Reducing production costs, what to do?

Master thesis

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Preface

In front of you the thesis ‘Reducing production costs, what to do?’. This thesis is written in the context of my graduation for the master Innovation and Entrepreneurship at the Radboud university. It has been an intensive and educational process and it has to be mentioned that COVID-19 has had an impact on the overall process. Now, August 4, it comes to an end. I would like to thank my fellow students for the cooperation and my supervisor dr. P.M.M. Vaessen for his time and feedback moments.

Please, enjoy reading this thesis.

Menno Jansen

Nijmegen, August 4, 2020

Abstract

This study focuses on the effect of technological process and/or organizational process innovations on the production costs of companies in the manufacturing industry. Goal of this research is to specify the innovation outcomes and to contribute to the cost part of the productivity paradox. This research has been executed as a quantitative study. The research results show that the implementation of organizational process innovations leads to a decrease in production costs. Technological process innovations do not have an effect on production costs. Furthermore, the interaction between organizational and technological process innovations on production costs does not show a significant impact. Scientific theories have been used which are common in the field of innovation. The results of this research are interesting, it contradicts scientific statements.

Keywords

Innovation, technological process innovation, organizational process innovation, firm performance and production costs.

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1. Introduction

Organizations innovate to operate efficiently, perform effectively, increase market share and generate economic wealth for their owners (Damanpour, 2017). Scientific theorists (Evangalista & Vezzani, 2010; Damanpour 2017) have researched and investigated the outcomes of the concept innovation. Damanpour is one of the scientific theorists who has a significant contribution to the topic innovation in the scientific literature. According to Damanpour and Evan (1984) are “innovations considered to be responses to environmental change or means of bringing about change in an organization” (p. 393). Innovations are important and have a crucial function in our modern society. Innovations are often the key for solving many problems (Godin, 2008). Innovations are considered as strategies for gaining organizational competitiveness and could lead to new clients, markets and organizational growth (Damanpour, 2010). However, Evangalista and Vezzani (2010) argue that the relationship between technological and organizational innovations and economic performance is not intensively investigated. Although research on organizational innovations has been done for quite a long period, technological process and product innovation is still the main innovation topic in scientific literature (Kraus, Pohjola & Koponen, 2012). Nevertheless, Kraus et al., (2012) state that the need to understand organizational innovations is equally important.

This equal importance could be problematic concerning implementation issues. The Dutch government for example has huge ambitions concerning ICT-projects, but many of them have failed in the recent years. According to Elias, Ulenbelt, Fokke, Slot and Van Meenen (2014), between 1 billion and 5 billion euros are wasted every year since 1995. The question raises why these ICT projects seem to be so problematic and what the underlying failure reason is. According to Elias et al., (2014), organizational problems seems to be the reason that new technologies and new ICT projects often fail. They state that the organizational structures and processes within projects are inadequate and sufficient expertise within the project staff is missing in order to facilitate these implementation processes (Elias et al., 2014). The ICT projects have huge potential, but at the same time, the government is according to Elias et al., (2014) insufficient aware of all the requirements for successful implementation. Although these ICT projects are mainly cases in the service industry and might not be completely comparable to the manufacturing industry, the implementation problems might be the case in the manufacturing industry as well and therefore interesting to further explore.

Earlier research has been done about the “IT productivity paradox”, which investigates the relationship between the rapid increase in IT use and the simultaneous slowdown in productivity (Jones, Heaton, Rudin & Schneider, 2012). The productivity output per worker grew by 16,6% between the mid 1970s and 1986. Afterwards, during the rise of new technologies, the growth of production rates decreased (Brynjolfsson, 1993). These new technologies imply new machines. However, according to Triplett (1999), it is not obvious that new machinery is the entire engine for increasing productivity. Triplett (1999) state that new technology on itself does not automatically increase productivity.

As stated by Ligthart, Vaessen, Kok and Dankbaar (2018); Kraus et al., (2012), a balanced adoption of organizational and technological process innovation is more effective in helping organizations to maintain or improve their organizational performance than either organizational or technological innovations alone. They state that both types of innovation have a complementary relationship. This indicates that the results and returns of these innovations are the highest when an organization integrates and realizes both organizational and technological process innovation (Ligthart et al., 2018). To frame this research, the focus is on technological process innovations and organizational process innovations in the manufacturing industry.

This topic is extremely important for companies that intend to implement a new technology, in order to increase productivity, performance and to decrease production costs. The technological process innovations on itself could be performing well, but if the organization does not support the technology, the results could disappoint. As explained by Elias et al., (2014) the government was not aware of all the requirements for successful implementation. Therefore, it is important for companies that intend to imply new technologies to understand the outcomes of technological and organizational process innovations and to be aware of all the requirements for successful implementation.

According to Damanpour (2017), technological process innovations could lead to a more appropriate and efficient use of resources and so increase the productivity. This corresponds with the findings of Hollen, Van Den Bosch and Volberda (2013) who state that resource efficiency could increase by implementing technological process innovations. Hollen et al., (2013) state that technological process innovation lead to lower production costs and lower disposal costs. The organizational process innovations are an immediate source of competitive advantage and according to Armbruster, Bikfalvi, Kinkel and Lay (2008) do realize a significant impact on business performance concerning productivity, lead times, quality and flexibility. Decreasing the production costs, as determinant of firm performance, can have a significant impact on the overall organizational results. Both technological and organizational process innovations have an effect on costs efficiency ratios (Damanpour 2017; Armbruster et al., 2008; Hollen et al., 2013).

The aim of this research is to specify the outcomes of technological and organizational process innovations, of organizations in the manufacturing industry, in order to contribute to the costs part of the productivity paradox. This leads to the following research question:
What is the effect of technological process and/or organizational process innovations on the production costs of companies in the manufacturing industry?

Specifying the outcomes of technological and organizational process innovations contributes to the cost aspect as part of the productivity paradox. Furthermore, this research contributes to the scientific literature about the possible synergetic relationship between technological and organizational process innovations for companies in the manufacturing industry.

This also represents the social relevance and the usefulness for organizations, because scientific insights can be translated into meaningful recommendations for organizations in the manufacturing industry. The research outcomes concerning effectiveness of both technological and organizational outcomes are helpful for companies that intend to implement new innovations. This research should lead to valuable outcomes regarding innovations in relationship with production costs.

The remainder of this thesis is structured as follows: chapter two will take into account the theoretic framework and will be about innovation and more specific about the relationship between different types of innovation. Two hypotheses and a conceptual model will be explained in this chapter. Chapter three is about the research method and the data gathering and analysis method. The research results will be analyzed in chapter four. Finally, the research ends with a conclusion, discussion and eventually some future recommendations.

2. Theoretic framework

The concept innovation is the central topic in this research and will be discussed in this chapter. This chapter aims to generate a fundament which makes it possible to answer the general research question. Scientific theorist come up with many definitions of innovations. These different perspectives and different opinions about innovations will be taken into account. This chapter starts with a description of innovation in general. Different types of innovation will be described, analyzed and eventual relationships will be considered. Two hypotheses will be set up before this chapter ends with a conceptual model which proposes some potential relationships and reflects the explained theory.

2.1 Innovation

Innovations are worldwide considered as a crucial factor for reaching a competitive advantage in a continuously changing environment (Dess & Picken, 2000; Tushman & O'Reilly, 1996). According to Crossan and Apaydin (2009), innovation capability is the most important determinant of firm performance. "At the organizational level, it represents the core renewal process and is usually defined as the development and use of new ideas or behaviors, where a new idea could pertain to a new product, service, production process, organizational structure or administrative system" (Damanpour, 2010, p. 997). It is very important to understand the reason why firms innovate. Based on the Oslo Manual (OECD, 2005) the ultimate goal of innovation is to improve performance. This could be realized by increasing demand or reducing costs. A new product or process can be a source of market advantage and could lead to a competitive advantage and increased profits (OECD, 2005). According to Marzi, Dabić, Daim, and Garces (2017), could innovations contribute to organizational growth and market position. Furthermore, Marzi et al., (2017) state that the innovation process in the manufacturing industry is mainly realized by the introduction of innovative products and processes. These processes can lead to new markets and can fill full customer demand (Marzi et al., 2017). Besides that, there are both internal and external drivers and internal and external sources of innovation. "An internal driver of the innovation process can be available knowledge and resources, whereas an external driver could be a market opportunity or imposed regulations" (Crossan & Apaydin, 2009, p. 1166). Crossan and Apaydin (2009) propose the concept 'ideation' as an internal source and an 'innovation invented elsewhere' as an external source of innovation. Armbruster et al., (2008) consider innovation as "a complex phenomenon including technical (new products, new production methods) and non-technical aspects (new markets, new forms of organization), as well as product innovations (new products or services) and process innovations (new production methods or new forms of organization)" (p. 644). Organizations are the unit of analysis in this research. Therefore, the framework of Armbruster et al., (2008) is used to make a distinction between different types of innovation. They distinguish four different types of innovation: (1) technical product innovations, (2) non-technical service innovations, (3) technical process innovations and (4) non-technical process innovations. These non-technical process innovations could be seen as organizational innovations. As mentioned before, this research takes into account technological process innovations and organizational process innovations. These concepts will be explained in dept in the next paragraphs.

2.2 Organizational process innovation

The terms 'organizational innovations' and 'administrative innovations' are interchangeable used in the scientific literature but considered as the same topic. In this research, the term 'organizational process innovation' will be used. Damanpour and Evan (1984) define organizational innovations as those that occur in the social system of an organization. "The social system refers to the relationships among people who interact to accomplish a particular goal or task" (Damanpour & Evan, 1984, p. 394). Armbruster et al., (2008) add some other aspects to this definition which results in the following expanded explanation:
"Organizational innovations comprise changes in the structure and processes of an organization due to implementing new managerial and working concepts and practices, such as the implementation of teamwork in production, supply chain management or quality management systems" (p. 654). Finally, Armbruster et al., (2008) shorten the definition of organizational innovation later on as the use of new managerial and working concepts and practices. So, an organizational innovation is not just a simple change of routines, it is the implementation of an organizational method (in business practices, workplace organization or external relations) that has not been used before in the firm. (OECD, 2005). This new organizational method is because strategic managerial decisions are taken (OECD, 2005). "By applying this definition it is possible to measure not only whether companies have changed their organization (structure and process) within a defined period, but also to provide an analysis of the adoption ratios of concrete organizational concepts in different companies and company types (sector, firm size) and the extent of use within one company" (Armbruster et al., 2008, p. 646). It is possible to even further differentiate organizational innovation. Armbruster et al., (2008) indicate intra-organizational and inter-organizational innovation as

two dimensions. Intra-organizational innovation exists within an organization while inter-organizational innovation is about new organizational structures or procedures beyond a company's boundaries (Armbruster et al., (2008). Examples of inter-organizational innovations are R&D cooperation with customers, just-in time processes with suppliers or supply chain activities. According to Armbruster et al., (2008), intra-organizational innovation is about particular departments or functions and it may affect the overall structure of the organization as a whole. Many scientific theorist (Damanpour and Evan, 1984; Damanpour 2017; Armbruster et al., 2008; Evangalista and Vezzani, 2010 and Hollen et al., 2013) illustrate organizational innovation by giving concrete examples. Examples of new organizational concepts are 'job enrichment and enlargement', 'improved management systems', 'integrating different departments', 'continuous improvement' and 'decentralization of planning'. Armbruster et al., (2008) did research about organizational innovation with the goal to formulate a clear definition and propose an accurate way of measuring organizational innovation and they have found an interesting result in their research. They argue that organizational practices on themselves already create a direct source of advantage, because they directly impact business performance concerning productivity, lead times, flexibility and quality (Armbruster et al., 2008). Organizational and managerial processes are resources that cannot be bought, these processes typically must be built (Ligthart et al., 2018).

Volberda, Commandeur, Van den Bosch and Heij (2013) investigated the performance outcomes of organizational process innovation. They state that a successful innovation requires more than just a technological innovation. Volberda et al., (2013) state that organizational process innovations are indirectly related to the physical primary processes. In comparison to technological innovations, organizational process innovations are more difficult to conceptualize and these organizational practices seems more difficult to quantify (Volberda et al., 2013). One of the findings of their research was that organizational process innovations determine 50% to 75% of the innovation success and technological process innovations the remaining part. One of the investigations of Volberda et al., (2013) among Dutch companies showed that organizational process innovations have a positive impact on production costs and organizational process innovations increase productivity and decrease lead time. The implementation of new organizational process innovations has resulted in maintenance savings, lower production costs and achieving goals in a better way. Volberda et al., (2013) argue that organizational process innovations have a positive impact on production costs.

2.3 Technological innovations

It has become clear that technological innovations improve resource productivity in the manufacturing industry (Hollen et al., 2013). This corresponds with the statement of Ligthart et al., (2018) who state that technological capabilities of organizations are key sources of competitive strength. Technological innovation is a broad subject and defined by many scientific theorists. Damanpour and Evan (1984) define technological innovations as "innovations that occur in the technical system of an organization and are directly related to the primary work activity of the organization" (p. 394). Besides that, Damanpour and Evan (1984) argue that "a technological innovation can be the implementation of an idea for a new product or a new service or the introduction of new elements in an organization's production process or service operation" (p. 394). In this case, technological innovations are considered as means of changing and improving the performance of the technical system of an organization. Based on this definition we can distinguish product and process innovations as two types of technological innovations. Damanpour (2017) explains the distinction as follows: "Product innovation is defined as the introduction of a new product or service to meet an external user need, and process innovation as the introduction of new elements in a firm's production or service operation in order to produce a product or render a service" (p. 12). The technological product innovations will not be included in this research, because including would go beyond the scope of this research.

2.4 Technological process innovation

As argued before, organizational process innovations do have a positive effect on production costs and could increase the organizational performance. On the other hand, scientific scientist argue that technological process innovations also positively influence the production costs. The following examples show the outcomes of technological process innovations of different studies.

Hollen et al., (2013), who gained a better understanding of the role of organizational innovation related to technological innovation, used illustrations from established process manufacturing firms in the port of Rotterdam. They collected public and company related documents and interviewed three directors as well as managers in three different established process manufacturing firms. Hollen et al., (2013) found that technological process innovations lead to a decrease in production costs, a decrease in disposal costs, the possibility to use cheaper raw materials and finally lead to product quality improvements. "These possible outcomes from technological process innovation imply a more appropriate and efficient use of resources and are hence associated with enhanced resource productivity, which is what makes companies truly competitive" (Hollen et al., 2013, p. 38). Thus, technological process innovations have an internal focus and are mainly manufacturing techniques (Damanpour, 2017). However, external effects occur as well because technological process innovations could facilitate the introduction of new products and increase product quality. The technological process innovations on itself are internally focused, whereas new products can accomplish changing customer need and improves market position.

Evangalista and Vezzani (2010) state that "process innovations provide a competitive advantage via the efficiency/productivity gains obtained through the introduction of more performing ways of producing (pre-existing) products" (p. 1254). They investigated the relative importance of technological and organizational changes as drivers of firms' economic performances and whether there are differences in the relevance and economic impact of these two different forms of innovations. They used manufacturing firm level data provided by the Italian CIS, referring to the period 2002 – 2004. Firms were asked about the type of innovation they introduced over the three years period. With these data they analyzed the innovation – performance relationship at 2192 companies. What they found is that process innovations play a positive role on firm's performance in manufacturing companies and that it reduces the costs.

Hassen, Akanmu and Yusoff (2018) giving strenght to previous statements by saying that technological process innovations can decrease the costs. They state that technologies with customer-centric and information-intensive features provide enormous benefits, such as reduced costs, increased flexibility, and enhanced coordination (Hassen et al., 2018). Hassan et al., (2018) did research about the relationship between technological integration and sustainable economic performance. Sustainable economic performance is achieved when continuous value for stake- and shareholders is created. Furthermore, sustainable economic performance is focused on reducing costs and increasing return on assets. Hassen et al., (2018) focused on Malaysian standard 14001 certified manufacturing firms in order to reach their research goal. They distributed 600 questionnaires and a total of 107 were returned. Hassen et al., (2018) conducted a multiple regression analysis in order to identify the best predictor influencing sustainable performance among manufacturing firms in Malaysia. Hassan et al., (2018) found that technological integration plays a significant role in achieving sustainable economic targets by improving the efficiency and effectiveness of new and more sustainable ways of development. The implementation of new technologies resulted in reduced production costs.

Furthermore, Vaessen, Ligthart and Dankbaar (2012) state that technological advances improve costs, quality, flexibility, delivery speed and design. They based their findings on the European Manufacturing Survey (2006), referring to the period 2003 – 2005.

Both part 2.2 and 2.4 explained and analyzed the relationship between organizational and technological process innovations and the production costs. The different examples of previous paragraphs have showed arguments and evidence that both types of innovation do have a positive impact on production costs. However, taking into account the arguments and evidence for both types of innovation, more evidence has been found for a stronger effect of technological process innovations on production costs than organizational process innovations have. The direct influence of technological process innovations seems to be stronger than organizational process innovations. Therefore, and based on previous statements, explanations and empirical data, the following hypothesis is formulated:

Hypothesis 1: Technological process innovations have a stronger effect on production costs than organizational process innovations.

2.5 Synergetic effects

As said by Evangalista and Vezzani (2010), the distinction between technological innovations and organizational process innovations should not be over emphasized. “These two types of innovations are often closely interrelated and their effects on performances are difficult to be disentangled” (Evangalista & Vezzani, 2010, p. 1254). Nevertheless, there are still some differences in terms of observability. Damanpour and Evan (1984) state that technological innovations are more observable, have higher trialability and are perceived to be relatively more advantageous than organizational innovations, while organizational innovations are perceived to be more complex than technical innovations to implement. However, it has become clear that technological innovation and organizational innovations are related with each other (Camisón & Villar-López, 2014). Different types of innovations often influence and complement each other (Damanpour, Szabat & Evan, 1989). When new machinery is implemented in a company, workers must be trained to operate it (Damanpour et al., 1989). Similarly, when a company offers a new service, new organizational processes have to be implemented to check the performance. A balanced rate of adoption of organizational and technological innovation is according to Damanpour and Evan (1984) more effective in helping organizations to maintain or improve their level of performance than either organizational or technological innovations alone. By integrating both types of innovation it is possible to generate a competitive advantage. “The two can have a complementary relationship leading to a combined effect on performance and upskilling that can be greater than their mere sum” (Armbruster et al., 2006, p. 18).

There is a stream of literature that state that there is some sort of sequence in which both types of innovation should be implemented. Armbruster et al., (2008, p. 645) argue that “organizational innovations act as the prerequisites and facilitators of an efficient use of technical product and process innovations as their success depends on the degree to which the organizational structures and processes respond to the use of these new technologies”. Thus, organizational innovations could be seen as a precondition for successful technological product or technological process innovations (Armbruster et al., 2008). Camisón and Villar-López, 2014) state that organizational innovation favors the development of technological process innovation. In addition to that, Kraus et al., (2012) argue that organizational innovation act as the antecedents and facilitators of an efficient use of technological product and process innovations. The introduction of new products depends on the degree to which the organizational structures and processes respond to the use of these new technologies (Kraus et al., 2012). Damanpour and Evan (1984) also state that organizational innovations tend to trigger technological process innovation ‘more readily than the reverse’. This suggest that innovation in a firm’s technical system is driven by innovation in its social system (Hollen et al., 2013), which can be seen as the organizational process innovations.

There exists another stream of literature with is consistent with previous statements that organizational process innovations act as facilitators of technological process innovations. This stream of literature is in line with the socio-technical system theory. The socio-technical system theory is about the design sequence of organizations. One of the statements of Lekkerkerk (2017) is that ‘systems follow structure’ in the design sequence. Lekkerkerk (2017) state that if an investment in ICT systems is necessary for example, it is important to check the viability of the structure first and make sure ‘system follow structure’. This implies that there is a sort of implementation sequence and that organizational process innovations should be implemented first, before the technological process innovations implementation moment. Damanpour (1989) state that if a company wants to meet the requirements for a technical system, the social structure should change before the technological implementation.

Previous statements state that synergetic effects of implementation lead to better organizational performance. It leads to better and more efficient use of resources which has a positive impact on the production costs as part of the organizational performance. Because of previous statements and examples there has been consensus between scientific theorist that organizational process innovations are facilitators for successful technological process innovations. Because of that, the following hypothesis will be tested:

Hypothesis 2: The implementation of technological process innovations has a stronger effect on production costs when organizational process innovations are implemented first.

This chapter will be finished with a conceptual model based on previous statements and hypotheses. Figure 1, the conceptual model, shows the proposed relationships between the independent and dependent variables. OPI is a short reference for organizational process innovations and TPI is a short reference for technological process innovations.

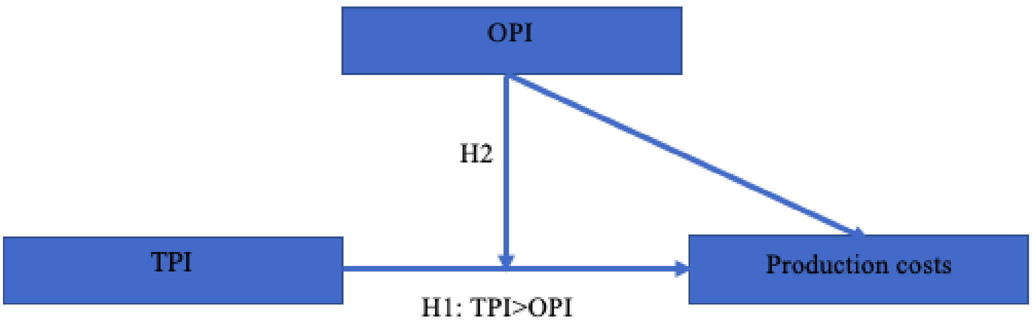

Figure 1. Conceptual model

The conceptual model shows that both technological process innovation and organizational process innovation have a direct influence on the production costs. However, the conceptual model shows the prediction that technological process innovation has a stronger effect on production costs than organizational process innovation. Besides that, it is assumed that technological and organizational process innovation are related with each other and could lead to a stronger effect when organizational innovations are implemented first.

3. Methodology

This chapter provides arguments for the chosen methodology and explains in what way the data is gathered and analyzed. The operationalization section consists of an operationalization table based on the Dutch EMS (2015). Furthermore, the technological and organizational process innovation will be operationalised based on the literature as well. This chapter ends with a methodological reflection where research quality aspects will be taken into account.

3.1 Research method

This research will be conducted as a mixed-method study. This implies that both qualitative and quantitative data will be used to answer the research question. By using these two research methods, it is possible to analyze the research question from different perspectives. Because of triangulation, the research results can be generalized to a greater extent, instead of the case when only one specific method is taken into account.

The quantitative data will be generated by using the Dutch EMS (2015). This database contains data about the modernization of production processes within Dutch manufacturing companies. The distinction between technological process innovations and organizational process innovations could be relatively easy determined, especially for companies in the manufacturing industry. There is an obvious difference between these types of innovations. The database contains data about both technological process innovation and organizational process innovation and is therefore adequate for answering the research question. The questionnaire is reached out to all the manufacturing companies in the Netherlands with at least 10 employees. The goal of the survey is to measure the efforts of the companies concerning their process modernization. The quantitative data will be analyzed with the use of SPSS. Analyzing these data should result in proving eventual relationships between the variables. Additionally, it shows the strength of the relationships and whether these relationships are positive/negative or significant/non-significant.

In order to generate the qualitative data, four semi-structured in-dept interviews will be conducted with companies in the manufacturing industry. Conducting these interviews should make it possible to dive deeper into the reasons why companies innovate, how they innovate and what the relationship is between innovations and total production costs. It is interesting to investigate the results and economic impact of innovation. Furthermore, some clarification about the sequentially of technological and organizational implementation moments can be explained in detail. The goal is to approach companies with at least 40 employees. These

semi-structured interviews create some space to dive deeper into the answer if necessary. Respondents will be asked for permission in order to record the interview, with the goal to generate a transcript and code the interview. The respondents will receive a list of both technological and organizational concepts based on the Dutch EMS (2015), a few days before the interview. They will be asked to fill in the list of innovations they have implemented and return the list. The interviews will be about one hour and will be conducted at the specific business location. Analyzing the data should lead to enough insights to test the hypotheses and answer the research question.
The unit of research are companies, or business locations of a specific company, which are approach directly. So, if a company has more business locations, the others will not be taken into account. The unit of observation is the person who is interviewed or who has signed the survey.

3.2 Operationalization

The main variables will be operationalized in this section. The variables are operationalized based on the Dutch EMS (2015). Operationalization should lead to the generation of accurate quantitative data. The four interviews are structured in a logical manner by covering both types of innovation and handle the motives and implementation processes. Both technological process innovation and organizational process innovation will be operationalized based on the research of Ligthart et al., (2018). They operationalize technological process innovation as the amount of new advanced manufacturing technologies used within manufacturing companies. Organizational process innovation will be measured as the number of new organizational concepts used including HRM- practices such as appraisal interviews, flexible labor, and task integration (Ligthart et al., 2018). Table 1 shows the operationalization scheme. The interview protocol is attached in appendix A. The detailed questionnaire is attached in appendix B.

Table 1. Operationalization

Type variable	Variable name	Description of item	Min	Max	Measurement level	Question no.
Independent	Organizational process innovation	Number of implementations realized	0	18	Ratio	7
Independent	Technological process innovation	Number of implementations realized	0	23	Ratio	8.1
Dependent	Production costs	Development of production costs	0	7	Ordinal	12

3.3 Methodological reflection

Conducting a mixed method study results in an improved validity because of the fact that the research question is analyzed from different perspectives based on both quantitative and qualitative data. This cross validation also improves the reliability. The Dutch EMS (2015) is a valid database and has been used for many researches. The Dutch EMS (2015) consist of different themes. These themes are measured based upon different constructs. Organizational innovation is measured by 18 items as technological innovation is measured by 23 items. The intern consistency and reliability between the items is measured based on Cronbach's Alpha. The validity of both technological and organizational process innovations is guaranteed in this way. The qualitative part should be valid as well, because of the fact that four identic in-dept interviews will be held. The research method must ensure that research quality aspects are met. According to Bleijenbergh (2015), validity, reliability and generalization are the most important research quality aspects. If these aspects are realized in a proper way, the research quality improves in a significant way. If this research will be conducted by another individual, the same results have to be realized. Given this fact, the reliability is guaranteed. This research can be generalized to a certain high. Many different aspects like industry and size of the company are taken into account, so the research results cannot fully be generalized.

The quantitative data will be analyzed via SPSS. A regression analysis will be conducted in order to generate a proper analysis. By conducting a regression model, it is possible to analyze relationships between variables. The analysis is conducted with the ultimate goal of answering the research question.

3.4 Ethical aspects

Respondents will be asked for permission in order to record the interview, with the goal to generate a transcript and code the interview. The generated information and data will only be used for internal reasons and will not be published online. The respondents will receive their interview transcript. Names of respondents, as well as company names will not be covered in this research.

4. Quantitative research

4.1 Introduction

This chapter takes into account multiple aspects of the quantitative analysis. The quantitative data is based on the Dutch EMS (2015). First of all, the response data will be highlighted, where type of industry and firm size are important topics. The construction of the variables will be the second step of the analysis. It describes how the variables are constructed and whether they are acceptable. Afterwards, a univariate analysis will be executed. This analysis describes the statistics of the data which will be used. The next step is to execute a bivariate analysis where the relationship between variables will be analyzed and multicollinearity will be checked. The final part of the analysis will be a multivariate analysis, where a multiple linear regression analysis will be executed in order to test the formulated hypothesis. Due to COVID-19, it was not possible to conduct a proper qualitative research. Because of this, the quantitative research part has been extended with a two-way anova test, where two models will be highlighted. This chapter ends with a summarization of the quantitative research outcomes.

4.2 Response data

The analyzed data consist of 177 companies. The mode of firm size is 20 to 49 with a number of 74 companies. Table 2 shows that 62.7 percent of the companies have less than 49 employees. The normality histogram is showing a positive right sided skewness, with a value of .554, meaning that the database consists of more small than big companies. This is in line with a general overview of Dutch companies (CBS, 2020). The kurtosis value is -.166, which is between the normality values of -1 and 1. The variable firm size is normally distributed.

Table 2. Overview firm size

	Frequency	**Percentage**	**Valid percentage**	**Cumulative percentage**
Less than 20	37	20.9	20.9	20.9
20 to 49	74	41.8	41.8	62.7
50 to 99	43	24.3	24.3	87.0
100 to 249	19	10.7	10.7	97.7
250 or more	4	2.3	2.3	100.0
Total	**177**	**100.0**	**100.0**	

Another important aspect of the response data is the type of industry. Two of the respondents did not fill in their type of industry, which means that table 3 consists of 175 companies instead of the original 177. Most companies (37%) are part of the metal industry. Electrical and machinery are respectively number two and three. The construction category is least represented in this database.

Table 3. Overview industries

Industry	Frequency	Percentage
Metals and metal products	37	21.1
Food, beverages and Tobacco	18	10.3
Textiles, Leather, Paper and Board	22	12.6
Construction, Furniture	13	7.4
Chemicals (energy and non-energy)	22	12.6
Machinery, Equipment Transport	31	17.7
Electrical and Optical equipment	32	18.3

4.3 Variable construction

The dependent and independent variables will be described in the next paragraphs. Technological and organizational process innovations are the independent variables in this case. Production costs is the dependent variable in this analysis.

4.3.1 Organizational process innovation

The Dutch EMS (2015) database consist of 18 items which do measure organizational process innovations. The EMS database is attached and related question number three can be find in appendix B. To measure the intern consistency and reliability, Cronbach's Alpha will be analyzed. The independent variable organizational process innovation has a Cronbach's Alpha value of .800, which is according to Field (2013) an acceptable value if Cronbach's Alpha >.6. If Cronbach's Alpha raises with > .05 when deleting an item, that specific item should be deleted. In this specific case Cronbach's Alpha could be raised to .801 and .802 if these specific items are deleted. Based on the criteria of Field (2013), the item construction will not be adapted, because deleting that specific item does not increase Cronbach's Alpha with >.05. Detailed information about the Cronbach's Alpha and the value if items deleted, is attached in appendix C, table 1. Table 4 summarizes the Cronbach's Alpha of organizational process innovation.

Table 4. Cronbach's Alpha - organizational process innovation

Cronbach's Alpha	**Cronbach's Alpha based on standardized items**	**N items**
.800	.798	18

4.3.2 Technological process innovation

The variable technological process innovation is measured based on 23 items in the Dutch EMS (2015) database. Technological process innovation has a Cronbach's Alpha of .715, which is an acceptable value according to Field (2013). Analyzing the item total statistics, Cronbach's Alpha could be raised to .721 when the item 'technologies for generating energy/heat' will be deleted. Deleting that item would mean an improvement of Cronbach's Alpha by .06. Since the improvement is not much higher than .05, and deleting the item has a negative influence on the validity, it is decided to keep that item included in the analysis. Detailed information about the total item statistics can be find in appendix C, table 2. Table 5 shows the Cronbach's Alpha analysis for technological process innovation.

Table 5. Cronbach's Alpha - technological process innovation

Cronbach's Alpha	**Cronbach's Alpha based on standardized items**	**N of items**
.715	.722	23

4.3.3 Upgrades technological process innovation

Respondents are asked whether they have upgraded the specific technological process innovations since 2012. In this case, it is possible to investigate the effect of the implemented upgrades on the dependent variable. Furthermore, it could imply the willingness to innovate of the organization.

4.3.4. Sequentially innovation implementation

In order to test hypothesis 2, it is necessary to create a variable which takes into account the sequentially of organizational and technological process innovations implementation moments. The hypothesis argues that the effect of technological process innovation on production costs is stronger when organizational process innovations are implemented first. The variables ‘per firm mean value years passed until 2016 since organizational process innovations first used’ and ‘per firm mean value years passed until 2016 since technologies first used’ will be used in order to create a new variable. The mean number of years of organizational process innovations first used will be divided by the mean number of years of technological process innovations first used. All the outcomes above 1 means organizational process innovations are implemented earlier. Outcomes between 0 and 1 mean technological process innovations are implemented earlier.

4.3.5. Percentage change in production costs per unit.

Percentage change in production costs per unit is the dependent variable of this research. This variable is measured based on a 7-point Likert scale and it measures that percentage of change in production costs per unit in the year 2014. The operationalization of this variable is attached in the questionnaire in appendix B, question 12.

4.4 Univariate analysis

This section takes into account the different variables which are used in the analysis. It describes the mean, standard deviation, maximum score, minimum score and skewness and kurtosis of each variable separately. An overview is given in table 6.

Table 6. Summary univariate analysis

Variable	Mean	Mode	St. deviation	Min	Max	Skewness	Kurtosis
Number of organizational process innovation	8.01	8	3.85	0	18	.095	-.517
Number of technological process innovation	4.62	4	3.17	0	19	1.20	2.22
Number of upgrades Technological process innovation	3.31	3	3.05	0	19	1.58	4.14
Mean value years passed until 2016 since technologies first used	13.22	3	7.86	1	46	.972	1.352
Mean value years passed until 2016 since organizational practices first used	13.88	6	9.45	1	51	1.33	1.98
Change in production costs per unit	3.88	3	1.28	1	7	-.029	-.417

4.4.1 Number of organizational and technological process innovations

The mean number of organizational process innovations is 8.01 with a standard deviation of 3.85. This means that a lot of companies did not execute all of the potential organizational process innovations according to the Dutch EMS (2015) questionnaire. Even though the possible technological process innovations are higher than the possible organizational process innovations, the number of technological process innovations is lower. The mean number is 4.62 with a standard deviation of 3.17. Again, companies did not execute all innovation possibilities. As can be seen based on the minimum and maximum scores, some organizations did not even implement one of the possibilities according to the Dutch EMS (2015) questionnaire.

4.4.2 Technological process upgrades

The number of potential technological upgrades is obviously the same as the number of innovations on itself. However, the mean of upgrades is 1.31 lower than the technological innovations.

4.4.3 Sequentially implementation moment OPI-TPI

Analyzing the mean value years passed until 2016 since technologies first used, it can be seen that the average is 13.22 years before 2016 and the mode is 3. This indicates that some companies introduced the first technologies quite a long period ago, but most of them on average 3 years before 2016. Taking into account the mean value years passed until 2016 since organizational practices used, the mean value is 13.88. Comparing the mode of 6 with the mode of 3 related to new technologies, it can be stated that most of the companies introduced the organizational practices 3 years earlier than new technological innovations.

4.4.4 Percentage change in production costs

The dependent variable percentage change in production costs requires some more explanation and therefore the frequencies are showed in table 7. The mode of the variable is category 3, which indicates a decrease of 0-5% of the production costs. Furthermore, the table shows that 42.4% of the companies involved in the questionnaire decreased their production costs, 23.2% kept their level stable and even 34.5% of the companies saw their production costs increasing in the year 2014.

Table 7. Frequencies percentage change in production costs

	Frequency	**Percentage**	**Cumulative percentage**
< -10%	6	3.4	3.4
-10 to -5%	15	8.5	11.9
-5% to 0	54	30.5	42.4
Stable	41	23.2	65.5
0 to 5%	44	24.9	90.4
5% to 10%	15	8.5	98.9
> 10%	2	1.1	100.0

4.5 Bivariate analysis

This section analyzes the extent of multicollinearity between the variables. Hair, Black, Babin, and Anderson (2014) describe multicollinearity as the extent to which a variable can be explained by other variables in the analysis. So, multicollinearity exist when a dependent variable highly correlates with a set of other independent variables (Hair et al., 2014). If the independent variables are relating too much among each other, they do not provide unique information for the analysis. If the correlation increases, it means that the unique variance of that variable explained by other independent variables decreases. This indicates that the shared prediction percentage rises. Correlation values >.70 may result in problems concerning the bivariate analysis (Hair et al., 2014). Table 8 shows the correlation between de different variables.

Table 8. Correlation matrix

	1	2	3	4	5	6	7
1. Percentage change in production costs	1						
2. Organizational process innovations	-.251**	1					
3. Technological process innovations	-.060	.563**	1				
4. Number of technologies upgraded	-.063	.512**	.897**	1			
5. Mean value years passed until 2016 since organizational practices first used	.282**	-.122	-.005	-.026	1		
6. Mean value years passed until 2016 since technologies first used	.024	-.104	-.049	-.060	.150	1	
7. Firm Size	-.072	.504**	.490**	.400**	-.080	.039	1

**. Correlation is significant at the .01 level (2-tailed)

As can be seen in table 8, the dependent variable is not highly correlated with the independent variables. The table shows some significant correlations between the variables in this sample. There exists a negative significant relationship between organizational process innovations and percentage change in production costs with a Pearson R value of -.251. The correlation matrix does not show a significant correlation between technological process innovations and percentage change in production costs. Technological process innovations and organizational process innovations do correlate with a positive significant value of .563. The variable technological upgrades exceed the critical Pearson R value of .7. However, this is understandable because this variable only differs in a minor way and is an extension of the variable technological process innovations.

The results in the bivariate analysis already indicate some relations, before taking into account the multivariate analysis. Hypothesis 1 expects a significant relationship between technological process innovations and production costs. Table 8 shows that this relationship has a non-significant value of -.060 and does not support the statement of hypothesis 1.

Hypothesis 2 cannot be analyzed so far, because in order to test hypothesis 2, a new variable have to be computed based on variable five and six as showed in table 8.

4.6 Multivariate analysis

In order to analyze the relations between organizational and technological process innovations and the production costs, a multiple linear regression analysis will be conducted. By conducting a multiple linear regression analysis with technological and organizational process innovations as independent variables, it is possible to compare the relationship and to analyze the strength of both independent variables. The following hypotheses have been formulated:

Hypothesis 1: Technological process innovations have a stronger effect on production costs than organizational process innovations.

Hypothesis 2: The implementation of technological process innovations has a stronger effect on production costs when organizational process innovations are implemented first.

4.6.1 Regression assumptions

Before running a regression analysis, some assumptions have to be checked (Hair et al., 2014). The first assumption is the sample size. Each variable needs at least 20 observations in order to run the analysis. For this analysis, that means 60 observations are needed. As previously highlighted in point 4.2, there are 177 cases, which means the first assumption is met. The next step is the check for normality of the dependent variable. This assumption can be checked by analyzing the significance of Shapiro-Wilk. The 0-hypothesis states that the dependent variable is normally distributed. However, this case shows a significance level of .000, which indicates a non-normally distributed dependent variable. The assumption of normality is violated in this case. However, since the analysis consists of a larger sample than the required 60, it is still acceptable to continue the regression analysis, even though the dependent variable is not normally distributed.

Table 9. Test of normality

	Kolmogorov-smirnof			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Percent change in production costs	.177	177	.000	.938	177	.000

The next assumption is linearity between the independent and dependent variables.
It can be seen that these points are more or less falling the line. Although there are some deviations across the line, they generally do appear to fall the line (Appendix C, table 3).
The next step that have to be taken is to look at the scatterplot and analyze the regression standardized residual. The values have to be between negative three and three, either on the X-axis and the Y-axis. Looking at Appendix C, table 4, it can be seen that the residuals are acceptable because none of them is greater than minus three or greater than three.
Furthermore, the residual statistics show a standardized residual of -2.188 and 2.852. Based on these data, the assumption of homoscedasticity has been met. Cook's Distance is another aspect which have to be taken into account. The Cook's Distance test for outliers of the predictor variable and a value between 0 and 1 is desirable. In this case, there is a minimum value of .000 and a maximum value of .136, which indicates that the assumption of an acceptable Cook's Distance value has been met.

4.6.2 Regression analysis

Based on previous analyses it can be stated that the assumptions have been met and the data is appropriate in order to execute a regression analysis. The analysis consists of two parts, where both parts are analyzing respectively hypothesis 1 and hypothesis 2.

4.6.3 Regression analysis 1

An important aspect of the regression analysis is to determine whether the model is relevant and significant. When the F-value with significance level $\leq$.05, it can be concluded that the model is significant based on 95% reliability. According to table 10, it can be concluded that the model is significant based on 95% reliability (F=3.436 P=.01). Furthermore, the model consists of 4 degrees of freedom. Another aspect of the model summary is to interpret the Adjusted R Square. As can be seen in table 10, the Adjusted R square is .052, which indicates that 5.2% variance of the dependent variable is explained by the independent variables. It means that the remaining variance is explained by other independent variables.

Table 10. Regression analysis 1

		Production costs
Independent variables		B (SE)
1.	Organizational process innovations	-.110 (.031)**
2.	Technological process innovations	.053 (.072)
3.	Number of technologies upgraded	-.012 (.070)
4.	Firm Size	.054 (.115)
Model information		
F-value		3.436*
F-change		
R^2		.074
R^2 change		
Adjusted R Square		.052
N		177
Explanation	*P<.05, **P<.01	

Based on the analysis showed in table 10, it is possible to test hypothesis 1. The hypothesis is as follows:

Hypothesis 1: Technological process innovations have a stronger effect on production costs than organizational process innovations.

The first step of the test is to check whether both individual effects are significant. Table 10 shows a negative significant effect for organizational process innovations (B=-.110, P=.001). However, the model shows a non-significant effect of technological process innovations on production costs (B=0.53, P=.460). There is no significant relationship between technological process innovations and production costs. The first hypothesis is rejected based on these data and with an exceedance probability of 5%.

The analysis shows some more interesting results. It can be concluded that organizational process innovations have a significant value (B=-.110, P=.001) on production costs. This means that for every unit of organizational innovations increasing, the production costs are decreasing by .110. Another interesting finding is the fact that the upgrades of technological process innovations do not have a significant impact on the production costs. The upgrades have a non-significant (B=-.012, P=.865) value.

4.6.4 Regression analysis 2

The second analysis tests the sequentially of implementation moments of the innovations. Before running the analysis, the way of constructing the specific moderator variable has to be explained more in detail. The 'mean value years passed until 2016 since organizational innovations first used' is divided by 'mean value years passed until 2016 since technological innovations first used'. This variable is centralized afterwards by subtracting the mean value of 1.4108. All the outcomes above 1 means organizational process innovations are implemented earlier. Outcomes between 0 and 1 mean technological process innovations are implemented earlier.

The analysis consists of 2 models. The first model includes variables which separately takes into account the mean value years of implementation for both types of innovations and their relationship with production costs. In the second model, the proportional difference between the duration that organizational and technological innovations have been introduced is added. This makes it possible to see whether the extent to which they interact over time adds anything to the first model.

The first step of the analysis is to conclude whether the model is relevant and significant. It can be concluded that both model 1 (F=4.337, P=.001) and model 2 (F=3.644, P=.002) are significant and thus relevant to interpret. Model 1 consist of 5 degrees of freedom and model 2 consists of 6 degrees of freedom. As can be seen in table 11, the Adjusted R square of model 1 is .093, which means that 9.3% variance of the dependent variable is explained by the independent variables. Taking into account model 2, the explained variance of the dependent variable is 8.3%. For both models it means that the remaining variance is explained by other independent variables.

Table 11. Regression analysis 2

		Production costs	
		Model 1	**Model 2**
Independent variables		b (SE)	b (SE)
1.	Organizational process innovations	-.093 (.033)**	-.093 (.033)**
2.	Technological process innovations	.036 (.038)	.039 (.039)
3.	Per firm mean value years passed until 2016 since organizational practices first used	.034 (.010)**	.028 (.015)
4.	Per firm mean value years passed until 2016 since technologies first used	-.005 (.012)	.002 (.018)
5.	Firm Size	.054 (.115)	.095 (.116)
6.	Sequentially implementation moments OPI-TPI	-	.070 (.132)
Model information			
F-value		4.337**	3.644**
F-change			.276
R^2		.121	.122
R^2 change			.002
Adjusted R Square		.093	.083
N		164	164
Explanation	*P<.05, **P<.01		

The results of model 1 will be analyzed before model 2 and the second hypothesis will be interpreted. The number of years passed until 2016 since organizational practices first used has a positive significant (B=.034, P=.001) value. This means that the longer ago organizational practices are implemented, the more the production costs are increasing. At the same time, the mean value of years passed until 2016 since technologies first used does not have a significant impact on the production costs.

In order to test the second hypothesis, model 2 of table 11 will be analyzed. As explained before, the proportional difference between the duration that organizational and technological innovations have been introduced, is added. This makes it possible to see whether the extent to which they interact over time adds anything to the first model. The information showed in model 11 makes it possible to test hypothesis 2. The second hypothesis is as follows:

Hypothesis 2: The implementation of technological process innovations has a stronger effect on production costs when organizational process innovations are implemented first.

Table 11 shows a non-significant effect (B=.070, P=.600) of the sequentially of implementation moments on production costs. There is no significant relationship between sequentially implementation moment and production costs. The interaction does not show any significant impact on the relation with production costs. Based on these data, the second hypothesis is rejected with an exceedance probability of 5%.

4.7 Two-way ANOVA

A two-way anova test with two different models will be carried out in order to analyze the previous results in more detail. The aim of the analysis is to detect potential differences between different groups. In the case of significant differences between groups, a post hoc test will be deducted to further explain these differences.

The goal of the analysis is to investigate whether there are differences between types of industry and groups of firm size in relation to the percentage change in production costs, under the condition that organizational and technological process innovations are implemented. The analysis will be divided into two different models. In order to execute this analysis, some new variables have to be computed. Table 12 and table 13 show the different groups which will be investigated in order to detect potential differences between these groups.

Table 12. Firm size

	Frequency	Percentage	Valid percentage	Cumulative percentage
Less than 20	37	20.9	20.9	20.9
20 to 49	74	41.8	41.8	62.7
50 to 99	43	24.3	24.3	87.0
100 to 249	19	10.7	10.7	97.7
250 or more	4	2.3	2.3	100.0
Total	**177**	**100.0**	**100.0**	

Table 13. Type of industry

Industry	Frequency	Percentage
Metals and metal products	37	21.1
Food, beverages and Tobacco	18	10.3
Textiles, Leather, Paper and Board	22	12.6
Construction, Furniture	13	7.4
Chemicals (energy and non-energy)	22	12.6
Machinery, Equipment Transport	31	17.7
Electrical and Optical equipment	32	18.3

4.7.1 Variable construction

First of all, the variables ‘firm size’, 'organizational process innovation’ and ‘technological process innovations’ are mean centered in order to reduce multicollinearity. The variable ‘industry’ is categorial and will therefore not be mean centered. The analysis will consist of two models, where model 1 takes into account ‘firm size’ and model 2 takes into account ‘type of industry’.

4.7.2 Model 1

Model 1 measures whether there are differences between groups of firm size in relation to percentage change in production costs, under the condition that organizational and technological process innovations are implemented. Therefore, two new independent variables are computed, which will be named as ‘Size*OPI’ and ‘Size*TPI’.
Size*OPI measures if there are differences between groups of firm size under the condition that organizational process innovations are implemented. Size*TPI measures if there are differences between groups of firm size under the condition that technological process innovations are implemented. The variables are constructed in the following way: The variable Size*OPI is constructed as ‘mean centered firm size’ multiplied by ‘mean centered organizational process innovations’. The variable Size*TPI is constructed as ‘mean centered firm size’ multiplied by ‘mean centered technological process innovations’. ‘Percentage change in production costs’ is the dependent variable in the two-way anova test.

First part of the analysis is the interpretation of the Levene’s Test. The Levene’s test measures the homogeneity of variances. The 0-hypothesis states that the error variance of the dependent variable is equal across groups. According to the data, the 0-hypothesis is rejected (F=4.583, p=.000). The model consists of 26 degrees of freedom. According to these data, the assumption of homogeneity of variances is violated. It means that the error variance of the dependent variable is not equal across groups. It could be seen as a limitation, however, it is not a reason to stop the analysis.

Table 14 shows whether there are differences between the groups of firm size in relation to the percentage change in production costs. The variable Firmsize*OPI has a non-significant (F=1.506, P=.102) value. The variable Firmsize*TPI also shows a non-significant (F=.783, P=.766) difference between the groups. Furthermore, the interaction effect shows a non-significant (F=.992, P=.517) difference between groups under the condition that both technological and organizational process innovations are implemented.

According to these analyses, it can be concluded that there are no significant differences between different groups of firm size in relation to percentage change in production costs. Due to the fact of no significant differences, no post-hoc test will be conducted. Table 14 shows the results and the complete output is attached in appendix C, table 6.

Table 14. Test of between - subjects effects

	DF	F	Significance
Firmsize*OPI	44	1.506	.102
Firmsize*TPI	35	.783	.766
Firmsize*TPI*Firmsize*OPI	53	.992	.517

4.7.3 Model 2

Model 2 measures whether there are differences between type of industry on percentage change in production costs, under the condition that organizational and technological process innovations are implemented. The variables are computed in a similar way as model 1. The two new independent variables will be named as 'Industry*OPI' and 'Industry*TPI. Industry*OPI measures if there are differences between type of industry under the condition that organizational process innovations are implemented. Industry*TPI measures if there are differences between type of industry under the condition that technological process innovations are implemented. Industry*OPI is constructed as 'industry' multiplied by 'mean centered organizational process innovations'. Industry*TPI is constructed as 'industry' multiplied by 'mean centered technological process innovations'. 'Percentage change in production costs' is the dependent variable in the two-way anova test.

The analysis starts with the interpretation of the Levene's Test. The 0-hypothesis states that the error variance of the dependent variable is equal across groups. According to the analysis, the 0-hypothesis is rejected (F=7.327, P=.000). The model consists of 19 degrees of freedom. Again, the assumption of homogeneity of variances is violated, but not a reason to stop the analysis.

The variable Industry*OPI shows a non-significant (F=.959, P=.570) difference between the groups. The variable Industry*TPI also shows a non-significant (F=.767, P=776) difference. Furthermore, the interaction affect is also non-significant (F=.559, P=.910). So, the situation where both technological and organizational process innovations are implemented, does not lead to any significant differences between different groups of industry. It can be concluded that no differences exist between the different industries and the relation with percentage change in production costs. Based on these findings, no post hoc test will be executed. Table 15 shows the results of the analysis and the complete output is attached in appendix C, table 7.

Table 15. Test of between - subjects effects

	DF	F	Significance
Industry*OPI	62	.959	.570
Industry*TPI	43	.767	.776
Industry*TPI*Industry*OPI	22	.559	.910

4.8 Outcomes

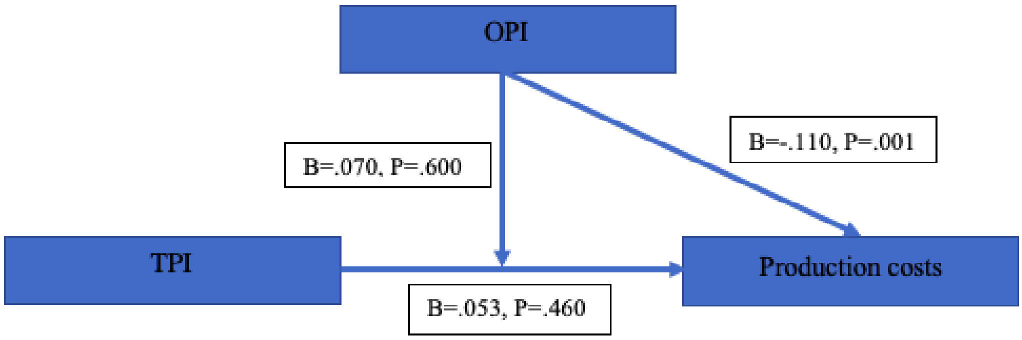

Figure 2. Tested and validated conceptual model

The results section has given insights in the different topics of this research. It has given insights about the formulated hypotheses and made it possible to test both of them with use of a regression analysis. Based on these results both hypotheses have been rejected. The figure above shows the tested and validated conceptual model once again. Because of the fact that both hypotheses showing a non-significant relationship, it is not possible to conclude whether they are positive or negative. The correlation between organizational process innovations and technological process innovation has a value of .563**. This indicates a strong relationship between the independent variables. It can be concluded that organizational process innovations have an impact on production costs while technological process innovations do not have a significant impact on production costs. Furthermore, the mean value of years since organizational practices are implemented shows a positive significant effect on production costs. It means that if the mean value of years since implementation increases, the production costs are increasing as well. The mean value of years since technologies are implemented does not show any significant effect on production costs. Besides that, the interaction between organizational and technological process innovations on production costs does not show a significant impact. Furthermore, the results of the two-way anova test do not show any significant differences between different types of industry and different firm sizes on production costs under the condition that organizational and technological process innovations are implemented.

5. Conclusion

This concluding chapter consists of a summarization of the theory, a summarization of the methodology and finally, the main research question will be answered in the coming paragraphs.

The theoretical framework explained the concept innovation and more in detail the differences between organizational process and technological process innovation. There is consensus about the fact that innovations are important in order to reach a competitive advantage. Organizational process innovations require changes in structures because new managerial practices will be implemented. An organizational innovation is something new to the organization. Technological process innovations could lead to lower disposal costs, increased resource productivity and have a positive impact on production costs. A balanced rate of adoption of organizational and technological innovation is more effective in helping organizations to maintain or improve their level of performance than either organizational or technological innovations alone. By integrating both types of innovation, it is possible to generate a competitive advantage. Scientific literature suggests some sort of sequence in which the innovations should be implemented. It is said that organizational process innovations act as prerequisites and facilitators of technological process innovations. The success and effect will be greater when both types of innovations are implemented together.

The Dutch EMS (2015) database is used in order to conduct a quantitative analysis. The questionnaire filled in by 177 companies made it possible to execute a multiple linear regression analysis in order to test the hypotheses and to answer the main research question. The central research question which has been investigated is the following: What is the effect of technological process and/or organizational process innovations on the production costs of companies in the manufacturing industry?

It can be concluded that organizational process innovations have a significant positive effect on production costs of companies in the manufacturing industry. Implementing organizational process innovations leads to a decrease of production costs. Based on the analysis it can also be concluded that technological process innovations and eventual technological upgrades of the innovations do not have an effect on production costs of companies in the manufacturing industry. Finally, the results of the two-way anova test did not show any significant differences between different types of industry and different firm sizes on production costs.

6. Discussion

This study is executed as a quantitative study. De validity concerning the quantitative analysis is acceptable. The constructs are measured based on different items. By repeating this quantitative analysis, the same results will be realized.

Goal of the research was to specify the outcomes of organizational and technological process innovations and to contribute to the cost part of the productivity paradox. The productivity paradox covers the rapid increase in IT and the simultaneous slowdown in productivity. It can be concluded that technological process innovations do not have a significant impact on the production costs and thus are some sort of relating to the field of productivity, because as increased productivity is expected, so are decreased production costs expected when technological innovations are implemented. The implementation of new technologies does not contribute to a decrease in production costs.

It is somehow remarkable that both of the formulated hypotheses have been rejected. There is an enormous stream of literature which argues that technological process innovations have a positive influence on the production processes, on the disposal costs and on the production costs. New technologies should lead to better production techniques and a cheaper use of material. These statements are completely contradicted by the quantitative analysis. More evidence has been found during literature research for the statement that technological innovations have more influence on production costs than organizational innovations. A potential statement for this research outcome could be that technological process innovations do have an impact on other organizational performance aspects rather than on production costs. Nevertheless, there was another stream of literature that argues that organizational process innovations on itself already have an impact on the production costs. The quantitative analysis supports this statement because of the fact that a significant relationship between organizational process innovations and production costs have been found. This finding indicates that companies should invest in organizational process innovations when they have the financial means and possibilities, if they want to decrease their production costs. The second hypothesis argues that the effect of technological process innovations on production costs is greater when organizational implementations are implemented first. The hypothesis is based on a stream of literature which has obvious and very strong arguments for this statement. Nevertheless, the hypothesis has been rejected based on the quantitative analysis. One of the reasons for this conclusion could be the fact that technological process innovations on itself do not have an impact on production costs and that the situation where organizational innovations are implemented first does not create any difference in that case. Another explanation could be that there is not much consistence between the implementation moments and that innovations are implemented on their own. It could also be the case that there is no interaction effect at all, which means that the mutual coherence does not have an effect on production costs.

Another minor aspect of the analysis was the impact of technological upgrades on production costs. Since the technological process innovations on itself do not have a significant impact on production costs, it is a logical finding that the upgrades do have a non-significant impact as well. This might be in contradiction to what can be expected, because new technologies/new upgrades usually lead to better production techniques.

The two-way anova test did not show any significant differences between different types of industry and different groups of firm size on production costs. Based on these findings, it can be stated that the effect of technological and organizational process innovations is comparable in different industries. Furthermore, the results of both types of innovations are not better in companies with more employees than companies with less employees, or the other way around.

Recommendations

The research results have resulted in some interesting suggestions for future research. There has been a difference between the literature and the findings of this research as explained earlier. These differences are reasons for future research. It is interesting to investigate and could lead to practical insights for companies if the reasons are clear why these differences exist. Since the fact the technological process innovations do not have an impact on production costs, it is interesting to investigate the effect of technological implementations on other aspects of organizational performance.

Technological upgrades should be investigated more in detail. It is interesting to see what the overall effect is of the implemented upgrades. As said before, it does not have an impact on production costs. Possible reasons for technological upgrades are quality improvements or filling customers' needs. This aspect could be taken into account more in detail in future research.

Theoretical limitations

This study investigated the relationship between technological and organizational process innovations and production costs. This study would have had more theoretical depth if technological product innovations were included. It could have given other relevant insights in the field of innovation and the relationship with production costs.

Another theoretical aspect is that the productivity paradox could have been explained in more detail with more theoretical and practical examples. The role of the productivity paradox in the context of this thesis might be underexposed and could have had a more central role. A more detailed relation between the research results and the productivity paradox could have been described.

Practical limitations

The initial plan and strategy of this research was to conduct a mixed method study, which implies both a quantitative and qualitative data analysis. However, due to COVID-19 and related uncertainties, it was not possible to conduct a proper qualitative analysis. Because of safety issues and time pressure, companies were unwilling to cooperate and to conduct an interview. Due to these unforeseen circumstances, it has been decided to skip the qualitative part and to focus on the quantitative analysis. However, the quantitative research part has been extended with the two-way anova test in order to analyze the results in more detail. The interview results would have made it possible to compare the quantitative and qualitative outcomes with each other and analyze the similarities and differences. Unfortunately, these unforeseen circumstances had a negative impact on the overall quality of this research. A mixed method study would have made it possible to realize triangulation and it would have improved the validity and reliability. The research results are difficult to generalize. The interviews would have given insights which would have made it more possible to generalize the results.

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Appendix A, Interview protocol

Introductie, 3 minuten

- Menno Jansen, student Radboud Universiteit.
- Doel van dit onderzoek is meer inzicht verkrijgen in uitkomsten van innovaties bij bedrijven in de maakindustrie.
- Aanleiding is dat dit van cruciaal belang kan zijn bij implementeren nieuwe innovaties.
- Volledig neutraal, alleen voor scriptie, bedrijf X

Oriënterende vragen over de respondent, het bedrijf, 5 minuten

- Wat is uw functie binnen het bedrijf?
- Wat zijn uw voornaamste activiteiten?
- Kunt u iets vertellen over de kenmerken van uw bedrijf?
    - Grootte
    - Corebusiness
    - Aanvullende diensten

- Wat is het doel van het bedrijf de komende 5 jaar?
- Op welke markten zijn jullie actief?
- Wat onderscheidt jullie van andere bedrijven?
- Op welke manieren bent u betrokken bij innovatie activiteiten in uw bedrijf?
    - Productieprocessen

Technologische proces innovatie, 20 minuten

- Uitleggen wat dit onderwerp inhoudt
- Voor mij heb ik de lijst die u heeft ingevuld wat betreft het aantal machines, installaties en instrumenten die zijn gerealiseerd binnen uw organisatie.

Heeft u in de voorbije drie jaar voor uw bedrijf nieuwe machines, installaties of instrumenten in gebruik genomen of bent u nieuwe technieken gaan toepassen? Zo ja, welke? Welke technieken hebben een update ondergaan?

- Wat vormt vooral de aanleiding tot het invoeren van deze verandering?
  - Vanwege de markt?
  - Vanwege leveranciers?
  - Suggesties uitvoerend personeel?
  - Vanwege concurrentie?
  - Vanwege de kosten?
- Wat is het ultieme doel van deze vernieuwingen?
- Hoe worden deze vernieuwingen geïmplementeerd?
  - Kunt u dit proces beschrijven?
  - Welke afdelingen zijn erbij betrokken?
  - Wie neemt het definitieve besluit?
  - Externe partners?

1. *Onze investeringen in de voorbije jaren in nieuwe machines, installaties of technologieën hebben geresulteerd in grotere productiecapaciteit.*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

2. *Onze investeringen in de voorbije jaren in nieuwe machines, installaties of technologieën hebben ons bedrijf grote kostenbesparingen opgeleverd.*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

3. *Het realiseren van een kostenbesparingen is het voornaamste doel van de nieuwe machines, installaties of technologieën.*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

4. *Onze investeringen in de voorbije jaren in nieuwe machines, installaties of technologieën hebben ons bedrijf de gewenste resultaten opgeleverd.*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

Scenario B, geen kostenbesparing gerealiseerd

In het geval deze vernieuwingen niet tot kostenbesparingen hebben geleid;

- Wat is daarvan volgens u de reden?
- Ligt het aan de machine, installatie, technologie, of aan manier van implementeren?
- Waren de medewerkers (nog) niet gereed om dit te realiseren?
- Was de organisatie (nog) niet gereed om dit te realiseren?
- Wat gaat u eraan doen om te zorgen dat implementatie wel tot kostenbesparing leidt?

Organisatorische proces innovatie, 20 minuten

- Zoals ik in het begin van dit interview al zei wil ik het graag hebben over twee soorten innovatie. De tweede soort is organisatorische proces innovatie.
  - Verandering werkprocessen
  - Decentralisatieplanning
  - Taakuitbreidingen
  - Kwaliteitsmanagement
- Welke vernieuwing/verbeteringen zijn er in de afgelopen tijd doorgevoerd in de werkprocessen in uw bedrijf? Daarbij kunt u denken aan het veranderen van taken/functies, het standaardiseren van procedures of veranderingen in het management.
- Wat vormt vooral de aanleiding voor deze innovaties?
- Wat is het doel van deze innovatie?
- Hoe worden deze innovaties geïmplementeerd?
  - Kunt u dit proces beschrijven?
  - Welke afdelingen zijn daar vooral bij betrokken?
  - Suggesties uitvoerend personeel?

- Worden er externe partijen betrokken bij het vernieuwen?

1. *Onze investeringen in de voorbije jaren in nieuwe organisatie hebben geresulteerd in een grotere productiecapaciteit.*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

2. *Onze investeringen in de voorbije jaren in nieuwe organisatie hebben ons bedrijf grote kostenbesparing opgeleverd.*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

3. *Kostenbesparingen is het voornaamste doel van de vernieuwingen in de werkprocessen in uw bedrijf.*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

4. *Onze investeringen in de voorbije jaren in nieuwe organisatie concepten hebben ons bedrijf de gewenste resultaten opgeleverd.*

   In welke mate bent hu het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

Scenario B, geen kostenbesparing gerealiseerd

In het geval deze vernieuwingen niet tot kostenbesparingen hebben geleid;

- Wat is daarvan volgens u de reden?
- Ligt het aan de complexiteit van de nieuwe werkconcepten?
- Waren de werknemers (nog) niet gereed om dit te realiseren?
- Was de organisatie (nog) niet gereed om dit te realiseren?
- Wat gaat u eraan doen om te zorgen dat implementatie wel tot kostenbesparing leidt?

Synergetische voordelen, 10 minuten

- Op het moment dat u een technologische proces innovatie implementeert, houdt u dan rekening met de organisatorische veranderingen die het met zich mee brengt? Een implementatie van een nieuwe machine kan bijvoorbeeld structuur aanpassingen vereisen voor succesvolle implementatie.
    - Zo ja, in welke volgorde gebeurt dit?
- Bent u zich altijd bewust van de 'gevolgen' van een technologische implementatie?
- Kunt u iets vertellen over de effectiviteit van beide soorten innovaties?
    - Wat als ze gecombineerd worden?

1. *Ook zonder deze aanpassingen van onze organisatie en medewerkers zouden onze investeringen in nieuwe machines, installaties of technologieën ons grote kostenbesparingen hebben opgeleverd.*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

2. *Organisatorische proces innovaties zijn van even groot belang als technologische proces innovaties voor het realiseren van een kostenbesparing*

   In welke mate bent u het eens met deze stelling (1 = volledig oneens; 7 = volledig mee eens).

Afsluiting, 2 minuten

- Hartelijk bedankt
- Anoniem
- Interesse in eindproduct?

Appendix B, Dutch EMS (2015) questionnaire

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 verschilllende 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

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

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
☐	☐	☐	☐	☐	☐	☐

Appendix C, Quantitative analyze models

Table 1. Item-total statistics organizational process innovation

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Method of 5S	7.5706	13.030	.428	.787
Standardized and detailed working instruction	7.2090	13.291	.461	.786
Integration of tasks (planning, operating or controlling functions with the machine operator)	7.2542	13.395	.388	.790
Method of Value Stream Mapping/Design	7.4463	12.953	.450	.786
Customer- or product-oriented lines/cells in the factory	7.4520	13.579	.268	.798
Production controlling by pull principles	7.4237	13.121	.404	.789
Method for optimizing of change-over time	7.7627	13.318	.417	.788
Visual Management	7.5537	12.862	.475	.784
Methods of assuring quality in production	7.3446	12.898	.496	.783
Methods of operation management for mathematical analyses of production	7.8079	13.236	.488	.784
Methods of continuous improvement of production processes	7.4350	12.554	.572	.777

Certified energy management system	7.9379	14.354	.207	.799
Instruments of life-cycle assessment	7.8983	14.069	.278	.796
Impact and performance measurements of social and environmental corporate activities	7.6554	13.079	.435	.787
Instruments to maintain elderly employees or their knowledge in the factory	7.5141	13.501	.288	.797
Instruments for promoting staff commitment	7.3051	13.884	.210	.801
Standardized methods of job design for improving health or safety conditions at work	7.7910	13.541	.364	.791
Broad-based employee financial participation schemes	7.7345	13.957	.197	.802

Table 2. Item-total statistics technological process innovation

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Industrial robots for manufacturing processes	4.2542	8.895	.311	.702
Industrial robots for handling processes	4.3785	8.998	.329	.700

Control system for shut down of machines in off-peak periods	4.5537	9.703	.173	.712
Control-automation systems for an energy efficient production	4.5254	9.285	.373	.700
Technologies for recuperation of kinetic and process energy	4.3842	9.442	.154	.716
Manufacturing technologies for micromechanical and microelectrical components	4.5763	9.700	.233	.710
Technologies for generation energy\ heat	4.5311	9.887	.033	.721
Nano-technological production processes	4.5537	9.510	.304	.705
Processing techniques for composite materials	4.5254	9.785	.086	.718
Biotechnology / genetic engineering methods	4.6045	9.809	.305	.711
Processing techniques for alloy construction materials	4.4407	9.396	.206	.711
Additive manufacturing technologies for prototyping	4.4181	9.154	.293	.704
Additive manufacturing technologies for mass production	4.3842	9.340	.194	.713
System for Machine2Machine communication	4.4633	9.102	.363	.698

Software for production planning and scheduling	3.8757	9.269	.209	.712
Near real-time production control system	4.2712	8.676	.398	.693
Systems for Cyber-Physical systems, cloud-computing	4.4802	9.319	.279	.705
Digital Exchange of product/process data with suppliers / customers	4.2881	8.729	.385	.694
Systems for automation and management of internal logistics	4.3503	9.024	.301	.703
Mobile/wireless devices for programming and operation	4.4633	9.409	.218	.710
Product-Lifecycle-Management-System	4.4633	9.148	.341	.700
Technologies for safe human-machine interaction	4.5028	9.342	.298	.704
Digital solutions for providing drawings, work schedules or work instructions directly on the shopfloor	4.2599	8.705	.384	.695

Table 3. Normal probability plot

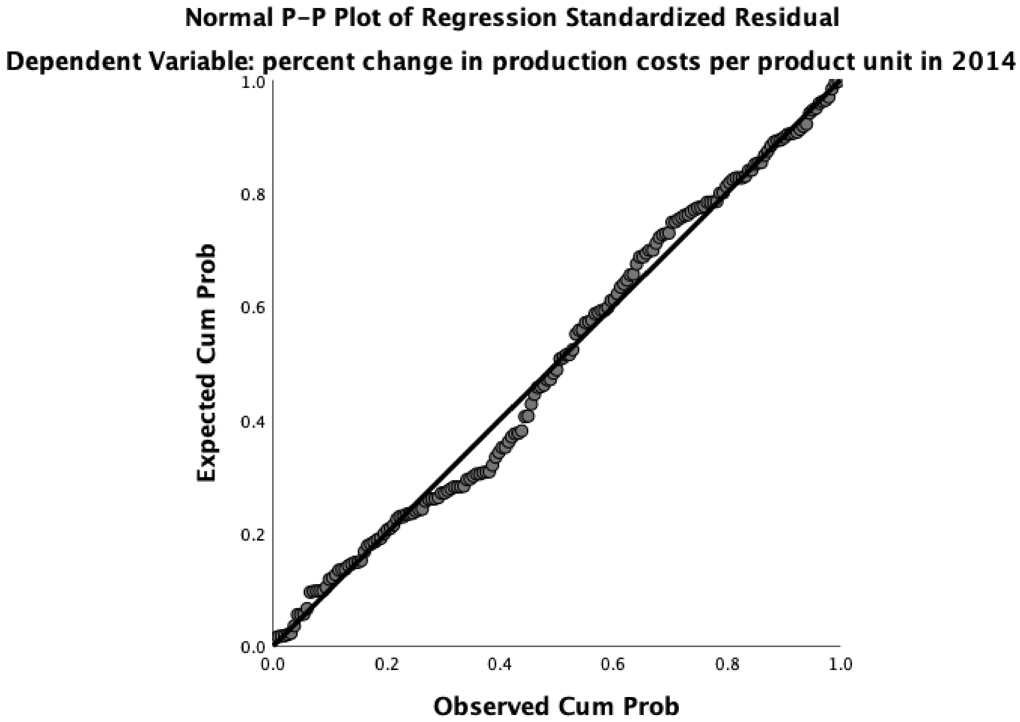

Table 4. Scatterplot

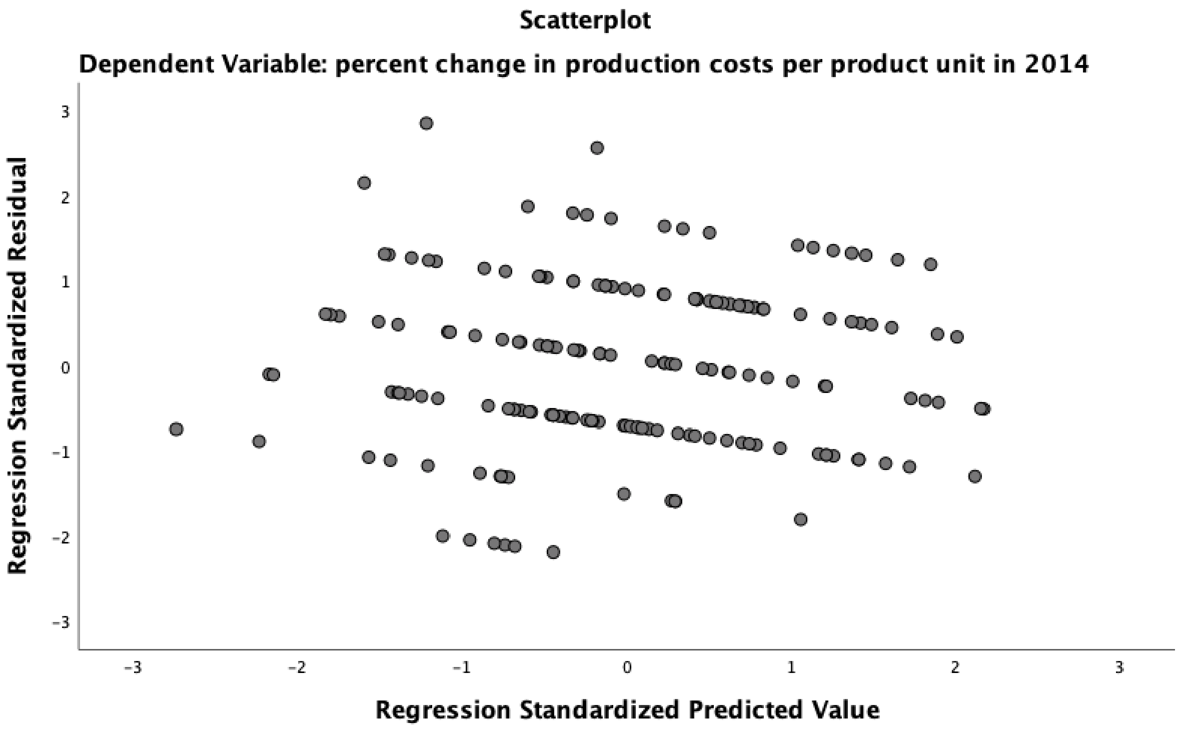

Table 5. Residual Statistics

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	2.9237	4.6300	3.8757	.34753	177
Std. Predicted Value	-2.739	2.171	.000	1.000	177
Standard Error of Predicted Value	.100	.504	.199	.063	177
Adjusted Predicted Value	2.9906	4.6923	3.8768	.35060	177
Residual	-2.72096	3.54729	.00000	1.22939	177
Std. Residual	-2.188	2.852	.000	.989	177
Stud. Residual	-2.209	2.961	.000	1.003	177
Deleted Residual	-2.77365	3.82204	-.00113	1.26457	177
Stud. Deleted Residual	-2.235	3.030	.000	1.008	177
Mahal. Distance	.136	27.970	3.977	3.565	177
Cook's Distance	.000	.136	.006	.012	177
Centered Leverage Value	.001	.159	.023	.020	177

a. Dependent Variable: percent change in production costs per product unit in 2014

Table 6. Anova model 1

Tests of Between-Subjects Effects

Dependent Variable: vnl12a percent change in production costs per product unit in 2014

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	232.682[a]	139	1.674	1.135	.335	.810
Intercept	1380.344	1	1380.344	935.683	.000	.962
Firmsize_cen_OPI_cen	97.732	44	2.221	1.506	.102	.642
Firmsize_cen_TPI_cen	40.406	35	1.154	.783	.766	.425
vSize5c	.000	0	.	.	.	.000
Firmsize_cen_OPI_cen * Firmsize_cen_TPI_cen	77.586	53	1.464	.992	.517	.587

Firmsize_cen_OPI_cen * vSize5c	.000	0	.	.	.	.000
Firmsize_cen_TPI_cen * vSize5c	.000	0	.	.	.	.000
Firmsize_cen_OPI_cen * Firmsize_cen_TPI_cen * vSize5c	.000	0	.	.	.	.000
Error	54.583	37	1.475			
Total	2946.000	177				
Corrected Total	287.266	176				

a. R Squared = .810 (Adjusted R Squared = .096)

Table 7. Anova model 2

Tests of Between-Subjects Effects

Dependent Variable: vnl12a percent change in production costs per product unit in 2014

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	243.042[a]	152	1.599	.844	.730	.854
Intercept	1890.324	1	1890.324	998.091	.000	.978
Industry_OPI_cen	112.590	62	1.816	.959	.570	.730
Industry_TPI_cen	62.492	43	1.453	.767	.776	.600
vIndustry	.000	0	.	.	.	.000
Industry_OPI_cen * Industry_TPI_cen	23.280	22	1.058	.559	.910	.358
Industry_OPI_cen * vIndustry	.000	0	.	.	.	.000
Industry_TPI_cen * vIndustry	.000	0	.	.	.	.000
Industry_OPI_cen * Industry_TPI_cen * vIndustry	.000	0	.	.	.	.000
Error	41.667	22	1.894			
Total	2896.000	175				
Corrected Total	284.709	174				

a. R Squared = .854 (Adjusted R Squared = -.157)