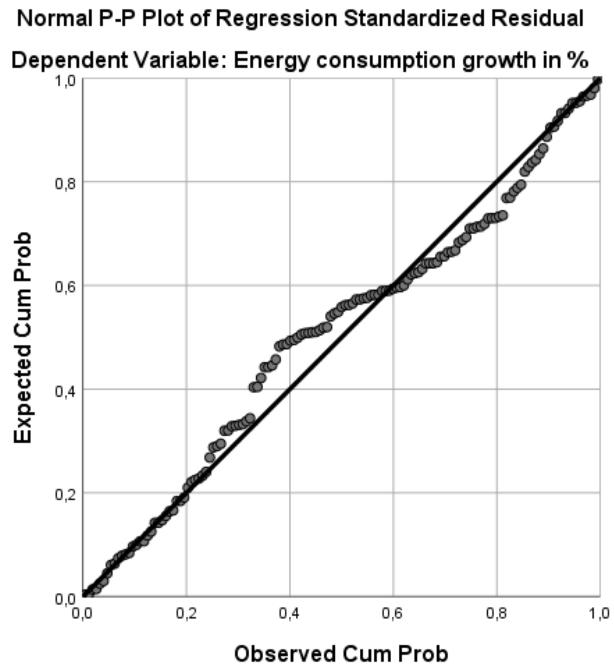


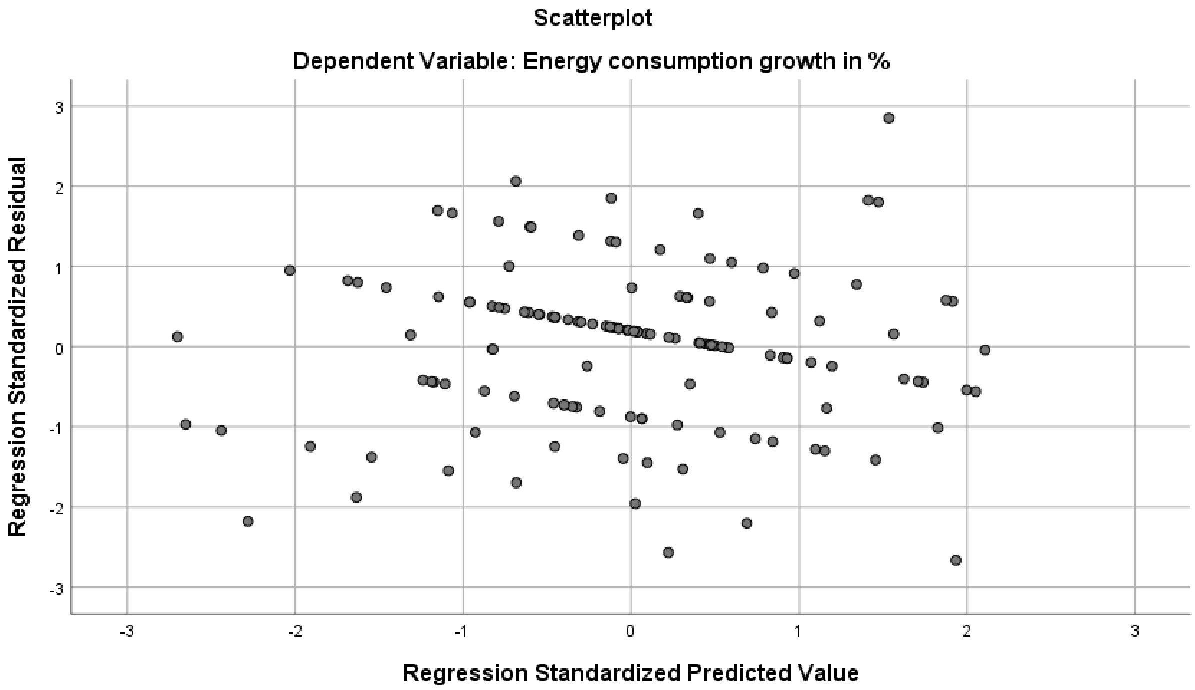
Appendix D: Normal probability plot and scatter plot for production cost growth regression





Appendix E: Normal probability plot and scatter plot for energy consumption growth follow-up regression





Appendix F: Output for revenue growth regression

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,126[a]	,016	,009	18,88270	,016	2,200	1	137	,140
2	,133[b]	,018	,003	18,93488	,002	,246	1	136	,621
3	,227[c]	,052	-,007	19,02904	,034	,776	6	130	,590

a. Predictors: (Constant), Effectiveness of green product innovations transformed

b. Predictors: (Constant), Effectiveness of green product innovations transformed, Firm size in number of employees transformed

c. Predictors: (Constant), Effectiveness of green product innovations transformed, Firm size in number of employees transformed, Textile industry, Chemical industry, Food industry, Construction industry, Electronic industry, Machinery industry

d. Dependent Variable: Revenue growth in %

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	784,307	1	784,307	2,200	,140[b]
	Residual	48848,199	137	356,556		
	Total	49632,506	138			
2	Regression	872,473	2	436,236	1,217	,299[c]
	Residual	48760,034	136	358,530		
	Total	49632,506	138			
3	Regression	2558,930	8	319,866	,883	,532[d]
	Residual	47073,576	130	362,104		
	Total	49632,506	138			

a. Dependent Variable: Revenue growth in %

b. Predictors: (Constant), Effectiveness of green product innovations transformed

c. Predictors: (Constant), Effectiveness of green product innovations transformed, Firm size in number of employees transformed

d. Predictors: (Constant), Effectiveness of green product innovations transformed, Firm size in number of employees transformed, Textile industry, Chemical industry, Food industry, Construction industry, Electronic industry, Machinery industry

Appendix F (continued)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	10,961	1,786		6,136	,000		
	Effectiveness of green product innovations transformed	-11,656	7,859	-,126	-1,483	,140	1,000	1,000
2	(Constant)	14,910	8,161		1,827	,070		
	Effectiveness of green product innovations transformed	-10,885	8,032	-,117	-1,355	,178	,963	1,039
	Firm size in number of employees transformed	-2,526	5,095	-,043	-,496	,621	,963	1,039
3	(Constant)	14,755	8,814		1,674	,097		
	Effectiveness of green product innovations transformed	-12,705	8,351	-,137	-1,521	,131	,899	1,112
	Firm size in number of employees transformed	-1,296	5,248	-,022	-,247	,805	,916	1,092
	Food industry	3,456	6,232	,055	,555	,580	,740	1,350
	Textile industry	-4,737	5,712	-,084	-,829	,408	,708	1,412
	Construction industry	-9,860	6,668	-,147	-1,479	,142	,743	1,346
	Chemical industry	-1,516	5,827	-,026	-,260	,795	,715	1,399
	Machinery industry	1,288	5,187	,027	,248	,804	,637	1,571
	Electronic industry	-3,400	5,323	-,067	-,639	,524	,666	1,502

a. Dependent Variable: Revenue growth in %

Appendix G: Output for production cost growth regression

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,048[a]	,002	-,012	1,25704	,002	,160	2	138	,852
2	,121[b]	,015	-,022	1,26311	,012	,559	3	135	,643
3	,222[c]	,049	-,032	1,26929	,035	,781	6	129	,586

a. Predictors: (Constant), Use of green process innovations, Effectiveness of green product innovations transformed

b. Predictors: (Constant), Use of green process innovations, Effectiveness of green product innovations transformed, Energy consumption growth in %, Firm size in number of employees transformed, Use of other process innovations

c. Predictors: (Constant), Use of green process innovations, Effectiveness of green product innovations transformed, Energy consumption growth in %, Firm size in number of employees transformed, Use of other process innovations, Construction industry, Chemical industry, Electronic industry, Textile industry, Machinery industry, Food industry

d. Dependent Variable: Production cost growth in %

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	,506	2	,253	,160	,852[b]
	Residual	218,062	138	1,580		
	Total	218,567	140			
2	Regression	3,183	5	,637	,399	,849[c]
	Residual	215,384	135	1,595		
	Total	218,567	140			
3	Regression	10,734	11	,976	,606	,821[d]
	Residual	207,833	129	1,611		
	Total	218,567	140			

a. Dependent Variable: Production cost growth in %

b. Predictors: (Constant), Use of green process innovations, Effectiveness of green product innovations transformed

c. Predictors: (Constant), Use of green process innovations, Effectiveness of green product innovations transformed, Energy consumption growth in %, Firm size in number of employees transformed, Use of other process innovations

d. Predictors: (Constant), Use of green process innovations, Effectiveness of green product innovations transformed, Energy consumption growth in %, Firm size in number of employees transformed, Use of other process innovations, Construction industry, Chemical industry, Electronic industry, Textile industry, Machinery industry, Food industry

Appendix G (continued)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	3,874	,144		26,993	,000		
	Effectiveness of green product innovations transformed	-,309	,562	-,048	-,550	,583	,958	1,043
	Use of green process innovations	-,002	,113	-,002	-,018	,985	,958	1,043
2	(Constant)	3,441	,720		4,777	,000		
	Effectiveness of green product innovations transformed	-,483	,583	-,075	-,827	,409	,898	1,114
	Use of green process innovations	-,060	,122	-,046	-,492	,624	,828	1,208
	Energy consumption growth in %	-,018	,115	-,014	-,159	,874	,928	1,078
	Use of other process innovations	,032	,047	,070	,688	,493	,704	1,419
	Firm size in number of employees transformed	,280	,378	,072	,742	,459	,771	1,297
3	(Constant)	3,285	,759		4,325	,000		
	Effectiveness of green product innovations transformed	-,362	,599	-,056	-,605	,546	,858	1,165
	Use of green process innovations	-,037	,131	-,028	-,281	,779	,725	1,379
	Energy consumption growth in %	,025	,119	,020	,213	,831	,871	1,148
	Use of other process innovations	,006	,051	,012	,108	,914	,593	1,687
	Firm size in number of employees transformed	,438	,394	,113	1,113	,268	,717	1,395
	Food industry	-,154	,419	-,039	-,367	,714	,646	1,549
	Textile industry	-,377	,373	-,110	-1,010	,314	,623	1,605
	Construction industry	,000	,475	,000	,001	,999	,770	1,299
	Chemical industry	-,727	,393	-,195	-1,849	,067	,664	1,507
	Machinery industry	-,092	,369	-,026	-,249	,804	,660	1,514
	Electronic industry	,008	,349	,003	,023	,981	,641	1,559

a. Dependent Variable: Production cost growth in %

Appendix H: Output for energy consumption growth follow-up regression

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,171[a]	,029	,022	,95361	,029	4,181	1	139	,043
2	,268[b]	,072	,051	,93935	,042	3,126	2	137	,047
3	,357[c]	,127	,067	,93131	,056	1,396	6	131	,221

a. Predictors: (Constant), Use of green process innovations

b. Predictors: (Constant), Use of green process innovations, Firm size in number of employees transformed, Use of other process innovations

c. Predictors: (Constant), Use of green process innovations, Firm size in number of employees transformed, Use of other process innovations, Construction industry, Chemical industry, Electronic industry, Food industry, Machinery industry, Textile industry

d. Dependent Variable: Energy consumption growth in %

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3,802	1	3,802	4,181	,043[b]
	Residual	126,403	139	,909		
	Total	130,206	140			
2	Regression	9,319	3	3,106	3,521	,017[c]
	Residual	120,886	137	,882		
	Total	130,206	140			
3	Regression	16,584	9	1,843	2,124	,032[d]
	Residual	113,622	131	,867		
	Total	130,206	140			

a. Dependent Variable: Energy consumption growth in %

b. Predictors: (Constant), Use of green process innovations

c. Predictors: (Constant), Use of green process innovations, Firm size in number of employees transformed, Use of other process innovations

d. Predictors: (Constant), Use of green process innovations, Firm size in number of employees transformed, Use of other process innovations, Construction industry, Chemical industry, Electronic industry, Food industry, Machinery industry, Textile industry

Appendix H (continued)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	3,957	,106		37,330	,000		
	Use of green process innovations	-,172	,084	-,171	-2,045	,043	1,000	1,000
2	(Constant)	4,155	,401		10,358	,000		
	Use of green process innovations	-,099	,090	-,099	-1,100	,273	,843	1,186
	Use of other process innovations	-,079	,033	-,223	-2,374	,019	,765	1,307
	Firm size in number of employees transformed	,038	,281	,013	,135	,893	,773	1,294
3	(Constant)	4,129	,425		9,726	,000		
	Use of green process innovations	-,128	,095	-,127	-1,348	,180	,747	1,338
	Use of other process innovations	-,055	,037	-,155	-1,498	,136	,621	1,609
	Firm size in number of employees transformed	-,075	,288	-,025	-,259	,796	,719	1,392
	Food industry	,488	,303	,161	1,614	,109	,668	1,497
	Textile industry	,084	,274	,032	,306	,760	,624	1,603
	Construction industry	-,184	,345	-,049	-,533	,595	,784	1,276
	Chemical industry	,522	,285	,181	1,835	,069	,682	1,467
	Machinery industry	,171	,271	,063	,633	,528	,663	1,508
	Electronic industry	-,107	,256	-,043	-,420	,675	,645	1,550

a. Dependent Variable: Energy consumption growth in %

Appendix I: Sobel test for the mediating effect of energy costs between the use of green process innovations and production cost growth

	Input:		Test statistic:	Std. Error:	*p*-value:
a	-0.172	Sobel test:	0.30892303	0.01948705	0.75738008
b	-0.035	Aroian test:	0.27819859	0.02163922	0.78085992
s_a	0.084	Goodman test:	0.35275634	0.0170656	0.72427112
s_b	0.112	Reset all	Calculate		