Competitors: rival or your best friend?

Mixed method research about collaborations within the Dutch manufacturing industry

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Abstract

The aim of this research is to gain more insight into how the digitalization of the manufacturing industry and a firm's innovation strategy affect inter-firm collaborations and whether or not both change the nature of the required and desired cooperation. Digitalization offers opportunities to increase the efficiency and the productivity of the manufacturing process and expand existing product portfolios with digital solutions to maximize customer value. If firms lack capabilities to keep up with the digital production changes or lack innovativeness, firms might need to look beyond their organizational boundaries and evaluate how the resources and abilities of external parties can be exploited to improve their own production process. The digitalization and innovation might increase the need to collaborate and force firms to find new collaboration partners, even considering competitors as potential co-workers. Both quantitative and qualitative data were gathered and analyzed to find out how digitalization and innovation influence inter-firm collaborations. The findings of the analyses conclude that digitalization does have a partial influence on inter-firm collaborations as it supports and stimulates the collaboration process, but it does not change the need to collaborate. Besides, a lack of consistency in the results of the analyses made it impossible to confirm a relationship between the innovative behavior of a company and the need to collaborate. In addition, both digitalization and innovation did not create a need to collaborate with competitors, as the lack of trust was too much of a barrier. The research made some theoretical and practical implications that are beneficial for manufacturing firms, but it also had a number of limitations that demonstrated the need for future research to find in-depth and comprehensive information that could lead to more generalizable conclusions.

Keywords: Inter-firm collaborations, digitalization, innovation, coopetition

Preface

This report is the final part of my master's Business Administration with a specialization of Strategic Management at Radboud University. This product is the result of several months of reviewing literature, gathering quantitative and qualitative data, analyzing the results, and finally making conclusions regarding all three of the constructs.

Due to the Coronavirus pandemic we all had to adapt to the quarantine measures. However, with some patience, creativity, and support from my supervisor and fellow students, I still managed to finish my master thesis from home.

First of all, I want to thank my supervisor P.E.M. Ligthart for helping me to come up with an interesting and achievable research question, guiding me in the right direction, and assisting me during the quantitative analyses. By providing useful feedback and answering my questions he helped me to move forward and carry out this research. I also want to thank the employees of the manufacturing companies that wanted to cooperate with this research and made some time for me to conduct interviews. Without their help and the information they provided, I would not have been able to conduct this investigation. Their opinions, explanations, and examples were of major importance. Finally, I would also like to thank my family, friends, and fellow students for supporting me through tough times and helping me with my thesis.

I wish everyone a pleasure reading my master thesis.

Fleur Schakel
Nijmegen, 19 August 2020

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Chapter 1 - Introduction

1.1 Introduction research topic

The transformation of the manufacturing industry towards a more digitalized environment is creating a paradoxical dilemma between businesses that are operating in the same market. Firms, on the one hand, are trying to create a competitive advantage over competitors. This can be realized by either obtaining an advantageous position in an industry or by mobilizing and deploying core competencies to offer superior products to customers relative to competitors (Porter, 1985; Prahalad & Hamel, 1990). However, success in today's business world frequently requires that firms pursue both competitive and cooperative strategies simultaneously (Lado, Boyd, & Hanlon, 1997). Cooperative strategies pursue strategic cooperation agreements with the goal of obtaining mutual benefits (Quintana-García & Benavides-Velasco, 2004). So instead of viewing competitors only as rivals, they could also be seen as potential collaboration partners, forcing manufacturing companies to rethink their competitive approaches. This form of horizontal inter-firm collaboration, in which firms simultaneously cooperate and compete, is also known as co-opetition. It enables firms to develop and create new technological knowledge and to stay innovative (Gnyawali & Park, 2011).

The latter is crucial for companies to survive in this changing market and anticipate changing customer demand. Innovation is widely regarded as a critical source of competitive advantage in an increasingly changing environment (Dess & Picken, 2000; Tushman & O'Reilly, 1996). According to Rachinger, Rauter, Müller, Vorraber, and Schirgi (2019, p. 1143), the digitalization has put pressure on companies to reflect on their current innovation strategy and explore new business opportunities systematically and at early stages. The innovation strategy is defined by Lendel and Varmus (2011, p. 819) as: *"The innovative direction of company approach to the choice of objectives, methods and ways to fully utilize and develop the innovative potential of the enterprise."* In recent years, academics started to accentuate the notion that corporations should include outside innovation within their innovation strategy. According to Enkel, Gassmann, and Chesbrough (2009), collaboration with external parties is a core initiative to increase innovativeness. These inter-organizational relationships have become progressively essential in ensuring corporate success and competitive advantage (Enkel et al., 2009). Being open to outside innovation also creates opportunities to join platform-based ecosystem innovations. Innovation platforms are a collection of firms that share their capabilities so that others can utilize it to develop complementary products, technologies, or services (Gawer & Cusumano, 2014). This challenges firms to look beyond their organizational boundaries and evaluate how the resources and capabilities of external parties can be exploited to create exceptional value in a digitalized environment, even with competing firms (Soosay, Hyland, & Ferrer, 2008). Examples of co-opetition in the context of innovation between well-known rival companies include collaborations between Samsung Electronics and Sony to share research and development costs, Apple and Microsoft teaming

up to design a mobile operating system, and even Google supporting Firefox to limit the expanding influences of other competitors (Hema, 2017). This research will indicate the issues concerning innovation that arise in such co-opetition, how innovation platforms can be beneficial, and how effective innovation strategies should look like, given that digitalization is taking place.

1.2 Context

This research will focus on the paradoxical dilemma between competing firms within the Dutch manufacturing industry. Change is a frequent phenomenon in today's manufacturing environment, forcing firms to constantly adapt themselves to survive. Businesses must adapt to products, customer demands, technologies, and regulatory requirements (ElMaraghy & ElMaraghy, 2016). The manufacturing industry is undergoing vast changes with the rapid development of production automation, process control, information technologies, and networking. This change towards a more digitalized environment has been identified as the so-called fourth industrial revolution (Industry 4.0) and it offers appealing opportunities for industrial companies (Geissbauer, Schrauf, Koch, & Kuge, 2014). It is characterized by the increasing digitization and interconnection of products, supply chains, and business models (Geissbauer et al., 2014). A critical aspect of Industry 4.0 is the progression of traditional supply chains towards a connected, smart, and highly efficient integrated supply chain ecosystem. Geissbauer et al. (2014) expect that the competitive landscape in the digital age is going to fundamentally change due to closer horizontal co-operation. So the digitalization of the manufacturing industry is creating opportunities to integrate and better manage horizontal collaborations. These new digital supply chains with closer co-operation and increased integration with other companies can lead to better satisfaction of customer needs and greater flexibility in manufacturing (Geissbauer et al., 2014). Organizations with highly digitized supply chains can expect to have efficiency gains of 4.1 percent annually which can increase the revenue by 2.9 percent a year (Schrauf & Berttram, 2016, p. 11).

1.3 Research objective and question

The digitalization of the manufacturing industry enables new innovations (products, services, processes) and business models in the manufacturing industry. It also changes the nature of required and desired cooperation in the manufacturing industry. After all, these digital innovations often involve complex systems that cannot be developed by a single party. If firms are not able to keep up with the change towards a digitalized environment, they might need to look for opportunities to use knowledge of others to enhance their internal capabilities or source them externally, increasing the need for collaborations. Previous literature suggests that the digitalization also influences innovation strategies, with shorter innovation cycles and, on the other hand, innovations of a disruptive nature, resulting in the need for constant updating (Kagermann, Wahlster, & Helbig, 2013). For this reason, companies must work on digital innovation strategies that also focus and include cooperation in a competitive environment. This raises the question how innovation strategies are affecting collaborations, incorporating the paradoxical

dilemma between competitive firms, eventually creating possibilities for collaborative prospects. This leads to the following question:

To what extend do digitalization and innovation affect inter-firm collaborations in the context of competing manufacturing companies, and if so, how?

The purpose of this paper is to gain more insight into whether the digitalization of the manufacturing industry forces a different emphasis on inter-firm collaborations between competing manufacturing companies and if the nature of the innovation strategy influences collaboration prospects. The research question will be answered by using both a quantitative and qualitative method, where the quantitative part focuses on the existence or non-existence of a relation between the constructs and the qualitative part focuses mostly on how the constructs affect each other and what factors influence these relations. By combining the data, more in-depth information could be gathered regarding the three concepts of digitalization, innovation, and collaboration, and their interrelationships. The research is divided into three sub questions:

1. *How does the digitalization of the manufacturing industry influences inter-firm collaborations?*

This question will be answered by using both the quantitative as the qualitative data. The quantitative part will focus on whether or not digitalization influences collaboration while the qualitative method will try to clarify how the constructs are affecting each other.

2. *How do manufacturing companies integrate collaboration within their innovation strategies?*

The second question will investigate the characteristics of digital innovations, and thereby also determine what role cooperation will play in this. After all, digital innovations, for example, are complex and require the integration of many aspects, so the question is then whether a company can do this itself or whether it should seek cooperation, and how. For this sub-question, the study will determine if companies pay attention to collaboration during the development process of their digital innovation strategy and which factors are decisive.

3. *How do manufacturing companies address the competitive environment to enhance their digitalization and innovation?*

The third question will focus on co-opetition and will determine how companies view collaboration opportunities with competitors in terms of their innovation strategy and digitalization opportunities.

1.4 Relevance

This study will contribute to the previous theory on collaboration, with a specific focus on the inter-firm collaborations between competing firms. It will try to map how organizations are currently collaborating and how these inter-firm collaborations are influenced by the digitalization of the manufacturing industry and a firm's innovation strategy. The willingness towards collaboration with competitors will

be analyzed and whether this has changed over the past view years. The mixed method approach will contribute to the literature by adding a multiple view perspective. It will give managers clarification on how the digitalization of the manufacturing industry can be beneficial for the collaboration process and whether a firm's innovation strategy should include collaborations nowadays. It will contribute to the collaboration literature by investigating whether there is a difference in how companies use digitalization, either integrated with their production process or added to their product and if both have a different impact on the need and intensity to collaborate. Besides, the research will also contribute to the literature on open innovation by conducting in-depth research and discovering whether there is a difference between radical and incremental innovation and the need to collaborate. It is intended that managers and their organizations can use the finding of this research to determine whether or not digitalization might be beneficial for their collaboration process and whether they should move towards open innovation instead of only relying on their own innovation capabilities. Finally, this research will give clarification on how firms are currently viewing the complex concept of coopetition and whether the digitalization and their innovative behavior are changing their willingness towards it. By combining the concepts of digitalization, innovation, and collaboration the study will create a total overview of how manufacturing companies are dealing with these subjects.

1.5 Research approach

The study will be based on a mixed-method, with both a quantitative and qualitative part. For the quantitative study, the data of the European Manufacturing Survey of 2018 will be used. This will be combined with six semi-structured in-depth interviews with manufacturing companies in the Netherlands to investigate and test the discovered phenomena with in-depth information.

1.6 Outline of the study

The outline of this study will start with chapter 2, in which the theoretical background of the key concepts regarding inter-firm collaborations, innovation strategies, and the digitalization will be explained. Within this chapter, several definitions of the concepts will be compared, discussed, and linked with each other. The chapter will end with a conceptual model in which the concepts will be linked. Chapter 3 will explain the methodology of this study. It will include the research strategy, the data collection approach and the operationalization of the constructs. The results of the quantitative and qualitative studies will be shown in chapter 4. Chapter 5 will provide the conclusions and limitations of the study, recommendations for future research and it will explain how this study has complied with research ethics.

Chapter 2 – Theoretical background

Chapter 1 already briefly introduced the concept of inter-firm collaborations, innovation and digitalization. This chapter will further elaborate on the theoretical background of these concepts. The concepts are defined, compared, and supplemented by the various perspectives of multiple authors. The chapter finishes with a set of hypotheses based on the theoretical background of the concepts. It links together the concepts and the connections between the concepts are made visual in the conceptual model.

2.1 Innovation

The introduction of new products and services is crucial for organizational performance, to survive and stay competitive (Damanpour, 1991). By establishing new products and services, firms can enter new markets (Burgelman, 1991) and adapt to meet new market demands (Brown & Eisenhardt, 1995). To identify how companies are developing an innovation strategy and find out if and how they include collaborations in their innovation process, innovation first has to be defined. Innovation is defined in many different ways by various academics. Crossan and Apaydin (2010, p. 1155) have defined innovation as: *"production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems. It is both a process and an outcome"*. This definition captures several aspects of innovation. As it includes both production and adoption, it refers to internally and externally established innovations. With including exploitation this definition not just sees innovation as a creative process, but it includes the application and usage of the innovation. West and Farr (1990, p. 282) have defined innovation as: *"the intentional introduction and application within a role, group or organization, of ideas, processes, products or procedures, new to the relevant unit of adoption, designed to significantly benefit the individual, the group, organization or the wider society"*. This definition can be seen as more comprehensive, as it includes the benefits not just for the firm itself, but also for the wider society.

Furthermore, Armbruster et al. (2006) define innovation with four different categories in which they made a distinction between technical and non-technical, and process and product innovation. These four categories are visible in figure 1. They are defined as (Armbruster et al., 2006, p. 19):

1. **Product innovation:** this type of innovation is defined as the development of new products or technologies supported by the R&D activities of the companies.
2. **Service-product innovation:** the second type of innovation is aimed at offering the customers new services which may stay alone or which might go along with a physical product, such as maintenance or operating services.
3. **Process innovation:** aims at finding new process technologies in order to produce more cheaply, faster, and in higher quality.

4. **Organizational innovation:** the last type of innovation comprises the development and implementation of new organizational structures and processes to offer customers more flexibility and efficiency.

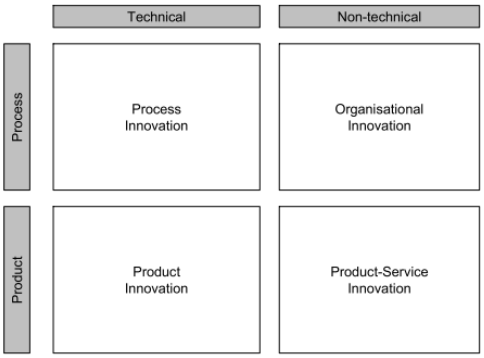

Figure 1 Domains of Innovation - Armbruster et al. (2006)

This paragraph has shown that there is not one consistent definition of innovation. Within the context of this research, the definition of Armbruster et al. (2006) will be used. This research aims to identify how manufacturing companies could benefit from collaborations in order to create new products, adding new services to products, improving the manufacturing processes, and optimizing organizational structures. Collaborations with several partners and in specific with competitors might only be beneficial for a particular innovation category of Armbruster et al. (2006), so this research will apply this model.

The usefulness of collaborations to improve the innovativeness might also depend on the innovation type. Within this research, a distinction is made between incremental and radical innovation, as these two differ regarding the complexity and newness of the required knowledge. Research has proven that the amount of accessible knowledge in a firm does affect the number of new products, so knowledge creation is of high importance to successful innovation and therefore a key dynamic capability (Smith, Collins, & Clark, 2005). According to Dewar and Dutton (1986), radical innovations contain a higher degree of necessary knowledge compared to incremental innovations, as it entails more complex, in-depth, and specialized knowledge. McDermott and O'Connor (2002, p. 424) also make a distinction between radical and incremental innovation: *"While incremental innovation is typically extensions to current product offerings or logical and relatively minor extensions to existing processes, radical innovations involve the development of application of significantly new technologies or ideas into markets that are either non-existent or require dramatic behavior changes to existing markets."* Kobarg, Stumpf-Wollersheim, and Welpe (2019) have already proven that there is a difference between the number of collaboration partners and the intensity of the interactions between these partners for both radical and incremental innovation. This research will also use this distinction to find out whether collaborations in a digitalized competitive environment will differ for incremental and radical innovation. After clarifying how the definition of innovation will be used in this research, the next step is identifying how innovation strategies are created and whether collaborations play a part in this.

2.2 Innovation strategy

As was already stated in chapter 1, Lendel and Varmus (2011) define an innovation strategy as the inventive direction of a company to utilize the innovative potential. Their definition includes the development process of innovative ideas, which is referred to as the innovation process. According to Hansen and Birkinshaw (2007), the innovation process consists of several phases. The first phase of the innovation process is the idea generation phase, in which ideas can be generated within the firm or by collaborations with external parties. The second phase is the conversion phase, in which the ideas are selected and products developed. The diffusion phase is the last phase. Within this phase, the new products or practices are distributed into the desired markets. There might be activities along the innovation value chain that companies struggle with, which are identified as the firm's weakest links or the bottlenecks. Identifying all of the phases of the innovation value chain helps managers to recognize where their weakest links are so that they can improve this and enhance their overall innovation capabilities and performance (Hansen & Birkinshaw, 2007). This research wants to identify in which phases of the innovation process collaborations with several partners, including competitors, might be beneficial to improve their weakest links.

As the manufacturing industry is faced with intensified competition and a turbulent economic environment over the last decades, the innovation processes and strategies of these companies have also changed, becoming more and more sophisticated over the years. The growing complexity and pace of the industrial-technological change forced firms to transform their innovation processes and become more open towards vertical and horizontal alliances (Rothwell, 1994). Rothwell (1994) stated that to be competitive in the fast-changing market, firms should develop an innovation model in which the network is integrated. His model, which is shown in figure 2, introduced the concept of open innovation and the importance of the network outside the firm. In order to be competitive in a fast-changing market, Rothwell (1994) explained that in his innovation model, efficiency and speed are derived from

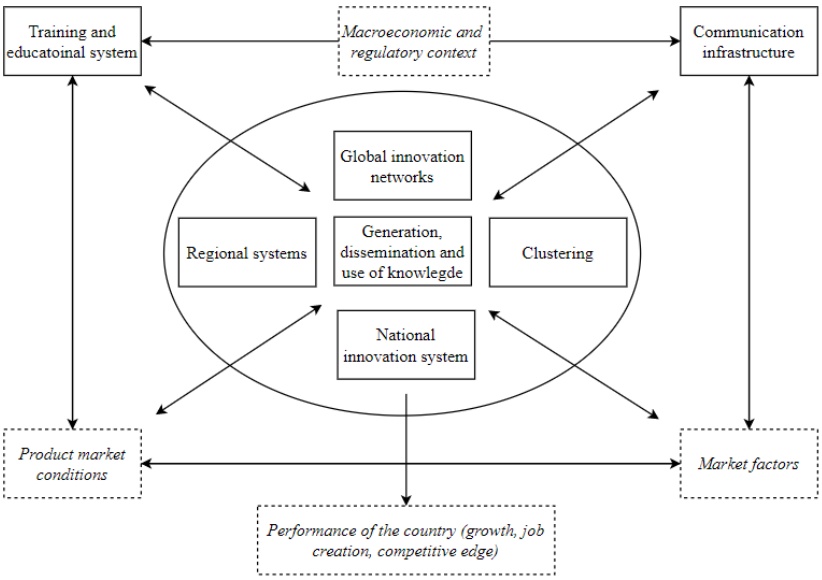

Figure 2 System Integration and Network - Rothwell (1994, p. 10)

continuous communication across the innovation network. Galanakis (2006, p. 1224) defined the usefulness of an innovation network as: "*A network of suppliers, customers, and other firms is developed in order to take advantage of the merging of technologies and to resolve the problem of the higher complexity of new products*". The purpose of the model is to meet market needs and uses available technological and scientific knowledge in order to satisfy the customer and improve the manufacturing process.

This shift from only focusing inwardly and relying on their own strengths into becoming receptive for horizontal and vertical alliances is according to Chesbrough and Crowther (2006) known as the transformation from a closed to an open innovation model. They define open innovation as "*the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation, respectively"* (Chesbrough & Crowther, 2006, p. 299). In addition, it also makes a distinction between inbound and outbound open innovation. Inbound open innovation is defined as the practice of leveraging the discoveries of others, in which Chesbrough and Crowther stress that companies should not rely exclusively on their own R&D. Outbound open innovation implies that companies should look for external organizations which have better suiting business models to commercialize an innovation, instead of completely relying on internal paths to the market (Chesbrough & Crowther, 2006). According to Angel (2002), technological process innovation collaborations can enhance innovation and the economic performance of companies. Manufacturers might be able to decrease costs of innovation, facilitate entering new product markets, and accelerate technology development by inter-firm technology collaborations (Angel, 2002). Tether (2002) added that another reason to enter collaborative arrangements is to reduce the risks associated with innovation or because the firm does not have all the necessary resources internally available.

Another definition of open innovation, is the open innovation model of van de Vrande, de Jong, Vanhaverbeke, and de Rochemont (2009). They have defined eight different open innovation activities, subdivided into technological exploitation and technological exploration. Technological exploitation is defined as leveraging the existing technological capabilities outside the boundaries of the organization. Companies can do this to better profit from internal knowledge. van de Vrande et al. (2009) have distinguished three open innovation activities related to technology exploitation; venturing, outward licensing of intellectual property (IP), and the involvement of non-R&D workers in innovation initiatives. Venturing is described as starting up a new organization based on internal knowledge, like spin-off and spin-out processes. Parent organizations might support with for example finance, human capital, legal advice, and administrative services. Outward licensing of intellectual property, the second open innovation activity regarding technology exploitation, plays a key role in open innovation as it involves the in- and outflows of knowledge. Arora (1995) stated that technology licensing an important mechanism is in which knowledge and technology are transferred so that agents other than the innovator can utilize it. Out-warding knowledge by for example licensing can generate income, however, it can

also negatively affects the company if the technology will be used by the licensees in the same market in order to compete. This exploitative open innovation activity of van de Vrande et al. is based on the research of Gassmann (2006), in which he analyzed Open Innovation identifying five different trends within the open innovation literature. He referred to outward licensing of intellectual property as the external commercialization of technology. And he stated that companies can gain leverage effects by offering their internally generated patents and trademarks to the outside world. As opposed to this is the "Free-rider problem". Teece (1992) defined this as the inability of firms to exclude other firms from using the technology they have developed. Other firms might use the technology without paying for it. If this is the case, the licensing firms do not earn anything from their intellectual property. The last practice to benefit from internal knowledge is to exploit initiatives and knowledge of the current employees who are not employed in the R&D department. Van Dijk and Van den Ende (2002) emphasize the importance of employee creativity in the innovation process. Employee creativity of non-R&D employees can be captured by suggestion systems, classic examples are the suggestion box or internal competitions.

While technological exploitation is aimed at the existing internal knowledge, technological exploration is defined as innovation activities capturing and benefitting from external sources of knowledge to enhance current technological development. It refers to activities focused on acquiring new knowledge and technologies from outside (van de Vrande et al., 2009). This corresponds with Chesbrough's definition of inbound open innovation. Five explorative open innovation practices were distinguished in the study of van de Vrande et al.; customer involvement, external networking, external participation, outsourcing R&D, and inward licensing of IP. The first open innovation practice is customer involvement. Firms can involve their customers in the innovation process by using the customer's ideas and innovations. This activity is also based on Gassmann's theory review. He states: *"Opening the innovation process to users and customers is a major constituent of open innovation"*(Gassmann, 2006, p. 226). The second explorative open innovation activity is external networking, and this is defined as: "*all activities to acquire and maintain connections with external sources of social capital, including individuals and organizations"*(van de Vrande et al., 2009, p. 425). This corresponds with the fourth and fifth-generation Innovation model of Rothwell, in which he stressed the importance of using networks to be more innovative. Rothwell stated that Japanese organizations were progressive examples that showed how firms could use their network, as they integrated suppliers in their innovation process. Gassmann (2006) agrees with this, as he confirmed that suppliers can contribute to the innovation process with their specific capabilities and enhance the success of the innovation projects with their involvement. External participation is the third explorative open innovation activity and it includes the recovering of innovations that were initially abandoned or that did not seem promising. An example is investing in start-ups to stay updated on potential opportunities and increase collaborations if their technologies prove to be valuable. The fourth open innovation activity regarding exploration is

outsourcing R&D. Gassmann (2006) explained that companies can outsource their R&D activities to for example engineering firms and high-tech institutions so they don't have to perform it themselves. This can reduce costs, create strategic flexibility, and increase access to new knowledge. The last explorative open innovation activity of van de Vrande et al. (2009) is inward licensing of intellectual property. Just like the out-warding knowledge with for example licensing, companies can also inward knowledge by using licenses of other companies to benefit from their innovations. This research will use these eight activities to identify whether firms are using open innovations models or only focusing on their own internal capabilities.

So within this research, innovation is focused on either radical or incremental production innovation and in addition a difference is made between product and process innovation. An application domain of process innovation is digitalization, as digitalization can be used to innovate, improve and upgrade the manufacturing process. As is explained in chapter 1, the digitalization of the manufacturing industry is strongly influencing firms within this sector. It can create opportunities, improve production efficiency, and establish new business models. However, digitalization can also have negative effects for firms, as they might not be able to cope with the changes which might lead to becoming irrelevant for their customers. The following paragraphs will explain the theoretical background of digitalization and its influences on collaborations between competing firms.

2.3 Digitalization

Digitalization is defined as the exploitation of digital opportunities and it combines different technologies, such as cloud technologies, big data, and 3D printing. These emerging technologies create many possibilities for firms, for example, to produce new products, optimizing resource utilization, and improving the supply chain (Rachinger et al., 2019). Unruh and Kiron (2017) define digitalization as firms that develop new business models and processes that can take advantage of the newly digitized products. Brennen and Kreiss (2016) state that digitalization also includes the restructuring of several domains of social life around digital communication and media infrastructures. Digitalization is part of a revolutionary process that started in the 18th century, which is also known as the industrial revolution. As explained in chapter 1, the manufacturing industry is undergoing major changes, and this has been the chase since the end of the 18th century. During this period, the First Industrial Revolution took place. This revolution is characterized by the transition of previously using hand production methods towards mechanical production based on water and steam power. The Second Industrial Revolution also referred to as the Technological Revolution, started at the beginning of the 20th century. During this period, mass labor was introduced based on electrical energy. The Third Industrial Revolution, also known as the Digital Revolution, is characterized by the introduction of automatic production based on electronics and internet technology. It enhanced the adoption of digital computers and communication technology within the manufacturing industry (Lu, 2017). The next step after the digitization of the production

processes is to connect all systems and let them communicate with each other, which is known as the 4th Industrial Revolution and is still ongoing nowadays. According to Ślusarczyk (2018), the fourth one improves information management and decision-making. Lu (2017) added that the goal of the fourth revolution was to achieve a higher level of operational efficiency and productivity and a higher level of automatization. Industry 4.0 emerged originally in Germany as the government made an initiative together with universities and private companies. This initiative was aimed at developing advanced production systems to increase the efficiency and productivity of the national industry (Kagermann et al., 2013). It enables communication between firms and their environment and business partners (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). The emerging technologies can add value to the whole product lifecycle (Dalenogare, Benitez, Ayala, & Frank, 2018; Wang, Wan, Li, & Zhang, 2016). As a result of industry 4.0, digitalization is nowadays affecting almost every part of a business and should therefore, according to Lerner (2015), be part of the business strategy, especially as it influences the future of planning within businesses. Besides, digitalization has even become a differentiating factor in ensuring company's success. As digital technologies are fundamentally transforming firm capabilities, products, business processes and even interfirm relationships, they should not only be seen as a function within firms but as an aligned strategy that drive competitive advantage and strategic differentiation. This digital business strategy determines the leverage of the digital resources to create differential value (Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013).

One of the emerging technologies that are established during the fourth revolution is Cyber-Physical Systems (CPS). Lu (2017, p. 4) defines CPS as: *"Industrial automation systems that integrate innovative functionalities through networking to enable connection of the operations of the physical reality with computing and communication infrastructures".* It manages interconnected systems between electronic capabilities and physical assets. CPS can, for example, manage the interconnectivity of machines and use big data to predict failure, configure themselves and adapt to changes. This can boost manufacturing productivity, encourage industrial development, and modify workforce performance. This all can result in improving the competitiveness of firms (Rüßmann et al., 2015).

Another aspect of the fourth revolution is the Internet of Things (IoT). IoT enriches devices with standard technologies that allow CPS to connect, communicate, and interact with one another. Integrating IoT into industrial processes enables manufacturing companies to become digital and generate value by analyzing and managing data to become more competitive. Fleisch, Weinberger, and Wortmann (2014) state that IoT creates the possibility to equip objects and locations with mini-computers so that they become smart objects. Smart objects are defined as objects that can collect information regarding their environment and communicate with the Internet and other smart objects (Fleisch et al., 2014). IoT provides customer solutions with the merging of physical products and digital services. An IoT system includes the machines and equipment, networks, the cloud, and personalized

products. It is capable to offer specific and personalized products (Lu, 2017). IoT makes it possible for firms to switch from mass production to customization. It goes far beyond just the optimization of manufacturing techniques (Geissbauer et al., 2014). A specific aspect of IoT is Social networking technologies. These enable owners to share data with the people they know through social communication platforms. As IoT merges physical products and digital services, it comes close to the concept of servitization.

Servitization

The concept of servitization is defined as the process of creating value by adding services to products to offer fuller market packages. Baines, Roy, Lightfoot, Benedettini, and Kay (2009, p. 554) defined services as: *"An economic activity that does not result in ownership of a tangible asset*". Combining a product with a service creates more value for the customers as it aims to offer better service to satisfy the customer's needs. The digitalization of the manufacturing industry creates an increased amount of possibilities for firms to include connected and automated services within their portfolio. Integrated solutions for offering products and combined services are considered to have significantly higher customer benefits. Companies can expand their existing product portfolio with connected solutions by integrating IoT and using relevant data to generate additional benefits and maximize customer value (Geissbauer et al., 2014). A servitization strategy includes developing digitalization capabilities to interact and co-create value with their customers. This changes the traditional customer-producer relationship as customers are involved much earlier in the product development process. According to lenkaLenka, Parida, and Wincent (2017) this changing relation with a focus on co-creation of value creates new challenging situations for manufacturing companies as it requires new capabilities. Utilizing digitalization can offer solutions to address these complex customer interactions by enabling new connected product features and integrating various operational processes (Porter & Heppelmann, 2014).

Business models

Rachinger et al. (2019) described that increased digitalization has also changed companies' business models. Digitalization facilitates new forms of collaboration between companies leading to new product and service offerings. The research of Rachinger et al. (2019), which focused on the effect of digitalization on business model innovation, has shown evidence that digitalization indeed affected business partner networks. Their respondents described an increased intensity of collaboration with current partners due to digitalization. Besides, they described that digitalization also increased the number of acquired partners within and beyond their industry sectors.

As this research focuses on the effects of the digitalization of the manufacturing industry and the nature of an innovation strategy on inter-firm collaborations, the next step is to define the latter. After analyzing several digital opportunities that companies can use to enhance their manufacturing process, the next paragraph will define and explain several aspects of inter-firm collaborations.

2.4 Inter-firm collaborations

To investigate inter-firm collaborations, this concept has to be defined. Chan and Prakash (2012, p. 4671) define collaboration as: "*An inter-organizational relationship in which the participating parties agree to invest resources, mutually achieve goals, share information, resources, rewards, and responsibilities, as well as jointly make decisions and solve problems".* It includes sharing the risks and rewards and is based on mutual trust and openness. As stated in paragraph 2.2, the growing complexity and the fast-changing industrial technology are forcing manufacturing firms to look for new vertical and horizontal collaborations to be able to create flexibility and efficiency in responding to market changes. To face the threats of the emergence of stronger competitors and increasingly demanding customers, firms are engaging in collaborative practices that offer cost reductions by pursuing economies of scale and scope and ability to focus on core competencies (de Soria, Alonso, Orue-Echevarria, & Vergara, 2009). By not being limited to their own resources and expertise, firms might be able to better respond to customer demand. According to Daidj (2017), collaborations are only possible if both firms expect to gain at least as much as it would have obtained when it remained independent. The inter-firm collaborations may differ regarding forms, frequency, reason to collaborate, and with different partners of the supply chain.

Supply chain collaboration

A supply chain contains all the links from raw material to an end product, so the totality of activities and goods transported between a supplier and a customer. Collaborations between the players of the supply chain are referred to as supply chain collaborations. Supply chain collaboration means that two or more autonomous firms are working jointly to plan and execute supply chain operations (Cao & Zhang, 2011). Vertical collaborations are collaborations where firms from different parts of the supply chain share their responsibilities, resources, and performance information to serve similar end customers. Examples are when the manufacturer, distributor, and retailer of the same supply chain decide to collaborate. This enables better flows of physical products and information, improvement of the trade-offs between the level of service and the average stock, more cost-effective inventory control, and better shipping systems (Chan & Prakash, 2012).

Horizontal collaboration occurs when parties that perform the same tasks or services in the same stage or level of the supply chain start to collaborate in order to achieve a common objective (Chan & Prakash, 2012). These firms could have been unrelated or even competing before the collaboration. Horizontal partners can be seen as complementors or substitutors. Complementors are defined as: "*players from whom customers buy complementary products or to whom suppliers sell complementary resources"*(Brandenburger & Nalebuff, 1995, p. 60). If firms are selling complementary products, they can help each other. For example, offering faster hardware will increase consumers' willingness to pay for more powerful software offered by another firm. Substitutors are defined as: *"Alternative players*

from whom customers may purchase products or to whom suppliers may sell their resources instead of from or to the firm."(Brandenburger & Nalebuff, 1995, p. 60). Substitutors are selling rival products and are mostly seen as enemies, however, there can also be a cooperative element in interactions with substitutors. When firms have a common location of raw material, they can collaborate by sharing inbound logistics. This leads to lower costs and allows more frequent and smaller deliveries as it can be shared. Regarding the operations, firms can collaborate to share assembly and control facilities or share the site infrastructure. Firms can even share the brand name and the marketing department to reduce advertisement costs and have a better capacity utilization. By cross-selling each other's products they can reach a larger group of potential customers. Another collaboration opportunity is to jointly developing technology, which causes lowers costs, enhances differentiation, and creates abilities to attract better people to innovate. Regarding procurement, if firms have common inputs, they can jointly purchase the items which might lower the costs and improves input quality (Porter, 1985, p. 339).

Strategic alliances

There are several forms of inter-firm collaborations. Alliances are a form of contractual relationships formed by two or more firms to perform a joint task that has the potential to create monetary or other benefits for both partners. By combining the resources, the partners can create value which they could not have created when they acted alone (Hitt, Freeman, & Harrison, 2005). Gerlach (1987) defined alliances as: "*neither formal organizations with clearly defined, hierarchical structures, nor impersonal, decentralized markets. Business alliances operate instead in extended networks of relationships between companies, organized around identifiable groups, and bound together in durable relationships which are based on long-term reciprocity"*(Gerlach, 1987, p. 127). According to Hitt et al. (2005), objectives to form alliances are speed, gaining economies of scale, reduce risk, promote stability, improving reputation and gain access to the other firm's knowledge and skills. The decision if a firm wants to enter a strategic alliance or do it on their own can be based on the transaction cost theory of Williamson (1981). This theory is aimed at keeping transaction costs resulting from transactions between parties as low as possible in order to create as much value in transactions as possible. Strategic alliances are preferred above acquisitions as it involves a less irreversible commitment and there is no transfer of ownership rights.

Collaborative networks

Another form of collaboration is entering a collaborative network. Hitt et al. (2005, p. 452) define networks as: "*a set of organizations linked by a set of social and business relationships that create strategic interfirm opportunities for the organizations".* According to Camarinha-Matos and Afsarmanesh (2006) can participating with a collaborative network establish a high potential for value creation. Examples are highly integrated and dynamic supply chains, extended and virtual enterprises, virtual organizations, and professional virtual communities. Participating in a collaborative network can

give access to new markets and knowledge, give opportunities to share risks and resources, create synergies and allow each entity to focus on its core competencies by combining complementary skills and capacities (Camarinha-Matos & Afsarmanesh, 2006). Camarinha-Matos and Afsarmanesh (2006, p. 28) have identified four different types of networks. It is of importance to highlight the difference between networking, coordinated network, cooperative network, and collaborative network as they all differ. As figure 3 shows, each type extends the previous one, increasing the amount of common goal-oriented risk-taking, commitment, and invested resources. Camarinha-Matos and Afsarmanesh stated that *networking* involves communication and information exchange for mutual benefit, but there is not necessary a common goal or common generation of value. In addition to exchanging information, *coordination* also involves aligning activities so that more efficient results are achieved, but all parties might still have different goals. *Cooperation* involves not only information exchange and adjustments of activities, but also sharing resources for achieving compatible goals. An example is cooperation within the supply chain, where each participant performs its part of the job in a jointly coordinated quasi-independent manner. Collaboration is the last type and the most extensive one. Camarinha-Matos and Afsarmanesh (2006, p.29) defined *collaboration* network as: *"a process in which entities share information, resources and responsibilities to jointly plan, implement, and evaluate a program of activities to achieve a common goal".* It implies mutual trust as it involves engagement of the participants to solve a dilemma together, so it can be seen as a process of shared creation. Within this research, it can be identified which network form is used by the participating firms.

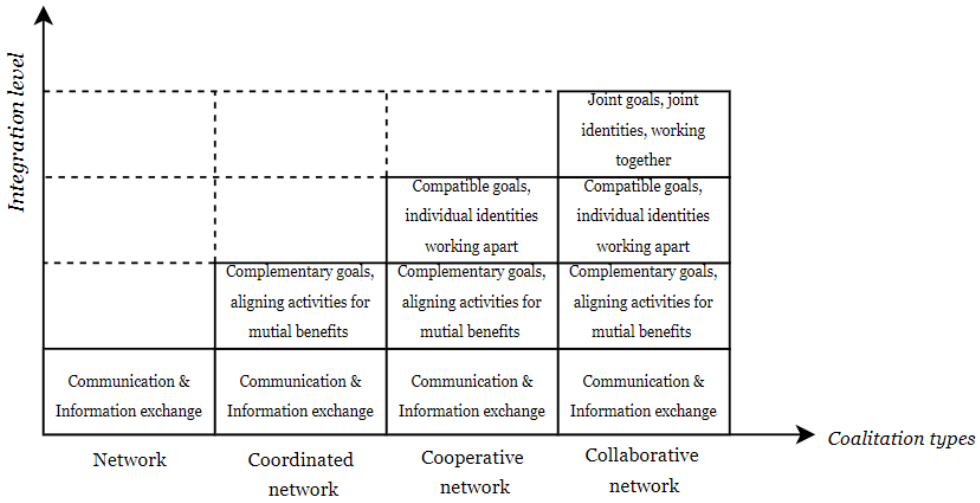

Figure 3 Network types - Camarinha-Matos & Afsarmanesh (2006)

Collaborations beyond the supply chain

Besides collaborating with partners within the supply chain, companies can also benefit from co-operative arrangements with other types of partners, such as universities, consultants, research institutes, research and technology organizations, and other associations (Tether, 2002). Firms can also choose to collaborate with their customers. Motivations for collaborating with customers can be to increase

knowledge of customer needs, increasing the likelihood that customers will accept the innovation and reducing the risks associated with introducing innovations on the market (Tether, 2002). Partnerships with and between public organizations and non-profit organizations can tackle social issues that otherwise might have fallen between the gaps of both organizations (Huxham & Vangen, 2005).

Co-opetition

A specific form of collaboration is a collaboration with competitors, also called co-opetition. This is a form of horizontal collaboration as both firms are at the same level within the supply chain. Co-opetition is defined as: *"a strategy embodying simultaneous cooperation and competition between firms."* (Gnyawali & Park, 2011, p. 650). It allows organizations to acquire and develop new technological knowledge and adopt the knowledge to innovate. Chapter 1 already briefly stated examples of collaborations between famous competing firms. Samsung and Sony were rivals on the consumer electronics market, both fighting for market share. The collaboration combined the world's leading television maker with the largest producer of liquid crystal displays to jointly offer a new product on the flat-screen market. The collaboration offered for both companies benefits, as it would help Sony to catch up with rival Sharp by having a reliable procurement source of LCDs. On the other hand, the collaboration offered Samsung the possibility to share the costs and the risks of the development of the LCDs and at the same time have a stable demand for the output (Ward, 2004). This is an example of competing firms that combine their strengths to improve their market position. Another example is the collaboration between Apple and Microsoft. Apple licensed patents to Microsoft, combined with an anti-cloning agreement, helped both parties. Apple had a new revenue stream through licensing and Microsoft was able to use the technology to improve their development department (Cabrera, 2014). This example shows how sharing information with competitors can create bigger success for both parties. Apple also collaborates with another massive rival, Samsung. The products of Samsung and Apple are competing goods, however, Samsung is also one of Apple's main suppliers for screens. According to Slywotzky and Drzik (2005) in order to successfully collaborate with competitors, companies need to have a clear understanding of their unique functions, as they still need to compete with the other firm. However, in the areas where the companies are doing the same job, they can collaborate in order to reduce the costs and be able to focus on their own specialized area. By combining the capabilities and overcoming coercive tensions, the firms can create a beneficial outcome for both companies.

2.5 Towards a conceptual model

Industry 4.0 offers many opportunities that the manufacturing industry can implement to become more efficient, reduce costs, and improve their competitive advantage with highly advanced products. According to Daidj (2017), inter-firm alliances are frequently found in the context of digital transformation. As previously stated, the digitalization of the manufacturing industry offers

opportunities for collaborations between several horizontal and vertical supply chain partners. To stay competitive within the fast-changing market, manufacturing companies need to integrate Industry 4.0 solutions. If firms lack competences in using cyber-physical systems, integrating IoT, or offering servitization, they need to look for opportunities to source them externally or use knowledge of others to enhance their internal capabilities. Otherwise, they might lose their competitive advantage as they fall behind the market. As digitization has an increasing impact on companies, companies need to consider and implement a digital strategy. It is necessary for actors who do not control the required resources and skills, to develop partnerships and collaborations with external partners. For this reason, companies must work on digital innovation strategies that also focus and include cooperation in a competitive environment.

To come up with suiting hypotheses, this research divides collaboration into two parts, on the one hand the collaboration domains and the other hand the collaboration intensity. Rachinger et al. (2019)'s respondents stated that digitalization increased the intensity of the collaboration with partners as these digital innovations often involve complex systems that cannot be developed by a one-off collaboration. Long term collaborations can facilitate firms to transfer knowledge and learn from each other (Kobarg et al., 2019). These long-term collaborations can enable companies to better capitalize on digital opportunities. So this distinction between collaboration domains and collaboration intensity matters, as digitalization might support the process to find new collaboration partners and also intensify the relationship with current partners by offering opportunities to integrate, align, and improve the collaboration.

Besides the distinction between collaboration domains and collaboration intensity, this research also divides digitalization into two parts to indicate how digitalized a firm is. Firms can use digitalization in two ways, to either improve their production process or use digitalization to improve their products by integrating digital elements into the product. First, the amount of integrated digital technologies in the manufacturing process is counted. Second, the extent of digital elements in the product itself is added up. This distinction is made to find out whether there is a difference between using digitalization to improve the process or to upgrade the product and whether this has a different influence on if firms collaborate or not. It is expected that both have a positive influence on the number of collaboration domains and the intensity of the collaboration. Both combined will lead to the following two hypotheses:

> H1A: *The digitalization of the manufacturing industry, involving a higher number of integrated digital technologies and digital product elements, increases the number of collaboration domains.*
>
> H1B: *The digitalization of the manufacturing industry, involving a higher number of integrated digital technologies and digital product elements, increases the number of intense collaborations.*

One of the collaboration domains that are of specific interest within this research, is collaboration with competitors, also called coopetition. Success in today's business world frequently requires that firms pursue both competitive and cooperative strategies simultaneously and view competitors as potential collaboration partners (Lado et al., 1997). Digitalization might increase the need to capture and benefit from external sources of competitors to enhance a firm's current technological development. Besides, collaborating with competing firms might offer opportunities to exploit their technological knowledge. However, the digitalization of the manufacturing industry can also create more competition on the market, as incumbents can be interrupted by new market entrants that might redefine the established industries (Rachinger et al., 2019). This means that higher competition caused by digitalization might lead to lower collaborations between competitors. Nevertheless, Rachinger et al. (2019)'s respondents stated that the digitalization mostly facilitated the process and offered opportunities to find new collaboration partners, leading to new collaboration domains. This leads to the expectation that the digitalization of the manufacturing industry increases the collaborations between competing firms, also known as coopetition.

The second part of this research focuses on the impact of innovation on collaboration. According to Enkel et al. (2009), collaboration with external parties is a core initiative to increase innovativeness. This challenges firms to look beyond their organizational boundaries and evaluate how the resources and capabilities of external parties can be exploited to create exceptional value in a digitalized environment (Soosay et al., 2008). However, there might be a difference between firms that focus on radical innovation and incremental innovation. According to Rachinger et al. (2019, p. 1143), digitalization has put pressure on companies to reflect on their current innovation strategy and explore new business opportunities systematically and at early stages. Change is a frequent phenomenon in today's manufacturing environment, forcing firms to constantly adapt themselves to survive. Previous literature suggests that the digitalization also influences innovation strategies, with shorter innovation cycles and, on the other hand, innovations of a disruptive nature, resulting in the need for constantly updating the product portfolio (Kagermann et al., 2013). To take this into account, a difference is made between radical and incremental innovation. Radical innovations are seen as more complex to come up with as they are distinguished as ground-breaking ideas including characteristics such as new-found knowledge, assets, and processes for the market. It might require firms to absorb various technological developments in their environment and use methods and materials that are new to the company (Kobarg et al., 2019). The increased complexity of the innovations might force firms to look beyond their organizational boundaries to use the capabilities of other firms to improve their innovation process. A higher amount of collaboration domains increases the diversity of accessible external knowledge and complementary resources, which firms might need to come up with radical innovations. This leads to the following hypothesis:

H2A: *When a firm focuses on radical product innovation, the number of collaboration domains will increase compared to firms with no product innovation.*

As a higher amount of collaboration domains is needed, radical innovation is also expected to influence the intensity of the collaborations. Since radical innovations are complex in nature, the ability to exchange and utilize external knowledge is required (Kobarg et al., 2019). To collaboratively create a radical innovation, a profound long term collaboration is needed. This leads to the following hypothesis:

H2B: *When a firm focuses on radical product innovation, the number of intense collaborations will increase compared to firms with no product innovation.*

Regarding the incremental product innovation, the hypotheses differ. As incremental innovations involve only relatively minor changes in technology, it is expected that the number of collaboration domains will not increase, as firms might be able to complete the innovation process themselves and will not search for extra collaboration partners. The need to share risks and use resources for incremental innovations is lower compared to radical innovation (Kobarg et al., 2019). This leads to the following hypothesis:

H2C: *When a firm focuses on incremental product innovation, the number of collaboration domains will* ***not*** *increase compared to firms with no product innovation.*

Incremental innovations will not generate a need to establish collaborations on new domains, however, these types of innovations are expected to influence the intensity of the collaborations. Incremental innovations consist of upgrades and adjustments to current products. To be able to improve specific product features, complex specialized knowledge is required. Long term collaborations can ensure deeper interactions which can benefit the product as both firms can complement each other's knowledge and improve the product (Kobarg et al., 2019). So incremental innovations can benefit from long term relationships, which leads to the following hypothesis:

H2D: *When a firm focuses on incremental product innovation, the number of intense collaborations will increase compared to firms with no product innovation.*

It is already conceptualized that innovation has a positive effect on collaborations, however as previously explained, coopetition is of specific interest within this research so the effect of innovation on coopetition will also be analyzed. The constantly changing manufacturing environment forces firms to adapt themselves to survive and improve their process and their products. This challenges firms to look beyond their organizational boundaries and evaluate how the resources and capabilities of external parties can be exploited to create their own exceptional value in a digitalized environment, even with competing firms. So it is expected that firms have to incorporate collaborations with competitors within their innovation strategy to stay competitive in today's manufacturing market, increasing the need for coopetition.

The six hypotheseses are made visually in the conceptual model, which is shown in figure 4.

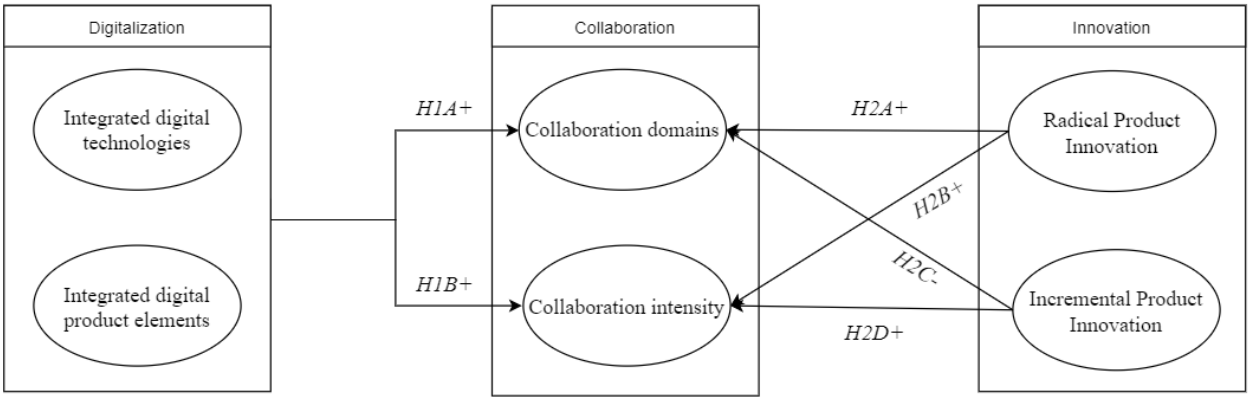

Figure 4 Conceptual model

Chapter 3 – Methodology

The previous chapters have described the several concepts that are of importance within this research. This chapter will describe how the research will be shaped, including the research strategy and the data collection, how the concepts are operationalized, and finally, it will address how it validates and takes into account the research ethics.

3.1 Research strategy

A research strategy is defined as: *"The coherent body of decisions concerning how the researcher is going to carry out the research, gather relevant material and process this material into valid answers to the research questions."*(Verschuren & Doorewaard, 2010, p. 155). The first decision that has to be made is whether the research will be focused on gaining a broad overview of the discipline (breadth) or if it will be focused on a thorough investigation of all aspects of a phenomenon (depth). This research will focus on depth, as the aim of this research is to identify the relation between the included variables and explore what the effects of the independent variables are on the dependent variables. This choice of going for depth research will enable gaining depth, elaboration, complexity, and soundness, which minimizes the risk of uncertainties. However, because depth investigations are of a smaller-scale approach, the research is less generalizable (Verschuren & Doorewaard, 2010). The second decision is whether the research will be inductive or deductive. As this research tested hypotheses that are distilled from the theoretical framework, it can be identified as deductive research. Within deductive research, the existing literature is used to build a conceptual model and the relations in the model are tested with empirical data (Verschuren & Doorewaard, 2010). The last question of the research strategy concerns the research method. It determines whether the research will use quantitative, qualitative, or mixed methods. As stated in chapter 1, this research will use a mixed-method approach. First, the research will apply statistical data to identify and confirm the hypothesized theoretical relations. After that, qualitative research will investigate the underlying reason for the occurrence of the identified phenomena.

3.2 Data collection

The data of this research will be collected by using a mixed-method, combining both quantitative and qualitative research methods. According to Sekaran and Bougie (2016, p. 158) combining both quantitative and qualitative methods increases the strength of the research, as data obtained on the same variable from different sources and through different data collection methods lend more credibility. The quantitative phase involves analyzing data acquired by a survey. This enabled the possibility to test the relation between the digitalization of the manufacturing industry and inter-firm collaborations of Dutch manufacturing companies and their innovation focus. The qualitative phase involves gathering in-depth information about this relation by conducting semi-structured interviews.

Survey

A questionnaire is defined as: *"A preformulated written set of questions to which respondents record their answers, usually within rather closely defined alternatives"* (Sekaran & Bougie, 2016, p. 142). The most distinctive characteristic of a survey is that it gathers large numbers of research units, which makes it reliable and generalizable (Verschuren & Doorewaard, 2010). The quantitative data used in this research originates from the European Manufacturing Survey (EMS) of 2018. The EMS has been organized by a group of research institutes and universities from and across Europe since 2001 ("European Manufacturing Survey," 2020b). Every three years, the survey collects new data on techno-organizational innovations in the manufacturing industry on the company level. Institutions which are responsible for the EMS include the Institute for Management Research of the Radboud University, Fraunhofer Institute for Systems and Innovation Research in Germany ("European Manufacturing Survey," 2020a). According to the survey, the purpose of the questionnaire is: *"To gain insight into the efforts of industrial companies in the Netherlands to modernize their production and business processes. The research focuses on production companies with at least 10 employees."* (European Manufacturing Survey, 2015, p. 1). The survey was carried out in eleven countries, but this research will only use the data of the Dutch manufacturing companies. The variables that will be analyzed using the data of the survey are the dependent variables collaboration and innovation and the independent variable digitalization. This research will check if there is a significant correlation between the digitalization (use of technologies and integrated product elements), collaboration (domain and intensity), and innovation (radical or incremental). The questions of the EMS that are used to measure these constructs are shown in appendix 1. The constructs will be described in detail in the operationalization section. The data will be analyzed by using multiple linear regression, as it includes several predictors (Field, 2013).

Semi-structured interviews

To validate the established phenomena that occurred from analysis of the quantitative data, several semi-structured interviews will be conducted with companies of the Dutch manufacturing industry. An interview is a method of obtaining data by having guided and purposeful conversations and they can be conducted face to face, by telephone or online (Sekaran & Bougie, 2016, p. 113). Information provided from interviews can help to identify several critical factors and evolve a theory of elements that influence the described phenomena. Using semi-structured interviews involves the use of pre-formulated questions, but also using new questions that might emerge during the conversation. The pre-formulated questions give structure and focus during the interview, while the interviewee also has the opportunity to add important insights that might arise during the conversation (Myers, 2013). The interviews will focus on how the digitalization of the manufacturing industry influences collaborations between competitors, what innovation strategies they use, and how these strategies influence the effects of the digitalization on collaborations. Appendix 2 shows the interview script, including the interview

questions and the corresponding tree diagram and appendix 3 shows an overview of the 6 interviewed firms, including the industry sector, company size, and job description of the interviewed employee.

3.3 Operationalization

This section explains how the concepts are operationalized. To be able to measure the previously explained abstract concepts, the concepts have to be operationalized. The concepts are operationalized by identifying the independent dimensions of the concepts and translating them into observable and measurable elements (Sekaran & Bougie, 2016). The concepts "Digitalization of manufacturing industry", "Innovation Strategy", and "Collaboration" are partly covered by the European Manufacturing Survey during the quantitative analysis. The structure of the interviews, which are part of the qualitative method, is divided into three separated parts and every part discusses one of the constructs. For each construct, questions are first asked about what kind of activities companies do in terms of digitization, innovation and cooperation. In addition, there is also explicitly asked if the respondents experience relations between the concepts and if so how they relate to each other. These two inputs, on the one hand focused on the constructs themselves and on the other hand focused on the relationships between the constructs, have ensured that the sub-questions of this research can be answered. An overview of the research design is visible in table 1. The constructs will be discussed in more detail below the table.

Research design					
Quantitative analysis					
Type of variable	*Variable name*	*Question in EMS*	*Scale*	*Dummy*	*Type of analysis*
Dependent variable	Collaboration 1. Collaboration domains 2. Collaboration intensity	 7 7	 Nominal: Dichotomous Nominal: Dichotomous		Multiple regression analysis
Independent variable	Digitalization of the manufacturing industry 1. Digital technologies 2. Digital product elements Innovation 1. Incremental product innovation 2. Radical product innovation	 10.1 15.2 14.1 14.3	 Nominal Nominal Nominal Nominal	 Yes Yes	
Control variable	Firm industry Firm size	2.1 21.1	Categorical Ratio	Yes	
Qualitative analysis					
Type of variable	*Research concepts*				*Type of analysis*
Dependent variables	Collaboration Coopetition				Theory-guided coding
Independent variables	Digitalization of the manufacturing industry Innovation				

Table 1 Research design

Dependent variable

Collaboration

To measure the concept of inter-firm collaborations, question 7 of the EMS 2018 will be used, which is shown in appendix 4.1. This question asks on which domains the firm cooperates with other firms. It includes 7 different domains and for each domain, the respondent has to choose between no (0) or yes (1). This question also asks about the intensity of the collaboration, whether the collaboration has occurred once, several times, or continuous. Since it is difficult to receive an overall score with ordinal variables, this variable is recoded and dichotomized into two categories. The firms that have answered that they don't collaborate or that they collaborated once, receive a score of 0 and the firms that collaborated multiple times or continuously receive a score of 1. To be able to count how many firms responded that they belong to the second group, so collaborating multiple times or continuously on that specific domain, a new variable is constructed that only includes this group. This new variable is called "Intense Collaborations". This new variable counts and adds up for every collaboration domain how many firms responded by saying that they collaborated multiple times or continuously on this specific domain. So while the qualitative data focuses on the overall effect of collaboration and the corresponding topics showed in the tree diagram (Appendix 2), the quantitative study is specified and subdivided into collaboration domains and collaboration intensity.

Independent variables

Digitalization of the manufacturing industry

In order to indicate how digitalized a firm is, digitalization is split up into two parts. Firms can use digitalization in two ways, to either improve their production process or use digitalization to improve their products by integrating digital elements into the product. First, the amount of integrated digital technologies in the manufacturing process is counted. Second, the extent of digital elements in the product itself is added up. This distinction is made to find out whether there is a difference between using digitalization to improve the process or to upgrade the product and whether this has a different influence on how firms collaborate. It is expected that both have a positive influence on the number of collaboration domains.

The independent variable Digitalization of the manufacturing industry will be measured by using two different questions of the EMS 2018, which are shown in appendix 4.2. First, it will be counted how many digital technologies are used in the production process. Respondents were asked which of the 12 different technologies they currently use. These items are several technologies and to decide if a firm has joined the trend of the digitalization the number of technologies will be counted and averaged. The second question asked whether the produced products of the respondents contain the proposed digital elements or if the products contain other digital elements. Both are binary variables, as the respondents can choose between yes (=1) and no (=0). By counting the results of both questions, it is determined

how digitalized a company is. The more integrated digitalized technologies in the production process or digital elements the products contain, the more digitalized a company is. So the quantitative study is specified and subdivided into digital technologies and digital product elements, while the qualitative research focuses on the overall effect of digitalization.

Innovation

The concept of innovation is also based on two different questions, first, whether the firms have introduced new products or drastically improved products since 2015 and second whether these new products were also new for the market. The questions are shown in appendix 4.3. By using these two questions, it can be determined whether a firm focuses on incremental, radical, or no innovation at all. As these variables consist of three categories, it is a nominal variable. To use these variables in the regression analysis, the variables will be transformed into dummy variables. A dummy variable is a special metric variable that is used to represent a single category of a nonmetric variable (Hair, Blak, Babin, & Anderson, 2014, p. 33). The three dummy variables will be "No Product Innovation", "Incremental Product Innovation" and "Radical Product Innovation". However, as the dummies have to be compared to one category, research always has one dummy variable less than the number of levels of the nonmetric variable. This means that one category is omitted in the research. This omitted category is also referred to as the reference category (Hair et al., 2014). In this research, the reference category is "No product innovation", so all the values of the other two variables will be compared to the values of the "No product innovation".

Control variables

The study might be influenced by certain aspects that are not included in the research. The control variables are used to make sure that when the hypotheses are confirmed, they are truly confirmed based on the hypotheses, and not because of other elements (Hair et al., 2014). Whether a firm collaborates or not, might depend on the industry it is operating in and the size of a firm.

Industry sector

The question in which sector the firm is operating is used as a control variable and this variable is called Industry Sector. It is of importance to use the industry sector as a control variable, as the variance in environmental opportunities and threats belonging to a certain industry can influence the innovativeness of firms(Butler, 1988). The original data contains 25 different categories, each representing a certain industry based on the segmentation of NACE Rev. 2, Statistical classification of economic activities in the European Community (Eurostat, 2008). These industries are shown in appendix 4.4. However, in this research, the data is recoded into 7 dummies, as some categories had an overlap and could be merged. These 7 recoded dummies are shown in appendix 4.5. As explained before, when using dummy variables, one category has to be omitted to compare the various categories. During the analyses, the

reference category will be the metal industry, so all the values of the other industries will be compared to the values of the metal industry.

Firm Size

To indicate the size of the company, the number of employees is used. This is a relevant valid indicator for size, as it is assumed that the more employees a company possesses, the more resources and opportunities a company has to develop activities. However, statements are also made that large incumbent firms rarely introduce radical product innovations, as they are stuck to bureaucratic guidelines and routines (Rajesh K. Chandy & Tellis, 2018). However, small firms might not possess the critical mass for research to introduce innovations (Rajesh K. Chandy & Tellis, 1998). This might differ for several sectors, however, for this research, which is focused on the manufacturing industry, size is determined by the number of employees. For the quantitative analysis, the variable Size only includes companies that have 10 or more employees, so the companies that have 9 or less employees won't be incorporated into the analyses. Looking at the SPSS statistics of Firm Size shown in appendix 5, it becomes clear that the distribution is skewed. Skewness values falling outside the range of -1 to +1 indicate a substantially skewed distribution and for the kurtosis to be normally distributed, the value should be equal to 3 (Hair et al., 2014). The variable Size will be transformed with the Log function in order to reduce the skewness and kurtosis and get a normal distribution. The new variable Size (log) has a Skewness of 1.04 and a Kurtosis of 3.36, which is an approvable distribution.

3.3.1 Data analysis

After the operationalization, the data has to be examined, if necessary transformed and the reliability, validation, and assumptions have to be checked.

Sample size

To be able to use the collected data to conclude something about the wider world, the sample should represent the population of interest. According to Field (2013), the sample size should at least be 30. The sample of the EMS 2018 is 203 (N=203), which is big enough to represent the population. The missing data also needs to be checked, in order to prevent potential problems with the data.

3.3.2 Reliability and validity

The reliability and validity indicate how well the research method fits the data and they have to be checked to evaluate the quality of the research and reduce the measurement error as much as possible.

Measurement error

A measurement error occurs when the observed values are not representative of the true values. The goal of the research is to reduce the measurement error as much as possible (Hair et al., 2014). To assess the degree of measurement error the validity and reliability should be checked. The validity is defined as *"Extent to which a measure or set of measures correctly represents the concept of the study, the*

degree to which it is free from any systematic or non-random error" (Hair et al., 2014, p. 3). The questions asked should be accurate and the concepts should be precisely specified to increase the validity. Reliability is defined as: "*Extent to which a variable or set of variables is consistent in what it is intended to measure"*(Hair et al., 2014, p. 4). When the measure is repeated and the results are consistent, the measure can be labeled as reliable.

Reliability

As within the quantitative analysis, both of the constructs Collaboration and Digitalization include several items, the internal consistency of the items need to be checked, also known as the reliability. The reliability checks whether the items consistently reflect the construct that is measured. To measure the reliability of each construct, the Cronbach's alpha will be used and it should at least be 0.7. However, as this is exploratory research, a Cronbach's Alpha of 0.6 is also tolerated (Field, 2013). The SPSS output of the reliability analysis is shown in Appendix 6. The first construct is Collaboration, which is measured by two questions. The first question, which includes the collaboration domains, has 7 items and it has a Cronbach's Alpha of .688. The second question regards the collaboration intensity, which has also 7 items and it has a Cronbach's Alpha of .699. As both are close to 0.7, the reliability of this construct is good enough. If the Cronbach's Alpha is not high enough, one of the items can be deleted in order to generate a higher Cronbach's Alpha (Hair et al., 2014). However, as there is no noteworthy improvement by deleting any of the items for both of the questions, all the items are kept. The second construct is Digitalization and it is also measured by two questions. The question regarding the integrated digitalized technologies is measured by 12 items, it has a Cronbach's Alpha of 0.608 and cannot be improved by deleting one of the items. The second question, concerning the digital elements within the product, is measured with 5 items. It has a Cronbach's Alpha of 0.702 and can also not be significantly improved by removing one of the items. It can be concluded that both of the constructs have an accredited reliability. For the qualitative analysis, the essence of reliability lies with consistency (Leung, 2015). To increase the consistency between the interviews, each construct will be introduced with a theoretical definition to the respondents. By giving all the respondents the same introduction of the concepts, it is made sure that the respondents all perceive the constructs the same which reduces biases and increases the consistency.

Validity

The validity checks whether the measures correctly represent the concept of study and checks the appropriateness of the tools, processes, and data of the research (Leung, 2015). The use of both quantitative and qualitative research methods increases the validity of the research as all the constructs are measured in different ways and the results will be combined to come to a comprehensive answer to the research question. The use of different research methods is also known as triangulation and it creates both generalizability and the possibility to go in-depth with the qualitative method, increasing the

validity of the research (Verschuren & Doorewaard, 2010). Besides, to increase the validity, a test interview will be conducted to find out whether the questions reveal the critical answers and to identify which questions need to be adjusted.

3.3.3 Assumptions multiple linear regression

The last part of the operationalization includes looking at the assumptions of the used method and confirming whether any of them are not violated. As the multiple linear regression is the appropriate research method for this type of variable, the corresponding assumptions are evaluated. The assumptions of normality, linearity, homoscedasticity, independence of the error terms, and multicollinearity must all be met (Hair et al., 2014). The dependent variable consists of two parts, the collaboration domains, and the collaboration intensity, so for every assumption, both of the parts need to be checked.

Normality

The normality refers to the shape of the data distribution, whether or not it is skewed by the presence of large outliers. This can be checked in a histogram, which compares the observed data values with a normal distribution. Both the Kurtosis (flatness) and the Skewness of the observed data need to correspond with a normal distribution (Field, 2013). As can be seen in appendix 7.1 and 7.2, the observed data shown in the histograms for both the collaboration domains as well as the collaboration intensity are both normally distributed. Besides looking at the shape of the histogram, the sample size also has to be sufficient in order to satisfy the assumption of normality. As the sample size is 201 (N=201), it is sufficiently large to satisfy the assumptions.

Linearity

The assumption regarding the linearity checks whether the relationships between the dependent variable and independent variables are accurately described by the equation. The linearity can be confirmed by controlling the scatterplot and identifying if there are any outliers or if there is a nonlinear pattern (Hair et al., 2014). As appendices 7.3 and 7.4 show, both the scatterplots of the collaboration domains and intensity of the collaboration are showing a linear pattern with no noteworthy outliers.

Homoscedasticity

The third assumption refers to a desired equal variance of the dependent variable values for each value of the independent variable. The same scatterplot used by the linearity will be checked to test this assumption. If the data is homoscedastic, there is no pattern in the residuals (Hair et al., 2014). Both scatterplots so no clear pattern, so this assumption is also fulfilled.

Independence of the error terms

This assumption ensures that any of the prediction errors are uncorrelated with the independent variable and will not influence the regression model. This can be checked by using the Residual Statistics table, which is shown in appendix 7.5 and 7.6. Looking at the Standardized Predicted Value, the mean should

be 0.00 and the standard deviation needs to be 1.00 to have independent error terms. This applies both to the areas of collaboration domains and the intensity of the collaboration.

Multicollinearity

The multicollinearity checks the correlations between the dependent and independent variables. According to Hair et al. (2014, p. 196): *"The ideal situation for a researcher would be to have a number of independent variables highly correlated with the dependent variable, but with little correlation among themselves."* The multicollinearity can be measured by the tolerance and the variance inflation factor (VIF). Hair et al. (2014) suggest that the VIF should be below 10 and the tolerance above .02. The statistics for both the collaboration domains and collaboration intensity are shown in appendix 7.7 and 7.8. As the items are all below and above the suggested limit, this assumption is also met.

This shows that all the assumptions of normality, linearity, homoscedasticity, independence of the error terms, and multicollinearity are all met. This means that the interpretation of the results and the conclusions of the research are valid.

Chapter 4 - Results

To answer the research question and test the established hypotheses, this chapter will present the results from both the quantitative and the qualitative research methods. The quantitative part consists of univariate analyses and two regression analyses. The qualitative part involves an analysis of the data retrieved from the semi-structured interviews. The chapter will finish with a conclusion that combines the results of both the quantitative and qualitative findings.

4.1 Quantitative analysis

The quantitative analysis will start with an overview of the descriptive data of the EMS and an analysis of the correlations between the independent, dependent, and control variables. After that, as collaboration is divided into collaboration domains and collaboration intensity, two separated multiple regression analyses will be performed for both the dependent variables. The results of the multiple regression analyses will be used to test the hypotheses.

4.1.1 Descriptive

First, an overview will be given of the descriptive data of the EMS 2018 by doing a univariate analysis. The descriptive data of the different concepts are shown in table 3 on the next page. As the firm size and firm industry are the control variables, these will be addressed first. The SPSS output of the control variables is shown in appendix 8.1. The sample consists of 203 manufacturing firms, divided into 7 different industry sectors. This division is compared to the distribution of all the Dutch manufacturing firms to find out whether it is a representative selection, both shown in table 2. Except for the chemicals and electrical industries, it turns out that all of the categories of the sample are a good representation of the population as the proportions are similar.

Industry Sectors			
Industry	**Mean**	**Frequency (%)**	**Distribution total Dutch industry** (CBS, 2020)
Metals and Metal products	0.1990	19.7	20
Food, Beverages, and Tobacco	0.0846	8.4	11
Textiles, Leather, Paper and Board	0.1443	14.3	22
Construction, Furniture	0.0249	2.5	18
Chemicals	0.1294	12.8	2
Machinery, Equipment Transport	0.1841	18.2	23
Electrical and Optical equipment	0.2338	23.2	4

Table 2 Industry Sectors

The second control variable is the size of the firm. The firm sizes of the sample have a range of 4490, starting with a minimum of 10 employees and the biggest firm has 4500 employees. As explained in section 3.3, the variable firm size has a skewed distribution, so the mean is not a precise representative, as the mean is very sensitive for outliers (Field, 2013). The median is a better representative for skewed distributions, which is the middle score and it has a value of 42. This means that within the sample, the average size of a firm includes 42 employees. This corresponds with the population as shown in

appendix 8.2, as 96.31% of the Dutch manufacturing firms own between 0 and 50 employees, and only 3.69% of the firms have more than 50 employees (CBS, 2020).

After looking at the control variables, the three concepts of the model will be discussed. The first concept of this research is digitalization. To determine how digitalized the firms are, the amount of integrated digitalized technologies and digital product elements are counted. The average number of integrated digital technologies is between 2 and 3 (Mean=2.83, appendix 8.3). As shown in appendix 8.4, the most commonly used technology is Software for production planning and scheduling, as 61.90% of the firms use this technology. Product-Lifecycle-Management systems are least used, with only 9.52% of the respondents saying they use it. It also turns out that the number of digital product elements is much lower than the amount of integrated digital technologies, as the mean of digital product elements is 0.89. This means that the products of the firms contain less than 1 digital element per product. Appendix 8.5 shows the SPSS output of digital product elements. It indicates that 53.7% of the firms don't have any of the proposed digital elements included in their products.

Descriptive Data EMS							
Variable	**Item**	**Mean**	**Standard Deviation**	**Median**	**Skewness**	**Kurtosis**	**Frequency (%)**
Firm Size	*Number of employees 2017*	81.44	317.08	42	13.54	189.27	
Firm Size (Log)		3.77	0.86	3.74	1.04	3.35	
Digitalization	*Integrated Digital Technologies*	2.83	2.08	3.00			
	Digital Product Elements	0.89	1.17	0.00			
Innovation	*No Product Innovation*						49.8
	Incremental						21.2
	Radical						29.1
Collaboration	*Collaboration domains*	2.64	1.96	2.00			
	Collaboration Intensity	2.33	1.94	2.00			

Table 3 Descriptive data

The second concept of the research is innovation, which is divided into radical, incremental, and no product innovation at all. Looking at the results shown in appendix 8.6, it seems that just over half of the number of the firm, 50.3%, use product innovation. Within the firms that do focus on product innovation, the majority focuses on radical product innovation rather than incremental product innovation.

The last concept of the model is collaboration. As explained before, collaboration is separated into two parts; collaboration domains and collaboration intensity. On average, firms collaborate on 3 domains (Mean=2.64) with other firms. As appendix 8.7 shows, 57.29% of the firms collaborate with buyers or

suppliers on R&D, which was the most popular domain as it received the highest frequency. Other popular domains to collaborate on are R&D with research institutes (41.21%), sales (40.20%), and R&D with other firms instead of buyers and suppliers (38.19%). Further analysis revealed that 18.2% of the firms do not collaborate on any of the domains, however, the vast majority have two or more collaborations and 3.9% of the firms even collaborate on all of the domains. One of the collaboration domains that are of specific interest within this research is called coopetition, which is known as cooperation with competitors. As there is no specific item in the EMS asking whether firms are collaborating with competitors, the item collaboration for production is used to get an indication of this concept. This item is chosen to measure coopetition as it asks whether firms collaborate for capacity expansion or joint use of machines, so the assumption is made that they have something in common as they have machines that produce related components so they might compete with each other. It does not fit the criteria precisely, but for this research, it does give an indication about collaborations between competitors. However, this subject will be given more devotion during the qualitative analyses. Looking at the SPSS output, it seems that 34% of the firms collaborate with firms to share their production process. This indicates that one-third of the companies might be open to coopetition by sharing production capabilities.

The second dimension of collaboration is the intensity of the collaboration. As explained before, the variable is transformed into the new variable "Intense Collaborations", which counts and adds up for every collaboration domain how many firms responded with saying that they collaborated multiple times or continuously for this specific domain. As the mean is 2.33, this means that on average firms collaborate on 2 domains multiple times or continuously. Appendix 8.8 shows the percentages of the amount of intense collaboration per domain. Just as with the collaboration domains, the domain collaboration for R&D with buyers and suppliers receives the highest score for intense collaborations (51.23%). 24.1% of the firms respond that they don't have any intense collaborations at all. This section has described the different concepts by using univariate analysis and only looked at the individual items. In addition, the next section will discuss the correlations between the concepts.

4.1.2 Correlations

In this section, a bivariate analysis is discussed with the aim of investigating whether the dependent, independent, and control variables are correlated with each other. The correlation matrix is shown in table 4 and it shows Pearson's correlation coefficients. The corresponding SPSS output is shown in appendix 9. Variables are highly correlated with each other when the values are close to -1 or 1 (Field, 2013). The table reveals that the highest value is .933, exposing that the items collaboration domains and collaboration intensity are highly correlated with each other, which potentially might lead to the same results for both variables. This may possibly be caused by the overlap between the variables, as both are a part of the same dependent variable collaboration.

However, as both of the variables will be analyzed by separated multiple regression analyses, this high correlation does not influence the individual analyses.

	Coll. Domains	Coll. Intensity	Size	Sector: *Food*	Sector: *Textile*	Sector: *Construction*	Sector: *Chemical*	Sector: *Machinery*	Sector: *Electronic*	Digital techn in process	Digital elements in product	Incr. Product Inno.	Rad. Product Inno.
Collaboration Domains	1.000												
Collaboration Intensity	.933	1.000											
Size	.114	.137	1.000										
Sector: *Food*	-.126	-.117	.094	1.000									
Sector: *Textile*	-.003	.023	-.075	-.125	1.000								
Sector: *Construction*	.013	.005	.029	-.049	-.066	1.000							
Sector: *Chemical*	.049	.047	-.104	-.117	-.158	-.062	1.000						
Sector: *Machinery*	.186	.162	.167	-.144	-.195	-.076	-.183	1.000					
Sector: *Electronic*	-.024	-.018	-.019	-.168	-.227	-.088	-.213	-.262	1.000				
Digital technologies in process	.231	.261	.348	-.035	-.095	.059	.068	.077	-.067	1.000			
Digital elements in product	.235	.245	.200	.101	-.076	-.124	-.096	.248	.055	.288	1.000		
Incremental Product Innovation	.164	.188	.037	-.024	.033	.075	.057	.008	.034	.207	.157	1.000	
Radical Product Innovation	.125	.163	.096	.197	-.047	-.103	-.183	.173	-.046	-.040	.165	-.331	1.000

Table 4 Pearson Correlation matrix

4.1.3 Multiple regression analysis

The multiple regression analysis is used to analyze the relationship between the single dependent variable and several independent variables. For this research, it will be tested whether the collaboration domains and collaboration intensity are influenced by the independent variables “Digitalization” and “Product Innovation”. As the dependent variable Collaboration consists of two dimensions; collaboration domains and collaboration intensity, this paragraph will perform two separate multiple regression analyses. The first regression analyses will study the relationship between the dependent variable collaboration domains, the independent variables digitalization, and product innovation, and the control variables firm size (log) and industry sector. The second regression analysis will study the relationship between the other dependent variable collaboration intensity and the same independent and control variables. The reference category are manufacturing companies with at least 10 employees, operating in the metal industry and not using product innovation. This reference category will be kept constant and all the other variables will be compared to this category. It is critical to hold the reference category constant as it allows to assess the effect of each variable in isolation (Hair et al., 2014).

Model fit

The model fit explains how much variation of the dependent variable can be explained by the established model. If the probability falls below the critical value of a 5 % error rate, the model explains a sufficient amount of variation to reflect a genuine effect in the population (Field, 2013). There are two models. The first model only includes the control variables firm size and industry sector and the second model contains all the variables belonging to the hypothesized effects. An overview is given in appendix 10.1 for both the dependent variables collaboration domains and collaboration intensity. The Model Summary output tests the explanatory power of the model and if the model fit improves as predictors are added (Field, 2013). The results are shown in appendix 10.2. First, the model summary for the dependent variable collaboration domains will be analyzed. The SPSS output is shown in table 5. The first model, only including the control variables, has an R Square of 0.065, which means that this model explains 6.5% of the variation in the dependent variable collaboration domains. The same goes for the other dependent variable, collaboration intensity, shown in table 6. Model 1 has an R Square of 0.064, which means that this model explains 6.4% of the variation of the dependent variable collaboration intensity. Both models have a Significance F Change value that is higher than the critical value of 0.05. This means that the control variables on their own do not significantly affect both the dependent variables. The second model includes the hypothesized effects. When these effects are included, the R Square of collaboration domains increases to 16.1%, and the R Square of collaboration intensity increases to 19.6%. This is for both a significant improvement compared to model 1, as the significance is 0.000 (<0.05). This indicates that for both the dependent variables the explanatory power of the independent variables gives a significant improvement over alternative explanations based on the control variables (Hair et al., 2014).

Model fit evaluation – Collaboration domains						
Model	**R Square**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**
Model 1: Control variables	0.065	0.065	1.923	7	193	0.068
Model 2: Control variables + Independent variables	0.161	0.096	5.421	4	189	0.000

Table 5 Model fit – Collaboration domains

Model fit evaluation – Collaboration Intensity						
Model	**R Square**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**
Model 1: Control variables	0.064	0.064	1.886	7	193	0.074
Model 2: Control variables + Independent variables	0.196	0.132	7.747	4	189	0.000

Table 6 Model fit – Collaboration Intensity

ANOVA is a second method to test whether the model captures the data and is not unnecessarily complex (Hair et al., 2014). The Anova tables in appendix 10.3 also confirm that the second models, including 11 parameters, are for both the dependent variables significant models (0.000 < 0.05) and are fitting the data good enough.

Statistical significance of the coefficients

To confirm the statistical significance of the coefficients, the significance values should be below the critical value of 0.05. Since the hypotheses are directionally formulated and indicating a positive direction, a one-tailed regression analysis is needed. The hypotheses not only indicate that an effect will occur, but it also states the direction of the effect (Field, 2013). The significance value for a directional hypothesis must be divided by 2 before comparing it with the critical value and accepting or rejecting the hypotheses. This will be done in the next section.

4.1.4 Hypotheses

As collaboration is divided into two separate parts to indicate whether there is a difference between the diversity and the intensity of the collaborations, two different regression analyses are performed with both their own dependent variable. The SPSS output of the regression analyses is shown in appendix 10.4. The analysis will start with analyzing the dependent variable collaboration domains. Afterward, the collaboration intensity will be analyzed.

Collaboration domains

The first concept is about the influence of Digitalization on collaboration domains. Digitalization is divided into two sections, the number of integrated digital technologies in the production process and the amount of integrated digital elements in the product. This results in the following hypothesis:

> H1A: *The digitalization of the manufacturing industry, involving a higher number of integrated digital technologies and digital product elements, increases the number of collaboration domains.*

The results of the regression analyses of the dependent variable collaboration domains are shown in table 7 on page 42. These results show that the hypotheses can be confirmed, as the significance values for both the number of digital technologies and the number of digital product elements are below the critical value of 0.05. At first glance, the values are not below the critical value of 0.05 as the value for

digital technologies is 0.55 and the value for digital product elements is 0.086. However, as both of the hypotheses are directional and the SPSS output includes a bilateral significance, the values should be divided by 2, resulting in values below the critical value of 0.05. This means that the digitalization does have a positive effect on the number of collaboration domains. So if firms integrate more digital technologies in their production process or include more digital elements in their product, the number of domains in which they collaborate increases.

Besides considering if there is an influence of digitalization on collaboration domains at all, the degree of the influence is also analyzed. The degree to which each predictor affects the outcome of the dependent variable is indicated by the size of the b-value (Field, 2013). The influence of digitalization on collaboration domains is significant in theory, however, the influence is relatively small, as b is 0.138 for the digital technologies and 0.221 for digital product elements. This means that when a firm has 1 extra digital technology integrated into the production process, the amount of collaboration domains increases with 0.138. This suggests that companies must have integrated a reasonable amount of digital systems, around 7 systems, to have one extra collaboration domain. For the number of digital product elements, this is slightly less. Firms should integrate between the 4 and 5 digital product elements to have one extra collaboration domain.

The second concept looks at whether a firm innovates incrementally or radically and whether this influences the number of collaboration domains. Based on different theoretical concepts, the next hypotheses are established:

> H2A: *When a firm focuses on radical product innovation, the number of collaboration domains will increase compared to firms with no product innovation.*
>
> H2C: *When a firm focuses on incremental product innovation, the number of collaboration domains will **not** increase compared to firms with no product innovation.*

As both the variables incremental and radical product innovation are dummies, they are compared to the reference category, which are manufacturing companies with at least 10 employees, operating in the metal industry, and not using product innovation. The results of the multiple regression analysis show that both radical and incremental innovation have a significant positive effect on the number of collaboration domains. The amount of collaboration domains for firms with radical product innovations is indeed increased compared to firms with no product innovation, so this hypothesis can be confirmed. Firms that focus on incremental product innovation have 0.759 more collaboration domains compared to firms that do not innovate their products. However, it was hypothesized that the number of collaboration domains of firms that focus on incremental product innovation would not increase, so this hypothesis has to be rejected. Firms that focus on radical innovation not only have more collaboration domains than the reference category, but they also have more collaboration domains than firms with incremental innovation.

To compare the different variables and their corresponding effects, the standardized coefficient Beta can be used. The standardized Beta of radical innovation is the highest with 19%, indicating that radical innovation has the most relevant effect on collaboration domains.

Finally, the control variables are also analyzed. The control variable firm size has a significance of 0.816, which is above the critical value and therefore not significant. This means that the size of the firm, so whether a firm is small, medium, or large, does not significantly affect the number of collaboration domains. Besides, the second control variable Industry sector was also not significant as all of the values are above the critical value. This implies that it does not matter in which industry sector a firm is operating as there is no significant difference in the number of collaboration domains for operating in a specific industry.

Results of multiple regression analyses – Collaboration domains				
Variables	**B**	**Standard Error**	**Beta**	**Significance (p<.05)**
Reference category				
Constant	1.242		-	0.056
Control variables				
Firm size	.039	.167	.017	.816
Food	-.835	.560	-.118	.138
Textile	.381	.458	.068	.407
Construction	.604	.891	.048	.499
Chemical	.661	.473	.113	.164
Machinery	.694	.448	.137	.123
Electronic	.198	.409	.043	.629
Independent variables				
Digital technologies	.138	.072	.147	.055
Digital product elements	.221	.128	.131	.086
Incremental Innovation	.759	.358	.157	.035
Radical Innovation	.819	.326	.190	.013

Table 7 Results Regression analysis - Collaboration domains

Collaboration intensity

The second dependent variable is collaboration intensity. This variable adds up together the continuous collaborations and the collaborations that have occurred several times. When a firm collaborates multiple times or even continuously with the same partner, the collaboration is called an Intense collaboration. It is assumed that when firms are more digitalized, they will have a higher amount of intense collaborations. This results in the following hypothesis:

> H1B: *The digitalization of the manufacturing industry, involving a higher number of integrated digital technologies and digital product elements, increases the number of intense collaborations.*

The results of the regression analyses of the dependent variable collaboration intensity are shown in table 8, next page. The regression analysis proves that the number of digital technologies as well as the digital product elements both have a positive significant effect on the number of intense collaborations, so the hypothesis can be confirmed. However, just as with the collaboration domains, the influence of digitalization on the amount of intense collaboration is relatively small. To actually achieve an effect of

digitalization on the amount of intense collaboration, a firm needs to integrate at least 6 digital technologies in their production process or include 5 digital elements in their product. Only with that amount of digitalization in a firm, the number of intense collaborations will increase with 1.

The second concept looks at whether there is a difference in the number of intense collaborations between firms that focus on incremental and radical innovation compared to firms that use no product innovation. It is expected that both radical and incremental innovations lead to a higher amount of intense collaborations compared to firms with no product innovation, which leads to the following hypotheses:

> H2B: *When a firm focuses on radical product innovation, the number of intense collaborations will increase compared to firms with no product innovation.*
>
> H2D: *When a firm focuses on incremental product innovation, the number of intense collaborations will increase compared to firms with no product innovation.*

The results of the multiple regression analyses show that both of the innovation types have a significant positive effect on the number of intense collaborations compared to firms with no product innovation. This means that both of the hypotheses can be confirmed. Especially the effect of firms with radical innovation is high, as they have 1.064 more intense collaborations compared to firms that use no innovation.

To compare the different effects, the standardized coefficient Beta is used. Radical innovation has again the strongest effect (25%) on a number of intense collaborations, making it the most relevant one. The effect of radical innovation not only has the strongest effect on the collaboration intensity, but it also has a higher percentage than all of the collaboration domain effects. It is also checked whether the control variables affect collaboration intensity. All of the significance values are above the critical value of 0.05 and are therefore not significant. Just like with the collaboration domains, the firm size and industry sector do not have a significant effect on the collaboration intensity of the participating firms.

Results of multiple regression analyses – Collaboration intensity				
Variables	**B**	**Standard Error**	**Beta**	**Significance (p<.05)**
Reference category				
Constant	.642	.626	-	0.306
Control variables				
Firm size	.074	.162	.033	.648
Food	-.827	.543	-.118	.129
Textile	.536	.444	.097	.229
Construction	.511	.864	.041	.555
Chemical	.697	.459	.129	.130
Machinery	.544	.434	.108	.212
Electronic	.242	.396	.053	.543
Independent variables				
Digital technologies	.162	.070	.174	.021/2 = .011
Digital product elements	.204	.124	.123	.100/2 = .005
Incremental Innovation	.932	.347	.195	.008/2 = .004
Radical Innovation	1.064	.316	.249	.001/2 = .001

Table 8 Results Regression analysis - Collaboration Intensity

4.1.5 Summary quantitative analysis

All six of the formulated hypotheses were tested by examining the quantitative data with a multiple regression analysis. The conclusions of all the hypotheses are shown below in table 9. The construct of digitalization was divided into the number of integrated digital technologies in the production process and the number of integrated digital elements in the products. Furthermore, the construct of collaboration was divided into the number of collaboration domains and the frequency of the collaborations. Both of the constructs of digitalization had a significant positive influence on the number of collaboration domains as well as on the intensity of the collaborations. Additionally, product innovation was also divided into two parts, incremental innovation, and radical innovation. Both forms of product innovation had a positive influence on the number of collaboration domains and the intensity of the collaborations.

Hypotheses		
Collaboration domains		
	Hypothesis	**Conclusion**
H1A	The digitalization of the manufacturing industry, involving a higher number of integrated digital technologies and digital product elements, increases the number of collaboration domains.	Supported
H2A	When a firm focuses on radical product innovation, the number of collaboration domains will increase compared to firms with no product innovation.	Supported
H2C	When a firm focuses on incremental product innovation, the number of collaboration domains will **not** increase compared to firms with no product innovation.	Rejected
Collaboration intensity		
	Hypothesis	**Conclusion**
H1B	The digitalization of the manufacturing industry, involving a higher number of integrated digital technologies and digital product elements, increases the number of intense collaborations.	Supported
H2B	When a firm focuses on radical product innovation, the number of intense collaborations will increase compared to firms with no product innovation.	Supported
H2D	When a firm focuses on incremental product innovation, the number of intense collaborations will increase compared to firms with no product innovation.	Supported

Table 9 Conclusions of hypotheses

The quantitative method provided insights regarding the presence, direction, and strength of the relationships between the dependent and independent variables. In the next paragraph, the constructs and the interconnecting relationships will be discussed in more detail by using the qualitative data. The qualitative data will be used to give clarifications, examples, and other information regarding the accepted and rejected relationships.

4.2 Qualitative analysis

To find more information about the constructs and the relationships between these constructs, six semi-structured interviews were conducted. The firms are kept anonymous concerning their name, but to differentiate the firms, they will be described according to their company size and industry sector. The interviewed firms vary in size from 7 employees to 20.000 employees and they are operating in six different industries. In appendix 11.1 an overview of the interviewed firms is given. The interviews are analyzed and coded based on theoretical constructs. For every construct, the most relevant quotes of the

interviews are selected and presented in this chapter. After discussing the constructs, the relations between the construct will be analyzed. This section will finish with an overview of the aggregated results of both the quantitative and qualitative analysis.

4.2.1 Main constructs

The three constructs product innovation, digitalization, and collaboration will be discussed in this paragraph. The definition of every construct will be briefly repeated, followed by a representation of the most relevant quotes per subject and the conclusions that can be drawn out of these statements.

Innovation

The first construct is innovation. Armbruster et al. (2006) describe innovation including product and process innovation. Product innovation is defined as the development of new products or technologies supported by the R&D activities of the company, while process innovation aims at finding new process technologies to produce more cheaply, faster and in higher quality. To find out how innovative the interviewed firms are, it is asked what innovations or improvements the company has added in their production process and whether they have improved their existing products or introduced new products in the recent years. The most relevant, interesting, and notable statements regarding this topic are viewed in table 10.

Table 10: Quotes on innovation

Company	**Quote**
1: CF	"Onze R&D afdelingen die over de hele wereld verspreid zitten werken nauw samen met elkaar, voor zowel grondstoffen als smaakstoffen. Op beide gebieden proberen we zo veel mogelijk in te zetten op innovatie van nieuwe smaakstoffen en nieuwe grondstoffen."
2: CT	"We zijn als het gaat om nieuwe producten ontwikkelen, daar doen we heel veel in. Dat is onze drijfkracht eigenlijk."
2: CT	"Doordat we veel aan pull marketing doen bij de brands, dan moet je dus voortdurend komen met nieuwe ideeën. Dat kan ook een oud idee zijn in een nieuw jasje, het hoeft niet altijd volle 100 procent nieuw zijn."
3: BS	"We proberen wel elk jaar nieuwe producten aan te bieden, maar het is niet zo dat we elke week een nieuw product lanceren, maar elk jaar wel 1 of 2 nieuwe smaken. Het is een erg conservatieve markt. Mensen zijn ook van wat de boer niet kent eet hij niet. Dus als het nieuw is denken ze al gauw van geef ons maar gewoon normale croissant of normale saucijs, dat ken ik dus eet ik."
4: FC	"Wij zijn echt enorm actief met nieuwe smaken en producten, dus ik denk dat per jaar we ongeveer 20 projecten lopen waar nieuwe smaken of verpakkingen worden geintroduceerd. Dus ik denk dat we gemiddeld 20 projecten lopen met iets van 4 producten daarin de producten, dus iets van 80 innovaties per jaar."
5: IE	"Vaak is de marktvraag kostreductie. Dus die komen vaak van jullie produceren dit product en we willen dit komende tijd weer bij jullie doen en we willen 10 procent prijs reductie. Hier komen veel van onze innovaties uit voort."
6: PT	"Elk jaar proberen we minimaal 1 product te innoveren, maar heel veel meer is het zeker niet, want we zijn maar een klein bedrijf."

Table 10 Quotes on product innovation

The interviews revealed a difference between the companies regarding their degree of innovativeness. The product innovations range from adding something new to an existing product, developing a completely new product, or even entering a whole new market. The two largest firms innovate the most

and they view innovation as the driving force for their competitiveness, while the two smallest firms only see innovation as a small contribution to their core activities. This means that even though the quantitative analysis showed that the control variable firm size was not significant, for the qualitative data it is. Besides product innovations, the companies were also asked what process innovations they have adopted. Most of the interviewed firms gave examples of digital process innovations, which are explained in the next section.

Another way to differentiate the products is by adding services to it. One of the firms gave this example of adding services to the product to create more value for the customers: *"If there are problems during the customer's production, we offer service to help think and solve the problem, we may even send people there(CF)".* The concept of adding a service to a product is also known as servitization, and it can include many different services to satisfy and maintain the customers, which corresponds to the statement of the chemical food company: *"We do workshops during the development of flavoring, at the request of the customer. Depending on what they want, we do marketing like workshops, give lectures, give information, even taking over part of the development of the end product(CF)".* Servitization is always included in the product, as customers don't have to pay for these extra facilities.

The firms were also asked what drivers and barriers they experience for their innovation. The main drivers for innovation are changes in the competitive conditions caused by new market entrants (PT), fluctuating market demand (BS), and improving the production process to become more efficient and reduce the costs (IE). A remarkable recurring answer to the question of how innovations are created are suggestions of the employees. So stated one of the companies: *"There are also innovations coming from the factory itself or from the people in the work preparation itself. Employees report that they experience a lot of problems and sometimes they even say: we can't do it like this, so we have to change it. Then sessions are organized to discuss that in class(IE)".* As the employees are closest to the production process, they might recognize where bottlenecks occur. However, one of the firms indicated that the most useful ideas come from the higher educated staff as they have suiting knowledge of a certain aspect and understand whether it is feasible or not. Besides drivers to innovate, the firms also experienced barriers that withhold them to innovate. Barriers to innovate are lack of manpower, knowledge, and budget: *"The main problem with innovating is manpower, to free up time in addition to your normal work because we are small(PT)".* Besides, one of the firms stated that the quality of their products is of higher importance than product innovation, so they don't invest much time and money in developing new products. They distinguish themselves by offering high-quality products and they stated that they are known for their flexibility, so product innovation is not of much relevance for them and definitely not a critical focus point.

Digitalization

The next construct is digitalization. Digitalization is defined as the exploitation of digital opportunities and it combines different technologies, such as cloud technologies, big data, and 3D printing (Rachinger et al., 2019). These emerging technologies create many possibilities for firms, for example, to produce new products, optimizing resource utilization, and augmenting the supply chain. To determine how digitalized firms are, it was asked what kind of digital transformations the company has gone through over the past few years. The most valuable and applicable results of the interviews are shown in table 10.

Table 10: Quotes on digitalization

Company	Quote
1: CF	"Wij zijn een bijzonder innovatief gedreven bedrijf, niet alleen op het gebied van ontwikkelen van nieuwe grondstoffen, maar ook het toepassen van nieuwe methodieken van werken vinden wij erg belangrijk. Ook omdat, om mensen aan te trekken om binnen ons bedrijf te werken, willen ze met de meest moderne tools die beschikbaar zijn werken. En dat betekent dat we op alle gebieden, of het nou HR systemen zijn, of operationele systemen, of dat het presentatie systemen zijn om presentaties te maken, video's daarin te implementeren, onze mensen binnen R&D hebben natuurlijk hun software nodig, eigenlijk op allerlei gebieden willen we altijd het nieuwste van het nieuwste hebben."
2: CT	"Innovaties in de productie zijn, zal ik maar zeggen, bijna niet aanwezig, omdat wij dus heel veel producten in relatief kleine batches maken is het automatiseren daarvan heel lastig, dus het batches proces is wat minder makkelijk te automatiseren dan een continu proces. Het is voortdurend anders."
3: BS	"Wat betreft digitale verandering alleen de website, verder niet echt. Ja je hebt onderhoudt, dat kan nu op afstand gebeuren. Voor de rest is er niet veel gedigitaliseerd. Soms is het handiger om iets met de hand te blijven doen in plaats van het te automatiseren. Op de oude manier was het ook goed, maar dat verschilt per bedrijf."
4: FC	"Wat er voor digitale vernieuwingen zijn, dat zit vooral in nieuwe verpakkingen die over de lijn kunnen worden geproduceerd. Ik denk dat de innovatie op dit moment vooral zit in nieuwe verpakkingen maar ook nieuwe ingrediënten, die we nog niet eerder in productie hebben gehad. Concreet aan de productielijn veranderd er niet veel."
5: IE	"Ja onze strategie, waar die echt gefocust op is, is wel echt digitalisering en automatisering. Wat ons dan onderscheidt ten opzichte van concurrenten is dat normaal zie je dat concurrenten die hebben veel robots en automatisering, alleen die produceren dan in een nachtshift voor 1 specifieke functie. Doordat wij die AGV hebben, kunnen wij nachts ook naar andere machines door rijden waardoor er een andere bewerking, zoals X waardoor wij nog sneller zouden moeten kunnen leveren en flexibel zijn."
5: IE	"Papierloze fabriek. Dat is een hele grote verandering geweest, dus we hebben hier overal in de fabriek hardware geïnstalleerd waar de mensen alle benodigde product en order informatie kunnen ophalen. Voorheen gingen alle orders, stukmateriaal met fysieke tekeningen de fabriek in."
6: PT	"Nu zijn we vorig jaar in december begonnen met een CRM pakket. Dat is in feite een papierloos, ja, CRM pakket. Customer Relatie Management systeem is dat. Dus klanten nemen contact met ons op, bedrijven worden er ingevoerd in systemen, klanten ingevoerd, alles gesprek, elk mailtje of elk dingetjes wat je doet, dat komt in het systeem."

Table 1 Quotes on digitalization

Again, just like with the construct of innovation, a difference between the interviewed firms was identified regarding their opinion towards digitalization. Some of the firms stated that digitalization is of high importance, as it is their core activity, they use it to differentiate themselves and are also including it in their strategy for the upcoming years: *"In the next 5 years we want to take that step of digitalization and automation further and further as this creates our distinctiveness and enables us to produce ever more efficiently(IE)"*. Some digitalized as much as possible, while others only integrated

one system. One of the most common given examples of digital changes was the implementation of online information systems, such as enterprise resource planning (ERP) or consumer relationship management (CRM) systems. The availability and utilization of data that comes with using these systems allowed the firms to know exactly what they have in stock and when they need to reorder something (CF), expand the product portfolio in accordance to obtained information on consumer behavior and predicted trends within the industry (CT), and be able to set precise targets based on historical data and forecasting programs (FC). Besides, these systems and the combined hardware have made the firms more sustainable by reducing the number of printed papers and becoming almost paperless factories. One of the firms stated: "*The systems make it much easier to exchange documents, work together in documents, and store documents. As a result, almost every one of the firm has access to many different types of documents, and the need to print is almost reduced to 0 (CF).''*Another positive impact of digitalization was the possibility to integrate robots into the manufacturing process. The industrial engineering company integrated an automated guided vehicle (AGV) to handle the internal logistics in their factory. According to them, the AGV transports the components of the products between the different production and assembly machines making the factory one automatic entity. This improved the speed, flexibility, and scalability of the manufacturing process. The chemical food firm illustrated another advantage of using robots: *''This artificial intelligence-driven tool allows perfumers to focus on their own creative work and at the same time get digital support from the robot, it really is an additional support (CF)"*. In addition, the firms stated that digitalization has also helped the companies to become less staff-dependent. The chemical textile company stated: "*The automated process makes man independent, so if someone falls away, it's not just a hole, but the processes keep going. So it gets more reliable (CT)"*. The patient transport factory verified this by explaining that their digitalized process gave much more clarity in the absence of people and that the company became much stronger as they were less dependent on a specific staff member.

However, the firms also identified several obstacles and barriers for the integration of robots and usage of the digitalization possibilities, such as that the design of the products had to be adapted to the working method of the robots (CF), that it is cheaper to outsource production in low-wage countries where it is done manually (CT), and that robots and automatization would eliminate the flexibility of the firm (BS). These are some of the reasons why several of the firms have only implemented small digital elements. In addition, according to the industrial engineering firm, digitalization also led to resistance among employees. This was the case because the employees did not like unknown change and the firm had difficulties with re-educating older factory employees who are not as familiar with digitization as the generally younger people who grew up with it. Besides, the industrial engineering firm also stated that digitalization made them more vulnerable as they became more dependent on their systems. One of the examples is that they recently had a data breach and therefore had to shut down the whole system.

Another example of how digitalization can be fatal for companies is that disruptive new digital technologies can change entire industries and exclude incumbent firms over just a few months. The chemical textile firm explained that 3D printing is an example of one of these upcoming techniques that might disrupt the whole textile chain. 3D printing makes it possible for consumers to print their textile products at home, excluding the practices of the textile producing firm out of the entire supply chain. This example shows that firms need to be extremely vigilant about digital technologies, as they can change the whole industry. The food company concluded the following about digitalization: *"Digitization is a very good development, it gives a lot of efficiencies, but is also very unpredictable and can be a very complicated process that takes much longer or is much more expensive than you had ever predicted (FC)."*

A few of the firms that participated with this research, do fit the definition of digitalization as they view digitalization as a major driver of change and they have to adapt themselves to survive and remain competitive. However, not all of the firms experience digitalization the same, as some responded that they have only implemented small digital changes. The smaller firms experience more obstacles to implementing digital opportunities as they have a lower budget, not enough space or lack the necessary knowledge. Furthermore, it also depended on which industry a firm is operating, as some of the industries are much more digitalized than others. The textile industry stated that their industry produces a lot of new products every year with new designs, but the production process has not changed much: *"The textile industry is a very strange industry, I think. On one hand, especially from a fashion and technical point of view, it is a highly innovative industry. Fashion has to come up with something new every time, design and technique as well. So there is a lot of innovation on that side. However, when I look at the production of textiles, we don't really do that much different than we did 50 years ago (TC)".* So this industry is not experiencing a lot of digitalization. However, on the other hand, the chemical food industry, for example, is a huge digitalized industry with implemented artificial intelligence systems, robots, and several more digital technologies. This means that how digitalized a company is, depends on the specific industry and the size of the company.

Collaborations

The third construct is collaboration. Collaborations are defined as inter-firm relationships in which the participating partners agree to invest resources, jointly achieve objectives, and sharing knowledge, rewards, and responsibilities (Chan & Prakash, 2012, p. 4671). As the quantitative part divided collaboration into the collaboration domains and intensity, the same division is made in the interviews. To obtain information about the collaboration domains and the frequencies, the firms were asked in which areas and with which partners their company collaborates. Examples are collaborations with suppliers, customers, start-ups, and universities and the collaboration frequencies vary between occasional and continuous. Table 11 shows the most relevant quotes regarding this topic.

Table 11: Quotes on collaboration	
Company	**Quote**
1: CF	"Wij werken ontzettend veel samen met heel veel verschillend partners, zowel leveranciers, klanten, startups, universiteiten, chef-koks."
2: CT	"Je kan wel een mooi verhaal hebben, maar hij mist een distributiekanaal. Na 2 jaar is hij zwaar gefrustreerd, want dan heeft hij 3 kilo verkocht van zijn producten, dat werkt dus niet. Wat ik dan doe, is aanbieden om hun distributiekanaal te zijn. Dus dan kan je met kleine partijen, kan je samenwerken."
3: BS	"Nou wij hebben onze machinefabriek hiernaast zitten, Rademaker, die als wij nieuwe machines nodig hebben, dan bouwen zij die voor ons. Daar tegen over staat dat zij bij ons langs mogen komen met bezoekers. Ja dat is eigenlijk de enige bekende samenwerking die we hebben."
4: FC	"Alleen samen gaat het lukken om echt verandering te weeg te brengen."
5: IE	"Dan zorgen we dat we samen met de eindgebruiker dat wij tegen dezelfde condities die spullen kunnen inkopen, omdat onze eind klant anders nog meer betaald terwijl als ze direct zelf inkopen zijn ze minder kwijt."
6: PT	"Dus dat is een goede samenwerking en dat is het nog steeds en ook heel competitief wat betreft prijzen zijn ze, zo'n samenwerking met een leverancier is dan wel erg belangrijk voor ons."

Table 2 Quotes on collaboration

The first domain in which companies collaborate relates to their R&D department and takes place mainly to stimulate their innovation. One of the firms gave the example of joining a consortium. A consortium is an association including several individuals, companies, organizations, and governments with the objective of contributing to a common activity or combining their resources for achieving a common goal (Venugopal Ramanathan, 2016). The firm stated: *"We are joining a few consortiums, all in the field of food and nutrition. We are joining as a flavoring company, but also companies like Mille, Unilever, Nestlé, several software companies, consultancy companies like McKinsey, and many more all joined. We all together look at which direction the world is going regarding food products (CF)."* A notable example of a knowledge consortium is the so-called Digital Factory, initiated by one of the firms. It is aimed to accelerate projects and combines the firm's experts, partners, and customers from all over the world to discover new ways to transform their business and lead opportunities in an ecosystem of innovation. The CEO of the firm stated in a media release: *"Innovation has always been at the heart of our strategy. In the past few years, we have successfully piloted the potential of artificial intelligence, big data, and emerging technologies. The launch of our Digital Factory will help us to accelerate these digital opportunities and further expand into new spaces as we continue shaping the future of our industry by leading the way into the next era of customer experience (CEO, CF)".* Combining the knowledge of several parties, enables the firm to widen its innovative space and reinvent ways to create, develop, and produce improved products.

Another example several of the interviewed firms gave was that they collaborate with universities. Collaborating with universities gives chances to use the knowledge of the students to come up with new products and optimize existing products (CT), get in contact with students who might be potential employees (CF), and sponsor projects which might be beneficial for the firm (IE): *"Now we sponsor HAN's hydrogen car because as a company we see a lot of future in hydrogen as a sustainable energy source (IE)."* A third partner which firms collaborate with regarding their R&D are start-ups: *"You try*

to work with start-ups that you think have a unique concept, you try to be the first to work with them, so that the competitor is not in it, that we don't miss the boat. (CF)". The firms can use the groundbreaking ideas of the start-ups, so they don't always have to come up with innovations on their own. One of the firms stated that the collaborative working method of their customers is changing in their industry and that firms are opening up for collaboration regarding their innovation: *"There are a number of our customers who are reducing their own R&D department and are now going to work much more with us to create innovations together. So that's the other way around, that you're really going to work with your customer to get something done (CT)".* Another firm stated that they also involve customers more in the development process of the products to include their demands: *"We sometimes even do part of the development of the end product, because customers are cutting back more and more on product development (CF)".*

The second collaboration domain is co-production, as firms also collaborate to share the production. One of the firms explained that the production process exists out of many different specialized activities and you cannot be able to do everything yourself: *"You cannot have all the equipment yourself, you have to work together. So at the moment, we have a network of I think 5 or 6 companies where we have certain processes that we can't do ourselves(CT)".* Another firm explained that they also outsource part of their production as other firms can produce much more efficiently. Furthermore, partnerships for co-production are also used in case they have capacity problems with their production, share purchase conditions to get competitive price agreements, and combining the strengths of both partners: *"That you can realize qualitatively priced purchasing components and that you can also use the know-how you lack from your partners. So really combining the strengths of each other(PT)".*

The frequency of the collaborations depends on both the collaboration domain and the goal of the collaboration. Participation in a consortium is intended to last several years, not just for a single project. The same goes for integrating customers in the development process, this collaboration is established to continue for several years and to be able to benefit from this for a longer period of time. However, other partnerships can be based on collaborations for a short period of time, such as the collaboration of the firm that is trying to transforms the purchase process to make it more sustainable. As soon as the transformation process is completed, the collaboration stops. Strikingly the control variables firm size and industry sector are of no importance for this construct. The size of the firm did not matter, as the small, medium, and even the big firms stated that collaborations are of high importance for them. There is one outlier, as the bakery supplier stated that they do collaborate as it is convenient, but certainly not necessary.

Coopetition

One of the collaboration domains that are of specific interest within this research, is a collaboration with competitors, also called coopetition. Success in today's business world frequently requires that firms

pursue both competitive and cooperative strategies simultaneously (Lado et al., 1997). So instead of viewing competitors only as rivals, they could also be seen as potential collaboration partners, forcing manufacturing companies to rethink their competitive approaches. To determine how firms view this form of cooperation, it is asked whether or not they have cooperated with competitors in recent years, how they selected competitors to work with and how they ensure that their market position is not jeopardized by the cooperation. The most relevant quotes are viewed in table 12.

Table 12: Quotes on collaboration with competitors

Company	**Quote**
1: CF	"Ja we hebben in het verleden wel eens samen gewerkt met concurrenten, dat hebben we gedaan om te kijken of we gezamenlijk iets kunnen doen. Dat is ver gegaan, dat we bepaalde programma's op gezet hebben waarbij we samen dingen gingen ontwikkelen, maar dat is helaas niet succesvol gebleken."
2: CT	"Ja wij werken zeker samen met concurrenten. We hebben zelfs 1 accountmanager die doet wat wij noemen de co-producers. Co-producers zijn onze concurrenten, groot en klein, waar wij ook chemie van kopen. Dus wij kopen van hen, zij kopen van ons en ook daar, soms is het letterlijk inkopen en verkopen en soms gaat het ook samen verder dingen ontwikkelen om dingen te doen omdat je het inderdaad zelf kan niet."
3: BS	"Nee, wij werken moment niet samen met concurrenten. We hebben wel begin het jaar een concurrenten geholpen toen zij niet konden produceren. Wij hebben toen voor hun geproduceerd wat weer voor een supermarkt keten was. Dat was meer op aanvraag dat je elkaar dan probeer te helpen als het uitkomt en past binnen de organisatie. Niet een verder gaande samenwerking, dat niet."
4: FC	"De missie is altijd nummer 1 en in principe ben je natuurlijk op zich concurrenten van elkaar, want je ligt in hetzelfde schap, maar uiteindelijk is ons doel dat zoveel mogelijk merken op deze manier inkopen. Dus we zijn in die zin niet competitief, als we mensen kunnen betrekken bij de missie, dan stellen we onszelf helemaal open en kunnen ze erbij."
5: IE	"Ja we hebben concullega's waar we mee samenwerken. Op het moment dat we capaciteitsproblemen, iets wat wij niet kunnen en zij wel of andersom, dan hebben we wel een aantal samenwerkingsverbanden mee."
6: PT	"Nee, dat hebben we wel eens geprobeerd maar op dit moment werken we niet samen met concurrenten."

Table 3 Quotes on collaboration with competitors

The interviews revealed that all of the firms have in the past few years tried to collaborate with competitors. Several reasons to collaborate with competitors according to the interviewed firms are to enter new markets where the firms are currently not yet strongly represented (CF), when the firms don't have the necessary equipment or knowledge on their own (CT), and when the competitors might be potential suppliers or buyers (IE). One of the firms explained that collaborations are always about the benefits for both of the parties: *"By also indicating what our competence in such cooperation could be. It's always about benefits, always making sure that someone sees that they can also benefit from the collaboration (CT)".* The industrial engineering firm gave an example of a firm that has the same customers, so they could be defined as competitors, however, the two firms still work in harmony and help each other out. When they needed extra expertise for their machines, they exchanged knowledge: *"We asked our competitor if one day one of them could come over here and explain about those machines. So things like that are also done, so even training sessions between competitors(IE)".* However, they could collaborate as they both offer several disciplines, so they are competitors on a

certain discipline, but they can help each other out on a discipline in which they are not both operating. Besides, the firms stated that in case of emergency, like water damage, machines that don't work, or other accidents, the firms are also open to coopetition: *"If we have a customer demand that we really need to be able to answer and deliver, we might ask a competitor if they can produce for us, but that would have to be done under strict quality control to make sure we could deliver the same quality (BS)"*. However, only 3 of the 6 firms are still collaborating with competitors. The firms stated that trust and suspicion is one of the reasons why collaborations with competitors did not work out: *" The mutual trust, you are vulnerable because you see opportunities to work together. If then the information you deposit is abused by the competitor as they place short-term profit above the collaboration, then you have no further need to work with together (PT)"*, and: *"Because they were competitors, on both sides there was a lot of suspicions if they were not going to use our innovation and use it in their own products instead of just in the program we were setting up together (CF)"*. One of the firms that are in favor of collaborating with competitors, also stressed the importance of trust in collaborations with competitors: *"Collaborations always start with Non-Disclosure Agreements, where you have your own input and the other party is not allowed to use it without the other party's permission. So it is legally established, but the day-to-day effect comes down to pure trust (CT)"*. The firm stated that when the market is large enough, collaboration with competitors can strengthen each other's core competencies and be beneficial for both. However, the firms stated that the lack of trust and the negative experiences caused the competition to rise above the collaboration.

4.2.2 Inter-concept relations

After describing the independent and dependent constructs isolated, this section will describe the relations between the different constructs. For every construct, the hypothesized effects will be repeated and afterward, the most important quotes for that specific relationship will be viewed and interpreted.

Relation Digitalization and Collaboration

It was conceptualized that digitalization has a positive effect on the number of collaborations as digitalization might facilitate the collaboration process (Rachinger et al., 2019) and industrial changes might force firms to enhance their internal capabilities with capabilities of others (Daidj, 2017). Whereas the quantitative analysis statistically calculated whether there was a correlation between both the concepts, the qualitative analyses will be based on the quotes of the respondents and whether they experience the conceptualized relation.

Table 13: Quotes on relation digitalization and collaboration	
Company	**Quote**
1: CF	"Als je kijkt naar andere leveranciers, daar zijn we veel meer mee gaan samenwerken door digitalisatie. Vroeger kocht je gewoon een paar dingen bij een leverancier en dat was het, nu is die samenwerking veel nauwer, intenser. Gericht ook op wat wij nodig hebben en dat ontwikkelen zij dan met ons."
2: CT	"Niet door de digitalisatie zelf, maar ik denk dat we wel meer partners hebben gevonden de afgelopen jaren. Digitalisering brengt mogelijkheden met zich mee om makkelijker in contact te treden met partners wereldwijd."
3: BS	"Nee denk niet dat digitalisatie onze samenwerkingen beinvloed, het is niet meer of minder geworden door digitalisatie."
4: FC	"Dat heeft denk ik niet echt heel erg verbinding volgens mij. … Ik denk op zich wel dat hoe meer traceerbaar X wordt, dat is hoe er wellicht meer digitalisering er bij komt kijken. Ik denk ook wel dat er een voordeel in zit hoor, om als je digitale proces hebt dat je dan ook beter kan traceren, dat misschien concurrenten daar ook meer geïnteresseerd in willen zijn."
5: IE	"Ik denk niet dat we op meer terreinen zijn gaan samenwerken, maar soms misschien wel minder persoonlijk contact met onze huidige partners."
6: PT	"Nee de noodzaak van samenwerken staat er los van. Digitalisering is meer een middel en een instrument."

Table 4 Quotes on relation digitalization and collaboration

Table 13 shows that five of the six companies have not directly confirmed that they have begun to collaborate to a greater or lesser extent as a result of digitalization. However, their additional explanation subsequently shows that digitalization does have a positive effect on collaboration as they confirm that they think that digitalization is a mechanism that supports the collaboration process. Only the first firm admitted directly that they collaborate a lot more because of digitalization, as digitalization allowed their collaboration with suppliers to be much closer, more intense, and more focused on the specific needs of both of the firms. The other firms themselves did not feel that they have started to cooperate more or less through digitalization, but they do confirm the benefits of digitalization. One of the firms stated that digitalization makes their resources more traceable which supports the accomplishment of their mission. This can benefit the collaboration process because it is easier for them to convince others to help make their procurement process sustainable, which is the main goal of their mission. Another firm stated that because digitalization automates many processes, they have less contact with partners. This might be detrimental for the relationship: *"When you see each other a lot, you can get a positive opinion on that person which creates a bond. A partner might be more expensive, but you will grant it because I enjoy working with someone like that. This may disappear as a result of digitalization and automatization as there is no reason to talk to a supplier(IE)"*. However, even though this might be a disadvantage, yet the efficiency, speed, and scalability that digitization offers are of greater value according to them. Furthermore, other firms stated that digitalization makes it easier to get in touch with current and potential new partners through online networks and systems (CT), that digitalization enables the various business processes to be better aligned, streamlining the entire supply chain (PT), and be able to retrieve customers preferences and meet them earlier in the process (FC). This shows that even though the firms do acknowledge the benefits of digitalization, they are unaware and unconscious of the underlying importance of digitalization in the collaboration process. Despite the fact that they do not directly

confirm the positive relationship between collaboration and digitalization, this relation does exist. Based on this information, the conceptualized hypothesis can, just like the quantitative analyses, be accepted.

Relation Digitalization and Coopetition

As previously explained, coopetition is a specific form of collaboration in which firms cooperate with their competitors, simultaneously competing and collaborating with the same firms. Even though these firms fight for the same market share, it is hypothesized that the accelerated change in the market caused by digitalization, may force companies to reconsider their collaboration strategy and view competitors as potential cooperation partners. If firms lack certain skills to take advantage of digitalized opportunities, they will not be able to benefit from it, which may entail the loss of their competitive position. This means that digitalization might increase the need to capture and benefit from external sources of competitors to enhance their own firm's current technological development. Table 14 views the most important quotes related to this relation.

Table 14: Quotes on relation Digitalization and Coopetition

Company	**Quote**
1: CF	"Als je zegt aantal samenwerkingen met concurrerende partijen dan is het denk ik gelijkblijvend, daar zit niet veel verschuiving in aangezien we dit al niet veel deden."
2: CT	"Niet perse meer gaan samenwerken concurrenten, het is hoogstens makkelijker, omdat je makkelijk met elkaar in contact treed. Ook door netwerken als LinkedIn of wat dan ook."
3: BS	"Nee, ook niet. Wij zijn de afgelopen jaren gewoon niet zo veranderd. Het gaat goed, dus we hebben ook geen reden om onze werkwijze te veranderen."
4: FC	"Nee, ik bedoel we hebben wel bureaus nodig en leveranciers nodig die bijvoorbeeld machine onderdelen leveren en programma's voor die IPad maken, maar niet met concurrenten samen."
5: IE	"Digitalisatie heeft zeker een invloed op de relaties met concurrenten, want wij kunnen ons meer onderscheiden. Maar we gaan niet meer samenwerken door digitalisatie, als wij kennis te kort hebben willen we dat niet bij een concurrent halen, dan gaan er voor zorgen dat we dat zelf in huis halen."
5: IE	"Dus dat soort dingen worden ook wel dingen gedaan, dus zelfs trainingen van concurrenten onderling. Zelfde klanten, maar daar hebben wij gewoon een hele goede verstandhouding mee."
6: PT	"Nee we werken niet samen met concurrenten, dus dat is totaal niet veranderd door digitalisatie en gaat ook denk ik niet veranderen."

Table 5 Quotes on relation Digitalization and Coopetition

It is already explained that firms have tried to collaborate with competitors in the previous years, but that only half of the firms are still doing it. Even though collaboration with competitors can strengthen each other's core competencies and be beneficial for both, the firms stated that the lack of trust and the negative experiences caused the competition to rise above the collaboration. The qualitative results shown in table 14 reveal that the digitalization of the manufacturing industry did not change the need to collaborate with competitors or shift the opinion on coopetition over the past few years. The firms do not see any need to enhance their technological development with competitors. Digitalization only slightly helped to find new potential collaboration partners and made it possible to better distinguish the firm from competitors, but it did not stimulate cooperation with competitors. This means that digitalization does not increases the need to collaborate with competitors.

Relation Innovation and Collaboration

Table 15 shows the most relevant quotes for the relation between innovation and collaboration. Although it was assumed that there was a positive effect between innovation and cooperation, some of the interviews revealed counter wise. The firms stated that they do not want to be dependent on other firms regarding developing new products: *"No if we have an idea for a new product, but we can't do it ourselves, we're not going to do it either (BS)"*. Another firm stated that when they innovate new products, they want to bring and secure this knowledge inside and invest in it. They don't want to outsource it, as this might influence the price: *"If we don't invest in this and we have to do this outside the company then you are often a bit more expensive. When you have to work with different parties, it becomes difficult to be competitive and get a competitive price since all the companies that cooperate have to earn something from it (IE)".* They state that they favor developing their products based on their own capacities and not collaborate for their innovation. However, the other three firms disagreed with this, as they indicated that they definitely needed collaborations for their innovation. One of the firms stated that they do collaborate more over the years as their industry has become more specialized and they are not able to innovate and survive on their own. The other firm indicated that they are too small to innovate on their own and they need collaboration partners to give their innovation strength and viability: *"Our partners often support us with things that are beyond our control (PT)".* Finally, the third firm concluded that they are in favor of open innovation: *"Why would you put a lot of effort into developing something yourself when another company already has. You don't have to constantly reinvent the wheel yourself (CF)"*. Since the companies participating do not give an unambiguous answer to this conceptualized relationship, this hypothesis cannot be accepted based on the qualitative data.

Table 15: Quotes on relation innovation and collaboration

Company	**Quote**
1: CF	"Dat is allemaal van enorm belang voor onze innovatie, wij kunnen echt niet zonder die samenwerkingen."
2: CT	"Ja dus, omdat je zoals gezegd niet alles zelf kunt en steeds minder zelf kan omdat het specialistisch wordt, dus je moet letterlijk samen werken om succesvol te kunnen blijven."
3: BS	"We gaan niet nieuwe samenwerkingsverbanden aan als het niet perse nodig is, want het gaat nu gewoon goed. We willen niet afhankelijk worden van anderen, het echt doen van onze eigen krachten."
4: FC	"Nee ik denk dat dat altijd het zelfde is gebleven. Dit is niet echt veranderd."
5: IE	"Als er iets in onze strategie staat, bijvoorbeeld nu automatisering en digitalisatie staat in onze strategie, dan willen wij eigenlijk niet afhankelijk zijn van extern. Dan willen wij die kennis zelf in huis halen, omdat het hoort bij onze bedrijf strategie en dat moeten we zonder hulp van andere dit kunnen. Dat is onze visie hierop."
6: PT	"Ook hebben we samenwerkingen nodig om innovatief te blijven ja. Het geeft zoals ik net al zei onze innovatie vaartkracht."

Table 15 Quotes on relation innovation and collaboration

Relation Innovation and Coopetition

Table 16 reveals the most important quotes regarding the relation between innovation and coopetition. While the chemical food company stated that to stay innovative they definitely need collaboration partners, it does not force them to collaborate with competitors. They state that they only collaborate

with firms that produce different resources or serve different customers, so no competitors: *"We would much rather develop new products with other organizations where trust does not play such an important role and there is less risk of working together(CF)".* Other firms agreed as they are more likely to modify their own product portfolio than to collaborate with competitors. The food company also agreed, they're trying to persuade competitors to buy sustainably resources, but developing products together with competitors is completely out of the question. There is one exception, as the chemical textile company revealed that they would collaborate with competitors to enhance their internal capabilities. However, as this is the only deviation, it can be concluded that innovation, in general, does not affect the willingness to collaborate with competing firms. While chapter 2 gave examples of famous firms that collaborated with competitors to develop new products, improve their market position, or share production costs, this does not apply for the interviewed firms. This means that the hypothesis that innovation effects coopetition has to be rejected based on the qualitative data.

Table 16: Quotes on relation innovation and coopetition

Company	Quote
1: CF	"Nee niet zozeer met concurrenten, wij werken om onze innovatie te verbeteren wat betreft horizontaal niveau vooral samen met andere organisaties, maar dat zijn bedrijven die andere werkzaamheden uitvoeren, niet zozeer concurrenten."
2: CT	"Wij werken wel samen omdat wij hiermee onze kern competenties kunnen versterken door te specialiseren en te focussen en waar wij niet op focussen doen we samen met samenwerkingspartners, vaak dus ook concurrenten."
3: BS	"Ons productportfolio sluit goed aan op wat de klant vraagt. Mocht dit veranderen, dan passen we onszelf aan, maar we zouden niet gaan samenwerken met andere om hieraan te voldoen. Ook niet met concurrenten."
4: FC	"Nee, we werken samen met concurrenten om onze missie te volbrengen en de industrie te laten beseffen de grondstoffen op een eerlijke manier in te kopen, maar we werken niet samen voor onze innovatie, om producten te ontwikkelen."
5: IE	"Nou ja wij hebben wel doordat wij geïnnoveerd hebben bepaalde product groepen aangetrokken die er dan ook weer toe geleid hebben dat wij investeringen moeten doen in andere machines. Hierdoor zijn wij juist minder gaan samenwerken met concurrenten, omdat onze focus echt is op de toegevoegde waarde en dit willen we in huis halen en niet afhankelijk zijn van anderen."
6: PT	"Nee dat zie ik niet zo snel gebeuren. We ontwikkelen samen producten met leveranciers en klanten, zodat het proces makkelijker is, maar echt met bedrijven die dezelfde klanten bedienen zou ik niet snel gebruiken om producten te ontwikkelen nee."

Table 16 Quotes on relation innovation and coopetition

4.2.3 Summary qualitative analysis

To find more in-depth information about the three constructs and the relationships between these constructs, six semi-structured interviews were conducted. The qualitative data is used to give clarifications, examples, and other information regarding the overall relationships. First, the three main constructs are discussed. The interviews revealed a difference between the companies regarding their degree of innovativeness, as some were highly innovative with multiple product innovations a year, and some mainly focusing on their current product portfolio, only making a few adjustments to existing products. The same goes for the construct of digitalization, as there was a big difference between the interviewed firms. Some firms only implemented a single digital system, while another firm even

included digitalization within their industry, trying to differentiate themselves by being known as the most digitalized and efficiently producing firm. The construct of collaboration had more consistent answers, as all the firms had some collaboration partners. Regarding the interconnections between the concepts, it turns out that the qualitative data only supports the influences of digitalization on the collaborations. Digitalization does not affect the need to collaborate, but it does support and stimulate to collaborate more with several partners. The hypothesized influence of innovation on digitalization could not be supported based on the qualitative data. The last construct of the qualitative analysis is coopetition, which are collaborations with competitors. It turns out that even though digitalization has a major impact on the manufacturing market, it does not force firms to collaborate with competing firms. Lack of trust is one of the barriers that withhold firms to cooperate with their competitors and the changes in the market as a result of digitalization are not a strong enough force to overcome this.

4.3 Concluding words

The qualitative data is used to complement the quantitative analysis, making this research a mixed-method study. By combining the data, more in-depth information could be gathered regarding the three concepts of digitalization, innovation, and collaboration, and their interrelationships. Figure 5 on the next page shows the combined results of quantitative and qualitative analysis. The qualitative data focused on the overall effect of digitalization on collaborations, while the quantitative study was specified and subdivided into digital technologies and digital product elements and collaboration domains and collaboration intensity. The same goes for the effect of innovation, as the quantitative analysis divided the constructs into radical and incremental innovation and collaboration domains and collaboration intensity, while the qualitative analysis focused on the overall effect of innovation on collaboration. The results show that the qualitative and the quantitative data both support the hypotheses of the influences of digitalization on collaborations, both confirming the interrelationships between those 2 constructs. The influence of innovation is, however, different as the quantitative data confirm the influence of innovation on collaboration, but the interviewed firms did not acknowledge this relation, making it impossible to accept the hypothesis that firms need collaborations for their innovation. This research also focused on an additional collaboration domain, called coopetition and this part is mainly discussed in the qualitative analysis. The majority of the firms conceded that they do not collaborate with competitors at all, which showed that the digitalization of the manufacturing industry did not stimulate coopetition, neither did the need to capture external knowledge to innovate.

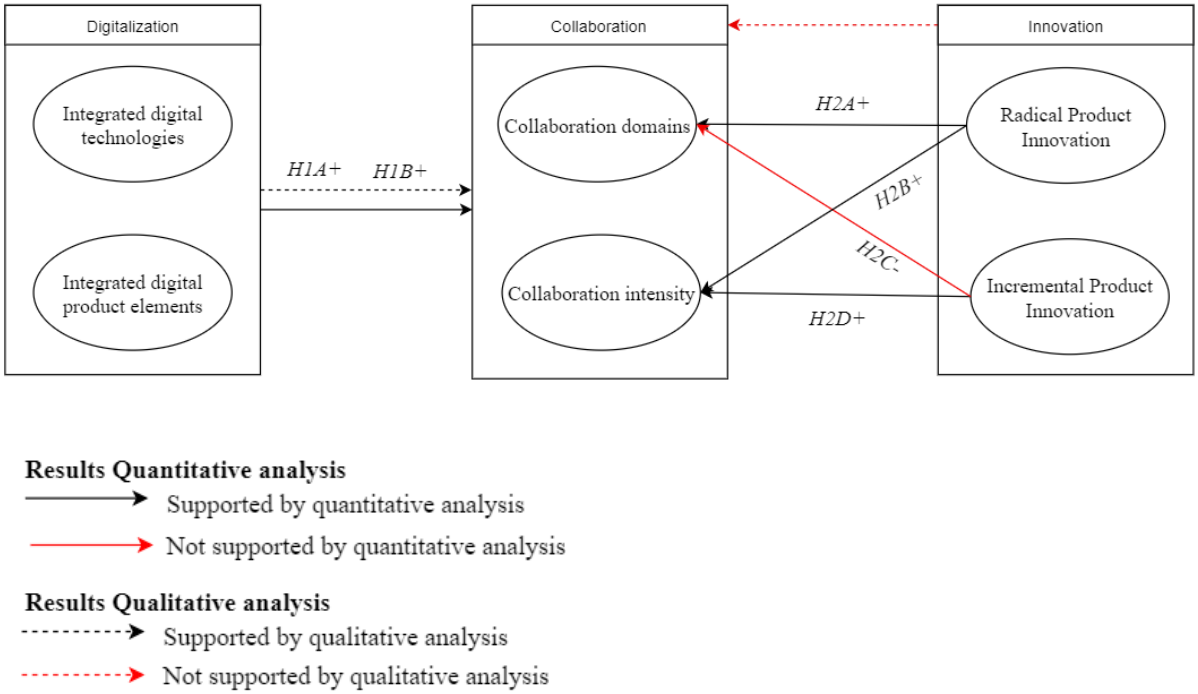

Figure 5 Conceptual model, including results analyses

Chapter 5: Conclusions, implications and limitations

This chapter will repeat the research question and will answer it with the retrieved results from the quantitative and qualitative data analyses. After that, the chapter will discuss the theoretical and practical implications of this research. The chapter will finish with the limitations of this study, which provide suggestions for further research.

5.1 Summary

The aim of this research was to gain more insight into how digitalization and innovation change the manufacturing industry, forcing a different emphasis on inter-firm collaborations between collaborating and competing manufacturing companies. After an introduction of the three concepts of digitalization, innovation, and collaboration, the following research question was formulated:

> *"To what extend do digitalization and innovation affect inter-firm collaborations in the context of competing manufacturing companies, and if so, how?"*

In the pursuit of an answer to this question, both quantitative and qualitative research was conducted. The quantitative research utilized the data of The European Manufacturing Survey of 2018, as it provided useful information that fitted the theoretical definitions of the constructs. The data, based on a sample of 203 Dutch manufacturing companies, was analyzed by using multiple regression analysis. In addition, six interviews were conducted to find additional in-depth information about the constructs and their interrelations. The quantitative data specified all the constructs into two dimensions, while the qualitative analysis focused on the overall effects of innovation, digitalization, and collaboration. First, innovation was divided into radical and incremental innovation, as the complexity of the specific innovation type might have had a different impact on the need to cooperate. Then, digitalization was also divided into two parts, hypothesizing the effect of either the number of integrated digital process technologies while also looking at the number of digital product elements involved. Finally, collaboration was divided into collaboration domains and collaboration intensity.

After a literature review, it was hypothesized that the digitalization of the manufacturing industry would increase the need to collaborate, as these digital innovations often involve complex systems that cannot be developed by a single party. If firms are not able to keep up with the change towards a digitalized environment, they might need to look for opportunities to use knowledge of others to enhance their internal capabilities or source them externally, increasing the need for collaborations. The EMS 2018 provided opportunities to divide collaboration into collaboration domains and collaboration frequency, making it possible to find out whether digitalization had a different impact on both of the items. The variable collaboration intensity counted and added up for every collaboration domain how many firms responded by saying that they collaborated multiple times or continuously on this specific domain. This distinction between collaboration domains and collaboration intensity matters, as digitalization might

support the process to find new collaboration partners and also intensify the relationship with current partners by offering opportunities to integrate, align, and improve the collaboration. Besides, digitalization was also subdivided into the number of digital technologies integrated into the process and the number of integrated digital elements in the product.

The results of the EMS 2018 revealed that all the hypothesized relations regarding the effect of digitalization on collaboration were significant. A higher amount of integrated digital technologies increased both the collaboration domains and the number of intense collaborations. The same went for the amount of integrated digital product elements, as it also increased both the collaboration domains and collaboration intensity. So the influence of digitalization on the collaboration domains and intensity is significant in theory, however, the influences are relatively small. A firm has to integrate at least 7 digital technologies into their manufacturing process or include 4 to 5 digital product elements to have one extra collaboration domain. To actually achieve an effect of digitalization on the number of intense collaborations, a firm needs to integrate at least 6 digital technologies in their production process or include 5 digital elements in their product. Only with that amount of digitalization in a firm, the number of intense collaborations will increase with 1. In addition, the qualitative analyses revealed that the correspondents we're not convinced that digitalization increased the need to collaborate, but that it did support the collaboration process as they confirmed the benefits of digitalization regarding collaboration. Digitalization has helped the firms to connect with new partners, improved supply chain alignment, and enabled firms to retrieve customer preferences and integrate them earlier in the process. So although both the quantitative and qualitative data confirm the interrelations, digitalization only has a limited effect on collaboration.

The second construct looked at the effect of innovation on collaboration. Based on the literature review, it was hypothesized that the changes in the manufacturing industry caused by digitalization forced firms to increase their innovativeness. Collaboration with external parties is a core initiative to increase innovativeness, so this challenges firms to look beyond their organizational boundaries and evaluate how the resources and capabilities of external parties can be exploited to create their own exceptional value in a digitalized environment. The quantitative analyses divided innovation into incremental and radical innovation. As radical innovations were seen as more complex to come up with, it was hypothesized that firms who would focus on radical innovation would look for more collaboration partners to improve their innovation process, compared to firms that do not innovate. Incremental innovations on the other hand, only involve relatively minor changes in technology. So for these innovations, it was estimated that the number of collaboration domains would not increase, because firms might have been able to complete the innovation process themselves and were not searching for extra collaboration partners. The results showed that the amount of collaboration domains for firms with radical product innovations has indeed slightly increased compared to firms with no product innovation,

confirming the hypothesis. Remarkably, the collaboration domains of firms that focus on incremental product innovation also increased, so this hypothesis was rejected. Besides looking at the collaboration domains, the influence of innovation on the collaboration intensity was also hypothesized and analyzed. It was expected that for both radical and incremental innovation the number of intense collaborations would increase. The multiple regression conducted with the EMS data revealed that indeed both the innovation types increased the number of intense collaborations, again, confirming the hypotheses regarding this topic. Overall, this means that innovation, either incremental or radical, had a positive influence on the collaborations. However, this is counter wise to the results of the qualitative analysis, as some of the firms denied that their innovation influenced the number of collaborations. While some of the firms stated that they definitely use external knowledge to improve their own innovation capabilities, others confirmed that they don't want to become dependent on external sources and mostly invest to obtain the knowledge internally. The lack of consistency in the answers made it impossible to accept the hypothesis that firms need collaborations for their innovation. The difference between the quantitative and qualitative analysis might indicate that the increased amount of collaboration domains and collaboration frequency is not caused by innovation practices and that the increasement is affected by other elements. This corresponds with the explanatory power of the regression model, as the included variables only determine 16.1% of the variance in the collaboration domains and only 19.6% for the variation in collaboration intensity. So the increasement of the number of collaboration domains and intensity could definitely be caused by other effects.

This research also looked at one specific collaboration domain, namely coopetition, which is known as collaborations between competitors. It was expected that the digitalization would not only increase the need to collaborate but in specific also increase the need to view competitors as potential collaboration partners. Both parties could benefit by pursuing both competitive and cooperative strategies simultaneously and combining the resources so they will be able to focus on their own specialized core capabilities. Digitalization might be a driver for this paradoxical dilemma, as it increases the need to enhance a firm's current technological development. Besides, to stay competitive in a fast-changing market, firms need to constantly adapt themselves by innovating their products and processes and being able to adapt to changing customer needs. This also challenges firms to look beyond organizational boundaries and indicate how potential new collaboration partners could increase the chances of survival in a fast-changing market. So innovation might also force companies to view competitors as potential partners. Even though the quantitative analyses showed that digitalization and innovation both significantly increased the number of collaboration domains, it turned out that coopetition was not part of one of those domains. The firms viewed the collaboration domain coopetition not as a voluntary desired choice. Even though digitalization has a major impact on the manufacturing market, it does not force firms to enhance their technological development through collaborations with competitors. Lack of trust is one of the barriers that withhold firms to cooperate with their competitors and the changes in

the market as a result of digitalization and innovation are both not strong enough forces to overcome this. Even though coopetition might be beneficial for both the companies, the competitive coercion overpowered the collaboration opportunities. So innovation and digitalization were not a strong enough force to stimulate coopetition.

To come to an overall answer to the research question, the results of the quantitative and qualitative analyses prove that digitalization does affect inter-firm collaborations because it mainly supports and facilitates the collaboration process. Innovation, on the other hand however, did significantly improve the amount and intensity of the collaboration domains, but according to the qualitative analysis, this was not mainly caused by the urge to innovate and could have been caused by other elements. Besides, collaborations between competing firms were out of the question, as trust and competitive pressures were too strong of force to be persuaded to cooperate. So taking into account the title of this research, the answer is that competitors stay a rival and fluctuations in the manufacturing industry, for now, won't change this perception.

5.2 Implications

5.2.1 Theoretical implications

This research tried to contribute to the existing literature on inter-firm collaborations. By digging into the existing studies on collaborations, it was found that open innovation, which is defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation (Chesbrough & Crowther, 2006, p. 299), is already an established phenomenon within this literature subject. Over the years, academics have accentuated the idea that companies should include external innovation within their innovation strategy. The manufacturing industry is an interesting market to investigate inter-firm collaborations because this market is highly influenced by digitalization. This study revealed that the utilization of data to improve stock management and respond more quickly to customer demand, the integration of robots to improve speed, flexibility and scalability of the production process, and the reduction of dependency on personnel are all examples of opportunities and benefits that the digitalization has offered. However, not all the participated firms experienced benefits of digitalization, as it was concluded that how digitalized a company is depended on the specific industry and the size of the company. By dividing digitalization into either the number of integrated digital technologies in the production process and the amount of digitalized product elements, it appeared that the latter had a stronger impact on collaborations.

Besides, in recent years not much research has been done into how competitors could be potential collaboration partners and whether digitalization and innovation changed this perception, so this research tried to link these concepts. The transformation of the manufacturing industry towards a more digitalized environment is creating a paradoxical dilemma between businesses that are operating in the same market. Instead of only viewing competitors as rivals, they might also be potential collaboration

partners by sharing the capabilities to stimulate internal innovation. By simultaneously pursuing both competitive and cooperative strategies firms might be able to survive in this fast-changing market. However, this research provided results that showed that even though firms tried multiple times to collaborate with competitors, they failed to do so. This research contributes to the literature on proving that digitalization and innovation did increase the number of collaboration domains and the intensity of the collaborations, but that both of these drivers did not stimulate collaborations with competitors.

Finally, to thoroughly study the collaborative behavior of companies, this study divided collaboration into collaboration domains and collaboration intensity. This division was made as both digitalization and innovation might have a different impact on the domains compared to the intensity of the collaboration. Especially with the construct of innovation the split up was of importance, as incremental innovation was expected to have a positive influence on the collaboration intensity, but a negative influence on the number of collaboration domains. However, the results of the analyses prove that this distinction was not relevant since the effects of the constructs on the collaboration domains and intensity were mainly the same. When companies have integrated more digital opportunities and focus on either incremental or radical innovation, they collaborate on more domains and simultaneously also collaborate more intensely.

5.2.2 Practical implications

The mixed method of this research has led to some practical implications. The quantitative study revealed that firms that have integrated digital opportunities have indeed an increased amount of collaboration domains and a higher number of intense collaborations. The interviewed firms did confirm this positive influence, as they acknowledged the benefits that the digitalization offers for their collaboration process. However, when the firms were asked whether or not digitalization directly influenced their collaboration, they disagreed. So even though the firms experience the benefits of digitalization, they are not aware of the underlying importance of their collaboration process. Especially the smaller firms are experiencing a lot of barriers towards digitalization, but this research tries to support the firms to become more conscious of the benefits so that they might be more willing to invest in digitalization before it is too late.

Besides the influence of digitalization, the influence of innovation on collaboration was also studied. It was hypothesized that open innovation would occur more nowadays due to the digitalization of the manufacturing industries. The quantitative study revealed that firms that invest in innovation, both radical as incremental, have an increased amount of collaboration domains and a higher number of intense collaborations compared to firms that make no use of innovation. This indicates that the more innovative a company is, the more they collaborate. However, the qualitative study revealed that not all the firms are agreeing on the importance of open innovation and the usage of collaborations to improve their innovation. Their independence takes precedence over opportunities to improve their innovation.

Nevertheless, the interviewed firms that agreed on using collaboration to improve their innovation provided examples of how beneficial collaborations can be. This indicates that some of the interviewed firms might need to change their behavior towards open innovation and reconsider to integrate collaborations in their innovation strategy and value partnerships. When they are more open towards sharing their innovation process with others and combining their capabilities, they might have more chance of survival in the fast-changing manufacturing market. Partnerships based on trust can help the firms to improve their innovation by combining the capabilities. Firms can also join consortiums to combine knowledge and expertise and be able to anticipate to the latest trends and drive opportunities.

5.3 Limitations

The study included both a quantitative and qualitative analysis to increase validity. As the quantitative analysis was based on a sample with a reasonably large number, the results are generalizable. Besides, the qualitative analyses provided opportunities to add additional information to the quantitative results to find more detailed clarifications. However, the mixed method also caused some limitations. As the quantitative data was based on the European Manufacturing Survey of 2018, the research was limited to the constructs that were provided by this survey. Information that was not part of the EMS, could not be included in this quantitative research. An example is coopetition. There was no specific question in the EMS regarding this subject, so this construct could not be measured quantitatively and could only be taken into account in the qualitative part. This might also be the reason why the explanatory power of the regression model was low, as the increasement of the number of collaboration domains and intensity could be caused by other effects than only innovation or digitalization.

Furthermore, the scope of the qualitative analysis is also a limitation of this research. While the quantitative sample was based on a reasonable number of participants, the qualitative analyses were based on only six firms. The qualitative analysis did provide useful information to cover the subjects of this research, but as this was only based on 6 companies, further research could dive into this topic to find more generalizable information. It was interesting to see that both digitalization and innovation increased the number of collaboration domains, but that competitors did not belong to one of these domains. So firms in the manufacturing are collaborating more, but just not with competitors. It might be interesting for further research to find out whether or not this also applies to other companies, industries, or even countries.

Besides the scope of the research, the depth might also be a limitation. The qualitative analyses were based on six firms that all operated in different companies and different industries. So all the qualitative conclusions were drawn on only one opinion regarding that specific firm and industry. More employees of a firm need to be interviewed to find more perspectives and extra depth information on a certain subject. This way generalizable conclusions could be drawn. The same goes for the industries, as for

every industry only 1 firm was interviewed. To find out whether or not more firms of the same industry have a similar view on the constructs, further research needs to be done.

5.3 Ethic reflection

As this research consisted of qualitative research including six interviews, the ethical aspects are of high importance. Ethics in business research is defined as: "A *code of conduct or expected societal norms of behavior while conducting research"*(Sekaran & Bougie, 2016, p. 13). Ethical behavior needs to be applied in each step of the research process, so during the data collection, the data analysis, and the reporting. A crucial ethical part and fundamental goal of doing research, is guarding the confidentiality and anonymity of the respondents (Sekaran & Bougie, 2016). All responses were be made anonymous by making the provided information irreducible, to guarantee the privacy of the respondents. By only categorizing and classifying the companies according to their industry and size, a thorough analysis could be carried out while still meeting all the ethical criteria and guaranteeing the privacy of the respondents. The interviews were transcribed and added in the appendix with the permission of the respondents. To guarantee anonymity, the respondent's names, company, and other traceable information has been omitted from the transcripts.

A second crucial part of ethical research behavior is the informed consent of the subjects as respondents should never be forced to participate (Sekaran & Bougie, 2016). The participants of the interviews were well informed about the aims, methods, and time consuming of the study and they were offered an opportunity to withdraw to make sure that the respondents participated voluntarily. Besides, all respondents have been informed in advance about the topics that would be discussed during the interviews. This allowed the respondents to prepare themselves and to let them know what could be expected.

Thirdly, all findings have been reported honestly and straightforwardly, without intentionally misinterpreting the data. During the interviews, the topics were all introduced with a theoretical definition, to make sure the respondents knew what was meant by the question and to counter any misconceptions. Prior to the interview, respondents were informed that they always had the opportunity to ask questions if they might not understand something or if something was unclear.

References

Angel, D. P. (2002). Inter-firm Collaboration and Technology Development Partnerships Within US Manufacturing Industries. *Regional Studies, 36*(4), 333-344. doi:10.1080/00343400220131115

Armbruster, H., Kirner, E., Lay, G., Szwejczewski, M., Coriat, B., Leguehennec, C., . . . Duh, M. (2006). Patterns of Organisational Change in European Industry (PORCH). (Final Report).

Arora, A. (1995). Licensing Tacit Knowledge: Intellectual Property Rights And The Market For Know-How. *Economics of Innovation and New Technology, 4*(1), 41-60. doi:10.1080/10438599500000013

Baines, T. S., Roy, R., Lightfoot, H. W., Benedettini, O., & Kay, J. M. (2009). The servitization of manufacturing. *Journal of Manufacturing Technology Management, 20*(5), 547-567. doi:10.1108/17410380910960984

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital Business strategy: Toward a next generation of insights. *MIS Quarterly, 37*(2), 471-482.

Brandenburger, A., & Nalebuff, B. J. (1995). The Right Game: Use Game Theory to Shape Strategy. *Harvard Business Review*(July-August 1995), 57-71. doi:DOI:10.1016/0024-6301(95)90326-7

Brennen, J. S., & Kreiss, D. (2016). Digitalization. In *The International Encyclopedia of Communication Theory and Philosophy* (pp. 556-566). Chichester: Wiley-Blackwell.

Brown, S. L., & Eisenhardt, K. M. (1995). Product Development: Past Research, Present Findings, and Future Directions. *The Academy of Management Review, 20*, 343-378.

Burgelman, R. A. (1991). Intraorganizational Ecology of Strategy Making and Organizational Adaptation: Theory and Field Research. *Organization Science, 2*.

Butler, J. E. (1988). Theories of technological innovation as useful tools for corporate strategy. *Strategic Management Journal, 9*, 15-29.

Cabrera, M. (Producer). (2014, 02 10). Use Co-opetition to Build New Lines of Revenue. *Harvard Business Review*. Retrieved from https://hbr.org/2014/02/use-co-opetition-to-build-new-lines-of-revenue

Camarinha-Matos, L. M., & Afsarmanesh, H. (2006). Collaborative Networks. *IFIP International Federation for Information Processing, 207*.

Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management, 29*(3), 163-180. doi:10.1016/j.jom.2010.12.008

Chan, F. T. S., & Prakash, A. (2012). Inventory management in a lateral collaborative manufacturing supply chain: a simulation study. *International Journal of Production Research, 50*(16), 4670-4685. doi:10.1080/00207543.2011.628709

Chandy, R. K., & Tellis, G. J. (1998). Organizing for Radical Product Innovation: The Overlooked Role of Willingness to Cannibalize. *Journal of Marketing Research, 35*(4), 474487.

Chandy, R. K., & Tellis, G. J. (2018). The Incumbent's Curse? Incumbency, Size, and Radical Product Innovation. *Journal of Marketing, 64*(3), 1-17. doi:10.1509/jmkg.64.3.1.18033

Chesbrough, H., & Crowther, A. K. (2006). Beyond high tech: early adopters of open innovation in other industries. *R&D Management, 36*, 229-236.

Crossan, M. M., & Apaydin, M. (2010). A Multi-Dimensional Framework of Organizational Innovation: A Systematic Review of the Literature. *Journal of Management Studies, 47*(6), 1154-1191. doi:10.1111/j.1467-6486.2009.00880.x

Daidj, N. (2017). *Cooperation, Coopetition and Innovation* (1 ed. Vol. 3): ISTE Ltd and John Wiley & Sons, Inc.

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics, 204*, 383-394. doi:10.1016/j.ijpe.2018.08.019

Damanpour, F. (1991). Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators. *The Academy of Management Journal, 34*, 555-590.

de Soria, I. M., Alonso, J., Orue-Echevarria, L., & Vergara, M. (2009). *Developing an Enterprise Collaboration Maturity Model: Research Challenges and Future Directions*. Paper presented at the IEEE International Technology Management Conference (ICE), Leiden.

Dess, G. G., & Picken, J. C. (2000). Changing roles leadership in the 21st Centry.

Dewar, R. D., & Dutton, J. E. (1986). The Adoption of Radical and Incremental Innovations: An Empirical Analysis. *Management Science, 32*(11), 1422-1433. doi:10.1287/mnsc.32.11.1422

ElMaraghy, H., & ElMaraghy, W. (2016). Smart Adaptable Assembly Systems. *Procedia CIRP, 44*, 4-13. doi:10.1016/j.procir.2016.04.107

Enkel, E., Gassmann, O., & Chesbrough, H. (2009). Open R&D and open innovation: exploring the phenomenon. *R&D Management, 39*, 311-316. doi:10.1111/j.1467-9310.2009.00570.x

European Manufacturing Survey. (2020a, 03 22). *Radboud University*. Retrieved from https://www.ru.nl/nsm/imr/our-research/hot-spots/innovation-entrepreneurship-business-ecosystems/selected-projects/projects/european-manufacturing-survey/

European Manufacturing Survey. (2020b, 03 22). *ISI Fraunhofer*. Retrieved from https://www.isi.fraunhofer.de/en/themen/industrielle-wettbewerbsfaehigkeit/fems.html#tabpanel-1605751840

Eurostat. (2008). *NACE Rev. 2 – Statistical classification of economic activites in the European Community*. Retrieved from Luxembourg:

Field, A. (2013). *Discovering Statistics using IBM SPSS Statistics* (4 ed.). London: Sage Publications Ltd.

Fleisch, E., Weinberger, M., & Wortmann, F. (2014). Business models and the internet of things.

Galanakis, K. (2006). Innovation process. Make sense using systems thinking. *Technovation, 26*(11), 1222-1232. doi:10.1016/j.technovation.2005.07.002

Gassmann, O. (2006). Opening up the innovation process: towards an agenda. *R&D Management, 36*(3), 223-228.

Gawer, A., & Cusumano, M. A. (2014). Industry Platforms and Ecosystem Innovation. *Journal of Product Innovation Management, 31*(3), 417-433. doi:10.1111/jpim.12105

Geissbauer, R., Schrauf, S., Koch, V., & Kuge, S. (2014). Industry 4.0 - Opportunities and Challenges of the Industrial Internet. Retrieved from https://www.pwc.nl/nl/publicaties/industrie-4-0.html

Gerlach, M. (1987). Business Alliances and the Strategy of the Japanese Firm. *California Management Review, 30*(1), 126-142.

Gnyawali, D. R., & Park, B.-J. (2011). Co-opetition between giants: Collaboration with competitors for technological innovation. *Research Policy, 40*(5), 650-663. doi:10.1016/j.respol.2011.01.009

Hair, J., Blak, W., Babin, B., & Anderson, R. E. (2014). *Multivariate Data Analysis* (7 ed.). Essex: Pearson.

Hansen, M., & Birkinshaw, J. (2007). The Innovation Value Chain. *Harvard Business Review, 85*, 121-142.

Hema, A. (Producer). (2017, 10 26). Successful Co-opetition: Examples of collaborations between competitors. *The Stakeholder Agency*. Retrieved from https://www.thestakeholderagency.co.nz/blog/successful-co-opetition-examples-of-collaborations-between-competitors

Hitt, M. A., Freeman, R. E., & Harrison, J. S. (2005). *The Blackwell Handbook of Strategic Management*.

Huxham, C., & Vangen, S. (2005). *Managing to Collaborate: The Theory and Practice of Collaborative Advantage*. Abingdon, UK: Routledge.

Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Recommendations for implementing the strategic initiative Industry 4.0: Securing the Future of German Manufacturing Industry. Final Report of the Industrie 4.0 Working Group*: Acatech, Forschungsunion.

Kobarg, S., Stumpf-Wollersheim, J., & Welpe, I. M. (2019). More is not always better: Effects of collaboration breadth and depth on radical and incremental innovation performance at the project level. *Research Policy, 48*(1), 1-10. doi:10.1016/j.respol.2018.07.014

Lado, A., Boyd, N. G., & Hanlon, S. C. (1997). Competition cooperation and the search for economic rents: a syncretic model. *Academy of Management Review, 22*(1), 110-141.

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering, 6*(4), 239-242. doi:10.1007/s12599-014-0334-4

Lendel, V., & Varmus, M. (2011). Creation and Implementation of the innovation strategy in the enterprise. *Economics and Management, 16*, 819-825.

lenkaLenka, S., Parida, V., & Wincent, J. (2017). Digitalization Capabilities as Enablers of Value Co-Creation in Servitizing Firms. *Psychology & Marketing, 34*(1), 92-100. doi:10.1002/mar.20975

Lerner, S. (2015). Digital Business Strategy. *Touro Accounting & Business Journal*, 48-52.

Leung, L. (2015). Validity, reliability, and generalizability in qualitative research. *J Family Med Prim Care, 4*(3), 324-327. doi:10.4103/2249-4863.161306

Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration, 6*, 1-10. doi:10.1016/j.jii.2017.04.005

McDermott, C. M., & O'Connor, G. C. (2002). Managing radical innovation: an overview of emergent strategy issues. *Journal of Product Innovation Management, 19*(6), 424-438.

Myers, M. D. (2013). *Qualitative Research in Business & Management*. London: SAGE Publications Ltd.

Porter, M. E. (1985). *The Competitive Advantage: Creating and Sustaining Superior Performance*. New York: Free Press.

Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. *Harvard Business Review, 92*, 11-64.

Prahalad, C. K., & Hamel, G. (1990). The core competence of the corporation. *Harvard Business Review, 68*(3), 79-91.

Quintana-García, C., & Benavides-Velasco, C. A. (2004). Cooperation, competition, and innovative capability: a panel data of European dedicated biotechnology firms. *Technovation, 24*(12), 927-938. doi:10.1016/s0166-4972(03)00060-9

Rachinger, M., Rauter, R., Müller, C., Vorraber, W., & Schirgi, E. (2019). Digitalization and its influence on business model innovation. *Journal of Manufacturing Technology Management, 30*(8), 1143-1160. doi:10.1108/jmtm-01-2018-0020

Rothwell, R. (1994). Towards the Fifth-generation Innovation Process. *International Marketing Review, 11*(1), 7-31.

Rüßmann, M., Lorenz, M., P., G., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). *Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries*. Retrieved from

Schrauf, S., & Berttram, P. (2016). *Industry 4.0: How digitization makes the supply chain more efficient, agile, and customer-focused*. München: PwC Strategy&.

Sekaran, U., & Bougie, R. (2016). *Research Methods for Business* (7 ed.). Chichester: John Wiley & Sons Ltd.

Ślusarczyk, B. (2018). Industry 4.0 – Are We Ready? *Polish Journal of Management Studies, 17*(1), 232-248. doi:10.17512/pjms.2018.17.1.19

Slywotzky, A., & Drzik, J. (2005). Countering the biggest risk of all. *Harvard Business Review, 83*(4), 78-88.

Smith, K. G., Collins, C. J., & Clark, K. D. (2005). Existing Knowledge, Knowledge Creation Capability, and the Rate of New Product Introduction in High-Technology Firms. *Academy of Management Journal, 48*(2), 346-357. doi:10.5465/amj.2005.16928421

Soosay, C. A., Hyland, P. W., & Ferrer, M. (2008). Supply chain collaboration: capabilities for continuous innovation. *Supply Chain Management: An International Journal, 13*(2), 160-169. doi:10.1108/13598540810860994

Teece, D. J. (1992). Competition, cooperation, and innovation Organizational arrangements for regimes of rapid technological progress. *Journal of Economic Behavior and Organization, 18*, 1-25.

Tether, B. (2002). Who co-operates for innovation, and why - An empirical analysis. *Research Policy, 31*(6), 947-967. doi:10.1016/S0048-7333(01)00172-X

Tushman, M. L., & O'Reilly, C. A. (1996). Ambidextrous organizations: managing evolutionary and revolutionary change. *California Management Review, 38*, 8-30.

Unruh, G., & Kiron, D. (2017). Digital transformation on purpose. *MIT Sloan Management Review, available at https://sloanreview.mit.edu/article/digital-transformation-on-purpose/ (accessed March 21, 2020).*

van de Vrande, V., de Jong, J. P. J., Vanhaverbeke, W., & de Rochemont, M. (2009). Open innovation in SMEs: Trends, motives and management challenges. *Technovation, 29*(6-7), 423-437. doi:10.1016/j.technovation.2008.10.001

Van Dijk, C., & Van den Ende, J. (2002). Suggestion systems: transferring employee creativity into practicable ideas. *R&D Management, 32*(387-395).

Verschuren, P., & Doorewaard, H. (2010). *Designing a Research Project* (2 ed.). The Hague: Eleven International Publishing.

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing Smart Factory of Industrie 4.0: An Outlook. *International Journal of Distributed Sensor Networks, 12*(1). doi:10.1155/2016/3159805

Ward, A. (Producer). (2004, 07 19). Samsung and Sony unite on flat screens. *NBC News*. Retrieved from http://www.nbcnews.com/id/5445121/ns/technology_and_science-tech_and_gadgets/t/samsung-sony-unite-flat-screens/#.XpxBIMgzZPY

West, M. A., & Farr, J. L. (1990). *Innovation and creativity at work: Psychological and organizational strategies*. Chichester, England: Wiley.

What is the difference between a Consortium and a Joint Venture? (2016). *LinkedIn*. Retrieved from https://www.linkedin.com/pulse/what-difference-between-consortium-joint-venture-venugopal-ramanathan/

Williamson, O. E. (1981). The Economics of Organization: The Transaction Cost Approach. *American Journal of Sociology, 87*(3), 548-577.

Appendices

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Appendix 1 – Operationalization EMS

Operationalization items of EMS (2018)		
Type of variable	*Construct*	*Items used from European Manufacturing Survey (2018)*
Independent variable	Digitalization of manufacturing processes: 1. Integrated digital technologies	**10.1** Welke van de volgende technologieën worden momenteel in uw bedrijfsvestiging toegepast? - Mobiele/ draadloze apparaten voor programmering en bediening van installaties en machines - Digitale oplossingen voor het direct beschikbaar maken van tekeningen, werkschema's en -instructies op de werkvloer - Digitale productieplanning en roostering - Digitale uitwisseling van productie planningsgegevens met toeleveranciers en/of klanten - Bijna real-time productiemanagementsystemen - Systemen voor geautomatiseerd management van interne logistiek en orderverzameling - Product Lifecycle Management systemen of product- of productieproces-datamanagement - Virtual Reality of simulatie voor productontwerp of productontwikkeling - Industriële robots voor bewerking en fabricage - Industriële robots voor hanteren van gereedschap en werkstukken in productie - 3D printertechnologie voor prototypes, demonstratiemodellen, 0-series - 3D printertechnologie voor de vervaardiging van producten, onderdelen, mallen, instrumenten, e.d.
	2. Digital product elements	**15.2** Bevat uw hoofdproduct (lijn van producten) de volgende digitale elementen?
Independent variable	Innovation Strategy 1. Incremental 2. Radical	**14.1** Heeft uw bedrijf sinds 2015 nieuwe producten geïntroduceerd of producten die ingrijpend technisch verbeterd zijn? **14.3** Bevonden zich bij deze nieuwe producten (nieuw sinds 2015) ook producten, die nieuw-voor-de-markt waren en die uw bedrijfsvestiging als eerste op de markt introduceerde?
Dependent variable	Collaboration 1. Collaboration domains 2. Collaboration intensity	**7** Werkt uw bedrijfsvestiging samen met andere bedrijven op de volgende terreinen? - Hoe frequent werkt u samen op de volgende terreinen? (op jaarbasis)
Control Variables	Firm industry	**2.1** In welke bedrijfstak is uw bedrijf actief?
Control variable	Firm size	**21.1** Aantal werknemers

Appendix 2 – Interview questions

	Thema	Open hoofdvragen uitgeschreven	Geschatte tijd
	Intro	Goedendag, mijn naam is Fleur Schakel en ik ben een masterstudent bedrijfskunde aan de Radboud Universiteit Nijmegen. Nogmaals hartelijk dank dat u mij te woord wilt staan. Fijn dat het op deze manier kan. Ik ben bezig met het afronden van mijn master Strategic Management aan de Radboud Universiteit Nijmegen en dit interview is onderdeel van mijn afstudeeronderzoek, waarin ik een onderzoek doe naar de digitalisering en andere innovatie activiteiten in de Nederlandse maakindustrie. Ik heb van te voren de vragen van het interview opgesteld. Mochten er onduidelijkheden zijn tijdens het interview, dan kunt u altijd om uitleg vragen. In verband met het **transcriberen** van het interview wil ik u vragen of ik dit gesprek mag opnemen? Het transcript is geheel anoniem en niet terug te herleiden het bedrijf. Mijn verwachting is dat het interview circa een uur in beslag zal nemen. Heeft u verder nog vragen vooraf?	**2 minuten**
0	**Oriënterende vragen respondent, bedrijf**	**Dan begin ik met een aantal introducerende vragen.** **A. Ik heb me natuurlijk kort ingelezen in wat jouw bedrijf, X doet, maar zou je toch nog even een korte introductie willen geven van het bedrijf?** - Hoeveel medewerkers heeft het bedrijf? **B. Wat is uw functie binnen het bedrijf?** (functie, ervaring algemeen, binnen bedrijf) **C. Ondernemingsstrategie: Wat probeert uw bedrijf vooral te bereiken in de komende 5 jaar?** **D. Welke klanten bedient uw bedrijf?** **E. Welke kernactiviteiten worden uitgevoerd, wat onderscheidt bedrijf van andere bedrijven?**	**5 minuten**

1.	**Innovatie**	Bedankt, mijn onderzoek bestaat uit drie verschillende thema's, namelijk innovatie, digitalisatie en samenwerking en over elk thema ga ik aantal vragen stellen na een korte introductie. Dan begin ik met eerste thema, innovatie. Innovatie is het toepassen van nieuwe technologieën in producten, diensten en processen. Innovatie wordt algemeen beschouwd als een zeer belangrijke bron voor het creëren van een concurrentievoordeel in een steeds veranderende omgeving. **A. Welke vernieuwingen en verbeteringen zijn er in de afgelopen tijd door gevoerd in de productie (bijv. machines, installaties, gereedschappen) in uw bedrijf?** (vooral productie!, marketing/verkoop, O&O, imago, design, product/ aanvullende diensten)? - Proces innovatie - Organisatie innovatie - Product innovatie - Product-service innovatie **B. Wat vormt vooral aanleiding tot het invoeren van deze veranderingen?** (aanbod leveranciers, verandering product; marktvraag; ondernemingsstrategie; suggesties personeel/ concurrenten; voorbeelden?) **C. Hoe komen deze innovaties in de productie tot stand?** (eigen onderzoek & ontwikkeling? Welke functies/ afdelingen zijn op welke manier bij betrokken? Externe partijen?) Een innovatie strategie is de innovatieve richting van de bedrijfsaanpak bij de keuze van doelstellingen, methoden en manieren om het innovatieve potentieel van de onderneming volledig te benutten en te ontwikkelen. **D. Hoe zou u uw innovatie strategie omschrijven?** - Plannen, ideeën, prioriteiten en selectie van zaken. - Wat willen ze innoveren? producten, productie, toetreding van nieuwe markten, domeinen van	**15 minuten**

	Innovatie Strategie	innovatie, of juist technologische varianten. Of product gerelateerde domeinen. **E. Hoe belangrijk is innovatie in uw branche om een onderscheidend vermogen te creëren ten opzichte van concurrenten?**	
2.	**Digitalisatie**	Mijn tweede onderwerp is de digitalisatie van de maakindustrie. In de afgelopen jaren ondergaat de maakindustrie verschillende veranderingen. De digitalisering, ook wel industrie 4.0, de overgang van informatie in papieren vorm naar een digitale vorm, is hier een voorbeeld van. Hierbij proberen bedrijven digitale mogelijkheden te benutten, zoals het digitaal optimaliseren van productieprocessen, toevoegen van slimme software en slimme robots, het gebruik van big data en de mogelijkheid om horizontale en verticale relaties in de Supply chain te integreren. Deze opkomende technologieën creëren mogelijkheden voor bedrijven, bijvoorbeeld om nieuwe producten te produceren, het gebruik van hulpbronnen te optimaliseren en betere voorspellingen te maken. **A. Wat voor digitale veranderingen heeft uw bedrijf de afgelopen jaren doorgemaakt?** (Hebben concurrenten dezelfde veranderingen doorgemaakt?) - Digitale Supply chain - Big Data - Artificial Intellegence - Robots **B. Wat voor invloed hebben deze veranderingen op uw bedrijf gehad?** Op welke manieren merkt u het, hoe merkt u het? **C. Waarom gaat uw bedrijf wel of niet mee in de digitalisering?** Mogelijk doorvragen: - Heeft de aanwezigheid van interne deskundigheid een rol gespeeld in het wel of niet mee gaan met de digitalisatie van de industrie?	**15 minuten**

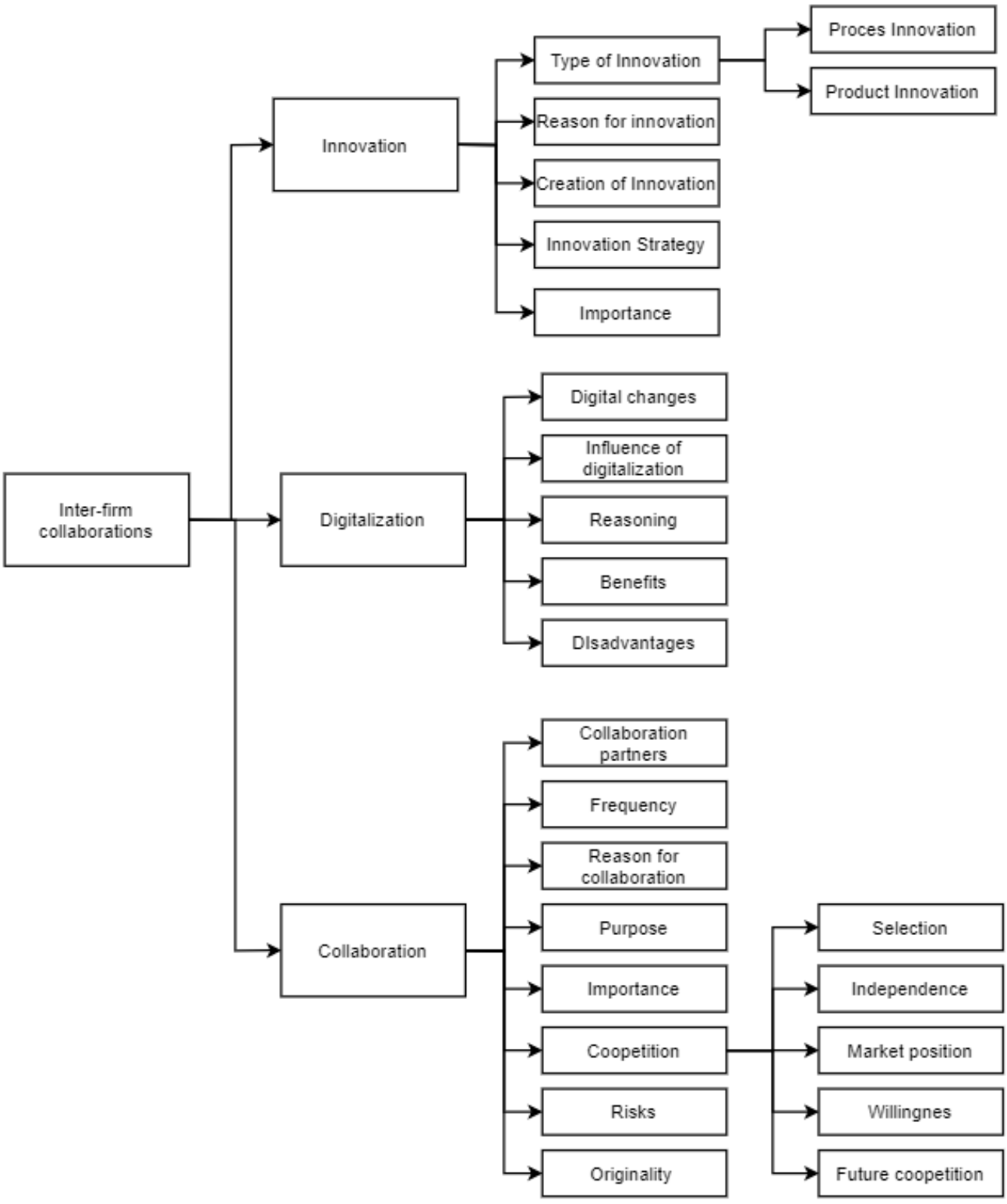
		- Is er markt vraag om mee te gaan in de digitalisering? Vragen de klanten hierom?
		- Speelt financiering een rol in het wel of niet meegaan met digitalisatie van de markt?
		- Zijn de afgelopen investeringen met betrekking tot de digitalisatie rendabel? Effectief om iets te investeren, ERP, of zijn jullie er juist voorzichtig mee. Extra informatie.
		
		D. Wat voor voordelen heeft de digitalisatie gecreëerd?
		
		C. We hebben het hiervoor gehad over de innovatie strategie. Hoe heeft de digitalisatie invloed gehad op uw innovatie strategie?
		
		Heeft de digitalisatie de innovatie strategie veranderd?
		- Meer gaan innoveren op een specifiek gebied?
		  o Proces innovatie
		  o Organisatie innovatie
		  o Product innovatie
		  o Product-service innovatie
		- Ben je anders gaan kijken naar de innovaties door digitalisatie?
		- Creëert de digitalisatie ook meer kansen om innovatief te zijn?
		- Kunnen jullie daardoor beter inspelen op de klantbehoeften?
		- Is uw innovatie cycle ook korter geworden door de digitalisering?
		- Wat voor invloed heeft dit op Doeko?
		
		Heeft de digitalisatie ook moeilijkheid of risico's met zich meegebracht?
		- Hoe gaan jullie hiermee om?	

3.	**Samenwerking**	Mijn derde en laatste thema is samenwerking. Volgens de theorie dwingen de toenemende complexiteit en de snelle veranderingen in de technologie productiebedrijven om op zoek te gaan naar nieuwe samenwerkingsverbanden om flexibel en efficiënt te kunnen inspelen op de veranderingen op de markt. Vandaar dat ik erachter wil komen hoe bedrijven daadwerkelijk samenwerken in een veranderende omgeving. **A. Op welke gebieden werkt uw bedrijf samen met andere bedrijven?** - Samenwerking in de inkoop, productie, verkoop, **innovatie**	**15 minuten**

	Samenwerking met concurrenten	- Hoe frequent werkt u samen op die terreinen op jaarbasis? o Eenmalig, meermaals, continu - Maakt u gebruik van een innovatie ecosysteem of innovatie platformen? **B. Wat vormt vooral aanleiding voor het samenwerken met andere bedrijven?** (aanbod leveranciers, verandering product; marktvraag; ondernemingsstrategie; suggesties personeel/ concurrenten; voorbeelden?) **C. Wat willen jullie bereiken met deze samenwerkingen?** (voordeliger inkoop, betere innovatie, sneller inspelen op klantvraag, flexibeler?) **D. Zijn samenwerkingen met andere bedrijven van belang voor uw bedrijf? Waarom?** (bedrijfsstrategie, bedrijfseconomische overwegingen, afstemming betrokken partijen?) **Uw noemde een aantal verschillende partijen waar u mee samenwerkt. Een andere partij op de markt zijn uw concurrenten.** Naast vechten om een aandeel van dezelfde markt, kunnen deze concurrerende bedrijven ook wellicht potentiele samenwerkingspartners zijn door de krachten te bundelen om zo jullie eigen marktpositie te verbeteren. **F. Heeft u in het verleden wel eens samengewerkt met concurrerende bedrijven?** Indien ja: - Hoe ziet die samenwerking eruit? - Hoe selecteert u een concurrent die geschikt is om mee samen te werken? - Hoe zorgt u ervoor u dat niet afhankelijk wordt van uw concurrenten door middel van die samenwerking? - Hoe zorgt u ervoor dat uw marktpositie niet verzwakt ten opzichte van de concurrenten waarmee u samenwerkt?	

		- Hoe zorgt u ervoor dat concurrenten willen samenwerken met u? Wat biedt u aan wat interessant zou zijn voor uw concurrenten? Indien nee: - Wat houdt u tegen om met concurrenten samen te werken? - Wat zou er moeten veranderen zodat u wel zou willen samenwerken met concurrenten? - Zou u in de toekomst willen samenwerken met deze bedrijven? **G. Hoe beperkt u risico's die gepaard gaan met samenwerken? (Kartel vorming)** - Hoe behoudt u uw originaliteit en exclusiviteit als u samenwerkt met andere partijen? - Hoe bepaalt u welke data gedeeld kan worden en welke veilig moet worden gehouden? **H. Heeft de digitalisering ervoor gezorgd dat u meer of minder bent gaan samenwerken met externe partijen? En waarom?** - Op een specifiek gebied gaan samenwerken? o Proces innovatie o Organisatie innovatie o Product innovatie o Product-service innovatie **Is er een andere nadruk komen te liggen op samenwerken met concurrenten door de digitalisatie?** **I. Heeft de digitalisering ervoor gezorgd dat u meer of minder bent gaan samenwerken met concurrerende partijen? En waarom?**	
4.	**Invloed Innovatie Strategie op samenwerking**	**We hadden het daarstraks over uw innovatie strategie en dat deze wel of niet veranderend is door de digitalisatie.** **A. Heeft uw innovatie strategie invloed op de noodzaak en behoefte om te gaan samenwerken met externe partijen?** **B. Heeft uw innovatie strategie invloed op de noodzaak en behoefte om te gaan samenwerken met concurrerende partijen?**	**5 minuten**

5.	**Outro**	Dit waren al mijn vragen. Nogmaals enorm bedankt voor dit interview! Hierbij wil ik nogmaals bevestigen dat het transcript geheel anoniem blijft. Heeft u wellicht interesse om aan het einde van het onderzoek mijn thesis te ontvangen?	**5 minuten**


Inter-firm collaborations
Innovation
Type of Innovation
Proces Innovation
Product Innovation
Reason for innovation
Creation of Innovation
Innovation Strategy
Importance
Digitalization
Digital changes
Influence of digitalization
Reasoning
Benefits
DIsadvantages
Collaboration
Collaboration partners
Frequency
Reason for collaboration
Purpose
Importance
Coopetition
Selection
Independence
Market position
Willingnes
Future coopetition
Risks
Originality

Appendix 3 – Interviewed firms

Participating firms				
	Abbreviation Company	**Industry**	**Size (number of employees)**	**Job Description(s)**
1	CF	Chemical Food	14.000 - Big	Regional Innovation EAME and Technical Director Tobacco
2	CT	Chemical Textile	20.000 - Big	Business Unit Manager
3	BS	Bakery semi-finished Goods	35 - Small	Product Manager Quality Assurance Employee
4	FO	Food industry	140 - Medium	Product Marketer
5	IE	Industrial engineering	65 - Medium	Supply Chain Manager
6	PT	Equipment transport	7 - Small	Director, Owner

Appendix 4 – Used questions of EMS

4.1 Collaboration

7: Werkt uw bedrijfsvestiging samen met andere bedrijven op de volgende terreinen?
(samenwerking is vrijwillige relatie tussen bedrijven die verder gaat dan alleen in- en verkoop transacties)

	Werkt u samen?		Hoe frequent werkt u samen op de volgende terreinen? (Op jaarbasis)		
	Nee (0)	Ja (1)	Eenmalig (1)	Meermaals (2)	Continu (3)
Samenwerking in inkoop (7.1)	X	X	X	X	X
Samenwerking in de productie (voor capaciteitsuitbreiding of gezamenlijke gebruik van machines) (7_2)	O	O	O	O	O
Samenwerking in verkoop/ distributie (7_3)	O	O	O	O	O
Samenwerking in service (7_4)	O	O	O	O	O
Samenwerking in onderzoek & ontwikkeling (O&O) met afnemers of leveranciers (7_5)	O	O	O	O	O
Samenwerking in O&O met andere bedrijven (uitgezonderd afnemers en leveranciers) (7_6)	O	O	O	O	O
Samenwerking in O&O met onderzoeksinstituten (bijv. universiteiten, TNO) (7_7)	O	O	O	O	O

4.2 Digitalization

10.1: Welke van de volgende technologieën worden momenteel in uw bedrijfsvestiging toegepast?

Subject	**Digitale technologieën**	**Nee (0)**	**Ja (1)**
Productiebeheersing	Mobiele/ draadloze apparaten voor programmering en bediening van installaties en machines (bijv. tablets) (10.1_1)	O	O
	Digitale oplossingen voor het direct beschikbaar maken van tekeningen, werkschemas en -instructies op de werkvloer (10.1_2)	O	O
	Digitale productieplanning en roostering (bijv. ERP-systeem) (10.1_3)	O	O
	Digitale uitwisseling van productieplanningsgegevens met toeleveranciers en/of klanten (elektronische data-uitwisseling (EDI)) (10.1_4)	O	O

	Bijna real-time productiemanagementsystemen (bijv. systemen voor gecentraliseerde besturing en machinemonitoring) (10.1_5)	O	O
	Systemen voor geautomatiseerd management van interne logistiek en orderverzameling (e.g. RFID, warehouse management system) (10.1_6)	O	O
	Product Lifecycle Management (PLM) systemen of product- of productieproces-datamanagement (10.1_7)	O	O
	Virtual Reality of simulatie voor productontwerp of productontwikkeling (bijv. Finite Element Method (FEM), digitale prototypes, computermodellen) (10.1_8)	O	O
Automatisering en robotisering	Industriële robots voor bewerking en fabricage (bijv. lassen, coaten, snijden) (10.1_9)	O	O
	Industriële robots voor hanteren van gereedschap en werkstukken in productie (bijv. verplaatsen, assemblage, sorteren, verpakken, automatic guided vehicle (AVG)) (10.1_10)	O	O
Additive manufacturing technologieën	3D printertechnologie voor prototypes, demonstratiemodellen, 0-series (10.1_11)	O	O
	3D printertechnologie voor de vervaardiging van producten, onderdelen, mallen, instrumenten, e.d. (10.1_12)	O	O

15.2 Bevat uw hoofdproduct (lijn van producten) de volgende digitale elementen?

Digitale elementen	**Nee (1)**	**Ja (2)**
Interactieve besturing (stemcommando's, databrillen, Virtual en Augmented Reality) (1)	O	O
Internet/netwerkverbinding voor geautomatiseerde datauitwisseling (real time) (2)	O	O
Sensortechnologie / controle-elementen voor digitale productfuncties (3)	O	O
Identificatie-tags (zoals RFID, QR of barcodes) (4)	O	O
Andere digitale elementen: (5)	O	O

4.3 Innovation

14.1 Heeft uw bedrijf sinds 2015 nieuwe producten geïntroduceerd of producten die ingrijpend technisch verbeterd zijn? (bijv. door nieuwe grondstoffen of materialen te gebruiken, veranderingen in productfuncties of werking etc.)	**Nee (0)**	**Ja (1)**

14.3 Bevonden zich bij deze nieuwe producten (nieuw sinds 2015) ook producten die nieuw-voorde-markt waren en die uw bedrijfsvestiging als eerste op de markt introduceerde?	**Nee (0)**	**Ja (1)**

4.4 Industry sector

In welke bedrijfstak is uw bedrijf actief?

o Vervaardiging van voedingsmiddelen (10)

o Vervaardiging van dranken (11)

o Vervaardiging van tabaksproducten (12)

o Vervaardiging van textiel (13)

o Vervaardiging van kleding (14)

o Vervaardiging van leer en van producten van leer (15)

o Houtindustrie en vervaardiging van artikelen van hout en van kurk, exclusief meubelen; vervaardiging van artikelen van riet en van vlechtwerk (16)

o Vervaardiging van papier en papierwaren (17)

o Drukkerijen, reproductie van opgenomen media (18)

o Vervaardiging van cokes en van geraffineerde aardolieproducten (19)

o Vervaardiging van chemische producten (20)

o Vervaardiging van farmaceutische grondstoffen en producten (21)

o Vervaardiging van producten van rubber of kunststof (22)

o Vervaardiging van andere niet-metaalhoudende minerale producten (23)

o Vervaardiging van metalen in primaire vorm (24)

o Vervaardiging van producten van metaal, exclusief machines en apparaten (25)

o Vervaardiging van informaticaproducten en van elektronische en optische producten (26)

o Vervaardiging van elektrische apparatuur (27)

o Vervaardiging van machines, apparaten en werktuigen, n.e.g. (28)

o Vervaardiging van auto's, aanhangwagens en opleggers (29)

o Vervaardiging van andere transportmiddelen (30)

o Vervaardiging van meubelen (31)

o Overige maakindustrie (32)

o Reparatie en installatie van machines en apparaten (33)

o Overige sectoren niet maakindustrie (34)

4.5 Industry sector dummified:

1. Metalen en Metaalproducten
2. Voedsel, dranken en tabak
3. Textiel, leder, papier en karton
4. Bouw, Meubilair
5. Chemische producten
6. Machines, Apparatuur Vervoer
7. Elektrische en optische apparatuur

Appendix 5 – Control variables Firm Size & Industry Sectors

Statistics

		Size number of employees 2017	lnSize number of employees 2017 (log)	Industry Industry sector	Metal	Food	Textile	Construction	Chemical	Machinery	Electronic
N	Valid	203	203	201	201	201	201	201	201	201	201
	Missing	0	0	2	2	2	2	2	2	2	2
Mean		81.4384	3.7695	4.2886	.1990	.0846	.1443	.0249	.1294	.1841	.2338
Std. Error of Mean		22.25454	.06028	.16063	.02823	.01968	.02485	.01101	.02373	.02740	.02993
Median		42.0000	3.7377	5.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Mode		45.00	3.81	7.00	.00	.00	.00	.00	.00	.00	.00
Std. Deviation		317.07837	.85880	2.27735	.40025	.27895	.35225	.15613	.33643	.38852	.42432
Variance		100538.693	.738	5.186	.160	.078	.124	.024	.113	.151	.180
Skewness		13.537	1.038	-.238	1.519	3.008	2.040	6.147	2.226	1.643	1.267
Std. Error of Skewness		.171	.171	.172	.172	.172	.172	.172	.172	.172	.172
Kurtosis		189.273	3.356	-1.496	.311	7.122	2.183	36.148	2.983	.705	-.398
Std. Error of Kurtosis		.340	.340	.341	.341	.341	.341	.341	.341	.341	.341
Range		4490.00	6.11	6.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Minimum		10.00	2.30	1.00	.00	.00	.00	.00	.00	.00	.00
Maximum		4500.00	8.41	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sum		16532.00	765.20	862.00	40.00	17.00	29.00	5.00	26.00	37.00	47.00

Appendix 6 – Reliability Analysis

6.1 Construct Collaboration – Collaboration Domains

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.688	.687	7

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Coll_purchase	2.3518	3.199	.282	.107	.683
Coll_production	2.3116	3.175	.279	.092	.685
Coll_salesDis	2.2513	2.926	.420	.244	.647
Coll_service	2.4121	3.082	.404	.282	.653
Coll_RDchain	2.0804	2.812	.491	.326	.626
Coll_RDotherFirms	2.2714	2.845	.482	.296	.629
Coll_RDuni	2.2412	2.921	.421	.375	.647

6.2 Construct Collaboration – Collaboration Intensity

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.699	.698	7

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
dCoFr_purchase	2.0591	3.145	.268	.090	.700
dCoFr_production	2.0197	3.059	.304	.105	.692
dCoFr_salesDis	1.9458	2.804	.444	.244	.656
dCoFr_service	2.1034	2.964	.433	.261	.660
dCoFr_RDchain	1.8177	2.754	.458	.266	.651
dCoFr_RDotherFirms	2.0000	2.752	.506	.334	.639
dCoFr_RDuni	2.0345	2.865	.447	.342	.655

6.3 Construct Digitalization – Integrated Digitalized Technologies

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.608	.616	12

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
ti_MobileDev Mobile/wireless devices for programming and operation	2.5397	3.633	.289	.170	.581
ti_DigSolutions Digital solutions for providing drawings, work schedules or work instructions directly on the shopfloor	2.4286	3.533	.305	.153	.578
ti_ProdPlanning Software for production planning and scheduling	2.2063	3.622	.257	.146	.589
ti_DigExchange Digital Exchange of product/process data with suppliers / customers	2.5556	3.652	.286	.161	.582
ti_RealtimeControl Near real-time production control system	2.6349	3.722	.302	.189	.579
ti_IntLogistics Systems for automation and management of internal logistics	2.6984	3.829	.303	.154	.581
ti_PLCsystems Product-Lifecycle-Management-System	2.7302	3.804	.388	.248	.570
ti_VirReality Virtual reality or simulation product design, development	2.7090	4.027	.160	.076	.604
ti_manuRobots Industrial robots for manufacturing processes	2.5503	3.674	.269	.135	.586
ti_handRobots Industrial robots for handling processes	2.6349	3.818	.236	.113	.592
ti_3Dprototype Additive manufacturing 3D for prototyping	2.6667	3.979	.153	.303	.607
ti_3Dprint Additive manufacturing 3D for products components etc	2.7249	3.988	.214	.341	.596

6.4 Construct Digitalization – Digital Product Elements

Reliability Statistics

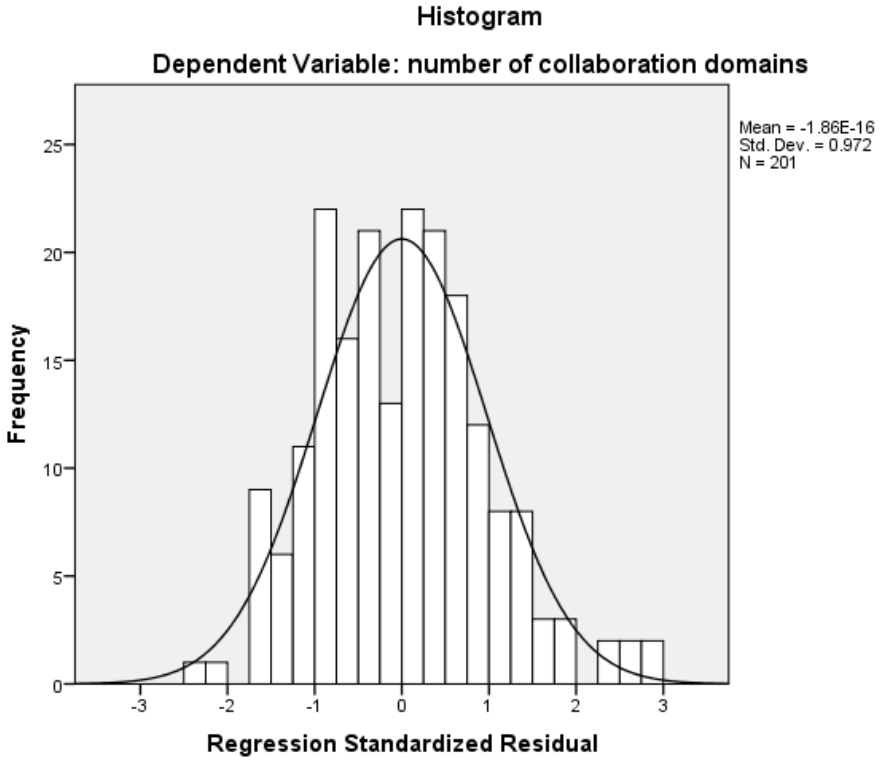
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.702	.720	5

Item-Total Statistics

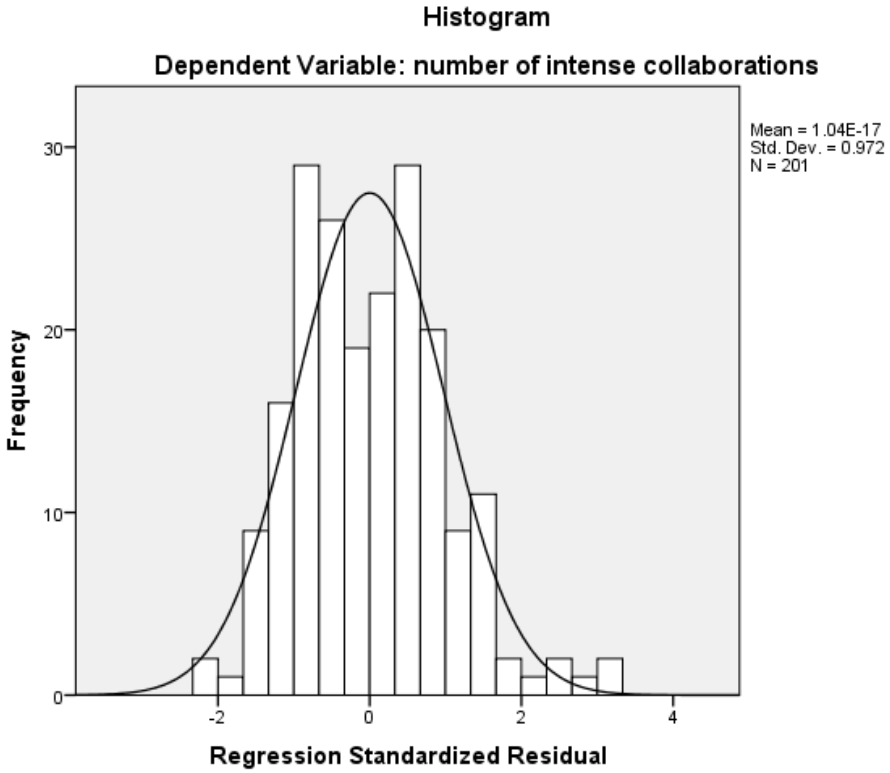
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
dp_Interfaces digital products - Interactive interfaces with the operator	.5461	.993	.297	.402	.719
dp_DataExchange digital products - Internet/network connection for automated data exchange	.3475	.557	.573	.334	.608
dp_Sensor digital products - Sensor technology, control elements for additional digital product functions	.4326	.647	.589	.380	.593
dp_Identification digital products - Identification tags	.3901	.597	.580	.390	.597
dp_DigOther digital products - Other digital elements	.5248	.908	.379	.432	.692

Appendix 7 – Assumptions Multiple Linear regression

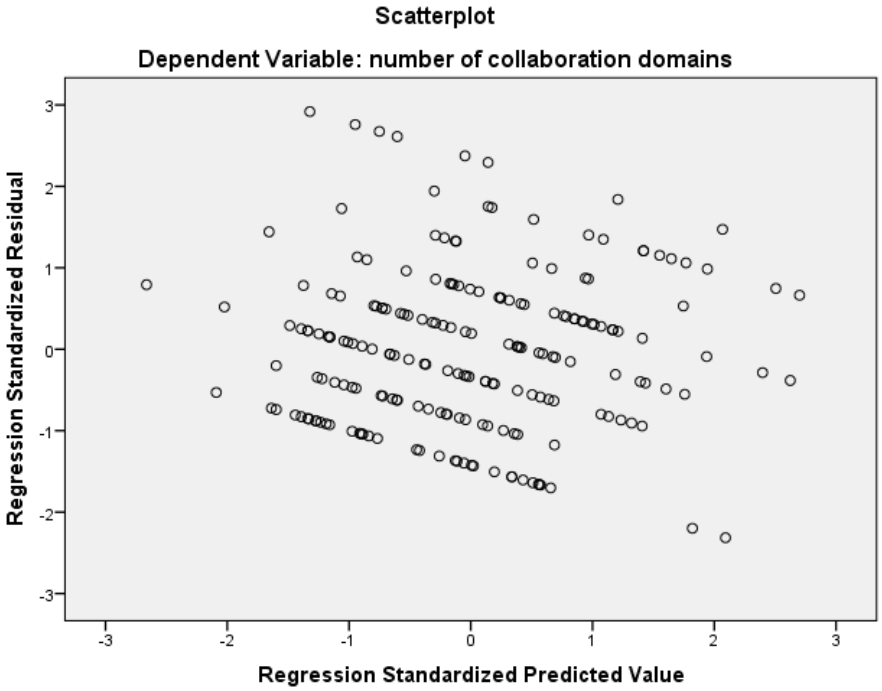
7.1 Normality - Collaboration domains



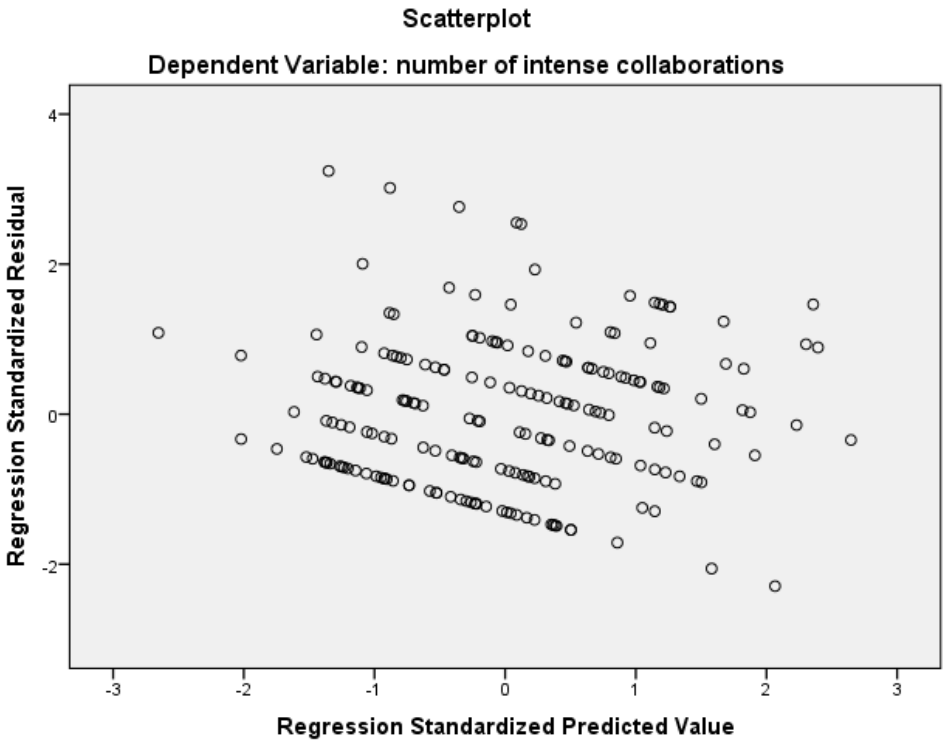
7.2 Normality - Collaboration Intensity



7.3 Linearity – Collaboration domains



7.4 Linearity – Collaboration Intensity



7.5 Independence of the error terms – Collaboration domains

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.5312	4.7719	2.6368	.79057	201
Residual	-4.29088	5.40798	.00000	1.80206	201
Std. Predicted Value	-2.663	2.701	.000	1.000	201
Std. Residual	-2.315	2.917	.000	.972	201

a. Dependent Variable: Collaboration number of collaboration domains

7.6 Independence of the error terms – Collaboration intensity

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0506	4.6202	2.3383	.86215	201
Residual	-4.11941	5.82623	.00000	1.74690	201
Std. Predicted Value	-2.653	2.647	.000	1.000	201
Std. Residual	-2.292	3.242	.000	.972	201

a. Dependent Variable: Coll_Intensity number of intense collaborations

7.7 Multicollinearity – Collaboration domains

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.347	.670		2.012	.046		
	lnSize number of employees 2017 (log)	.233	.163	.102	1.432	.154	.950	1.052
	Food	-.465	.564	-.066	-.824	.411	.757	1.320
	Textile	.431	.472	.077	.911	.363	.677	1.476
	Construction	.537	.920	.043	.583	.560	.909	1.100
	Chemical	.712	.488	.122	1.458	.146	.695	1.439
	Machinery	1.108	.447	.219	2.479	.014	.622	1.608
	Electronic	.333	.417	.072	.800	.425	.599	1.668
2	(Constant)	1.242	.646		1.923	.056		
	lnSize number of employees 2017 (log)	.039	.167	.017	.233	.816	.827	1.209
	Food	-.835	.560	-.118	-1.491	.138	.705	1.419
	Textile	.381	.458	.068	.832	.407	.660	1.515
	Construction	.604	.891	.048	.678	.499	.888	1.127
	Chemical	.661	.473	.113	1.397	.164	.679	1.474
	Machinery	.694	.448	.137	1.548	.123	.567	1.763
	Electronic	.198	.409	.043	.484	.629	.572	1.750
	Digi_Production index of digitalization process innovations used	.138	.072	.147	1.927	.055	.764	1.309
	Digi_Product index of digital elements in products	.221	.128	.131	1.728	.086	.772	1.295
	incProductInnovation	.759	.358	.157	2.123	.035	.809	1.237
	radProductInnovation	.819	.326	.190	2.514	.013	.777	1.287

a. Dependent Variable: Collaboration number of collaboration domains

7.8 Multicollinearity – Collaboration intensity

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.800	.663		1.207	.229		
	lnSize number of employees 2017 (log)	.294	.161	.130	1.822	.070	.950	1.052
	Food	-.398	.559	-.057	-.713	.477	.757	1.320
	Textile	.586	.468	.106	1.252	.212	.677	1.476
	Construction	.445	.911	.036	.489	.626	.909	1.100
	Chemical	.737	.484	.127	1.523	.129	.695	1.439
	Machinery	1.002	.443	.200	2.264	.025	.622	1.608
	Electronic	.377	.413	.082	.912	.363	.599	1.668
2	(Constant)	.642	.626		1.026	.306		
	lnSize number of employees 2017 (log)	.074	.162	.033	.458	.648	.827	1.209
	Food	-.827	.543	-.118	-1.524	.129	.705	1.419
	Textile	.536	.444	.097	1.206	.229	.660	1.515
	Construction	.511	.864	.041	.591	.555	.888	1.127
	Chemical	.697	.459	.120	1.520	.130	.679	1.474
	Machinery	.544	.434	.108	1.253	.212	.567	1.763
	Electronic	.242	.396	.053	.610	.543	.572	1.750
	Digi_Production index of digitalization process innovations used	.162	.070	.174	2.330	.021	.764	1.309
	Digi_Product index of digital elements in products	.204	.124	.123	1.651	.100	.772	1.295
	incProductInnovation	.932	.347	.195	2.689	.008	.809	1.237
	radProductInnovation	1.064	.316	.249	3.369	.001	.777	1.287

a. Dependent Variable: Coll_Intensity number of intense collaborations

Appendix 8 – Results analyses

8.1 Descriptive: Industry Sector & Firm size

Industry Industry sector

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00 Metals and Metal products	40	19.7	19.9	19.9
	2,00 Food, Beverages and Tobacco	17	8.4	8.5	28.4
	3,00 Textiles, Leather, Paper and Board	29	14.3	14.4	42.8
	4,00 Construction, Furniture	5	2.5	2.5	45.3
	5,00 Chemicals (energy and non-energy)	26	12.8	12.9	58.2
	6,00 Machinery, Equipment Transport	37	18.2	18.4	76.6
	7,00 Electrical and Optical equipment	47	23.2	23.4	100.0
	Total	201	99.0	100.0	
Missing	-99,00 niet industriele bedrijven: verhuur diensten	2	1.0		
Total		203	100.0		

Statistics

		Size number of employees 2017	lnSize number of employees 2017 (log)	Industry Industry sector	Metal	Food	Textile	Construction	Chemical	Machinery	Electronic
N	Valid	203	203	201	201	201	201	201	201	201	201
	Missing	0	0	2	2	2	2	2	2	2	2
Mean		81.4384	3.7695	4.2886	.1990	.0846	.1443	.0249	.1294	.1841	.2338
Std. Error of Mean		22.25454	.06028	.16063	.02823	.01968	.02485	.01101	.02373	.02740	.02993
Median		42.0000	3.7377	5.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Mode		45.00	3.81	7.00	.00	.00	.00	.00	.00	.00	.00
Std. Deviation		317.07837	.85880	2.27735	.40025	.27895	.35225	.15613	.33643	.38852	.42432
Variance		100538.693	.738	5.186	.160	.078	.124	.024	.113	.151	.180
Skewness		13.537	1.038	-.238	1.519	3.008	2.040	6.147	2.226	1.643	1.267
Std. Error of Skewness		.171	.171	.172	.172	.172	.172	.172	.172	.172	.172
Kurtosis		189.273	3.356	-1.496	.311	7.122	2.183	36.148	2.983	.705	-.398
Std. Error of Kurtosis		.340	.340	.341	.341	.341	.341	.341	.341	.341	.341
Range		4490.00	6.11	6.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Minimum		10.00	2.30	1.00	.00	.00	.00	.00	.00	.00	.00
Maximum		4500.00	8.41	7.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sum		16532.00	765.20	862.00	40.00	17.00	29.00	5.00	26.00	37.00	47.00

8.2 Firm size CBS

Firm Sizes CBS (CBS, 2020)		
Size	**Amount**	**Percentage**
0 tot 50 werkzame personen	62520	96,31%
50 tot 100 werkzame personen	1165	1,79%
100 tot 150 werkzame personen	475	0,73%
150 tot 200 werkzame personen	225	0,35%
200 tot 250 werkzame personen	145	0,22%
250 tot 500 werkzame personen	250	0,39%
500 tot 1000 werkzame personen	100	0,15%
1000 tot 2000 werkzame personen	35	0,05%
Total	64915	100,00%

8.3 Descriptive: Digitalization

Statistics

		Collaboration number of collaboration domains	Coll_Intensity number of intense collaborations	Digi_Production index of digitalization process innovations used	Digi_Product index of digital elements in products	ProductInnovation3c
N	Valid	203	203	203	203	203
	Missing	0	0	0	0	0
Mean		2.6355	2.3300	2.8276	.8966	1.7931
Std. Error of Mean		.13783	.13622	.14607	.08187	.06075
Median		2.0000	2.0000	3.0000	.0000	2.0000
Mode		2.00	.00	2.00	.00	1.00
Std. Deviation		1.96381	1.94082	2.08123	1.16642	.86548
Variance		3.857	3.767	4.332	1.361	.749
Skewness		.409	.523	.728	1.111	.414
Std. Error of Skewness		.171	.171	.171	.171	.171
Kurtosis		-.607	-.541	-.107	.253	-1.543
Std. Error of Kurtosis		.340	.340	.340	.340	.340
Range		7.00	7.00	8.00	5.00	2.00
Minimum		.00	.00	.00	.00	1.00
Maximum		7.00	7.00	8.00	5.00	3.00
Sum		535.00	473.00	574.00	182.00	364.00

8.4 Descriptive: Integrated Digitalized Technologies

Item Statistics

	Mean	Std. Deviation	N
ti_MobileDev Mobile/wireless devices for programming and operation	.2857	.45295	189
ti_DigSolutions Digital solutions for providing drawings, work schedules or work instructions directly on the shopfloor	.3968	.49054	189
ti_ProdPlanning Software for production planning and scheduling	.6190	.48691	189
ti_DigExchange Digital Exchange of product/process data with suppliers / customers	.2698	.44506	189
ti_RealtimeControl Near real-time production control system	.1905	.39372	189
ti_IntLogistics Systems for automation and management of internal logistics	.1270	.33384	189
ti_PLCsystems Product-Lifecycle-Management-System	.0952	.29432	189
ti_VirReality Virtual reality or simulation product design, development	.1164	.32156	189
ti_manuRobots Industrial robots for manufacturing processes	.2751	.44777	189
ti_handRobots Industrial robots for handling processes	.1905	.39372	189
ti_3Dprototype Additive manufacturing 3D for prototyping	.1587	.36639	189
ti_3Dprint Additive manufacturing 3D for products components etc	.1005	.30150	189

8.5 Descriptive: Digital product elements

Item Statistics

	Mean	Std. Deviation	N
dp_Interfaces digital products - Interactive interfaces with the operator	.0142	.11867	141
dp_DataExchange digital products - Internet/network connection for automated data exchange	.2128	.41072	141
dp_Sensor digital products - Sensor technology, control elements for additional digital product functions	.1277	.33490	141
dp_Identification digital products - Identification tags	.1702	.37716	141
dp_DigOther digital products - Other digital elements	.0355	.18560	141

Digi_Product index of digital elements in products

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	109	53.7	53.7	53.7
	1.00	39	19.2	19.2	72.9
	2.00	28	13.8	13.8	86.7
	3.00	22	10.8	10.8	97.5
	4.00	4	2.0	2.0	99.5
	5.00	1	.5	.5	100.0
	Total	203	100.0	100.0	

8.6 Descriptive: Product Innovation

ProductInnovation3c

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00 no product innovation	101	49.8	49.8	49.8
	2,00 incremental product innovation	43	21.2	21.2	70.9
	3,00 radical product innovation	59	29.1	29.1	100.0
	Total	203	100.0	100.0	

8.7 Descriptive: Collaboration domains

Item Statistics

	Mean	Std. Deviation	N
Coll_purchase	.3015	.46007	199
Coll_production	.3417	.47548	199
Coll_salesDis	.4020	.49154	199
Coll_service	.2412	.42889	199
Coll_RDchain	.5729	.49591	199
Coll_RDotherFirms	.3819	.48708	199
Coll_RDuni	.4121	.49345	199

Collaboration number of collaboration domains

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	37	18.2	18.2	18.2
	1.00	26	12.8	12.8	31.0
	2.00	40	19.7	19.7	50.7
	3.00	33	16.3	16.3	67.0
	4.00	35	17.2	17.2	84.2
	5.00	10	4.9	4.9	89.2
	6.00	14	6.9	6.9	96.1
	7.00	8	3.9	3.9	100.0
	Total	203	100.0	100.0	

8.8 Descriptive: Collaboration Intensity

Item Statistics

	Mean	Std. Deviation	N
dCoFr_purchase	.2709	.44554	203
dCoFr_production	.3103	.46378	203
dCoFr_salesDis	.3842	.48762	203
dCoFr_service	.2266	.41967	203
dCoFr_RDchain	.5123	.50108	203
dCoFr_RDotherFirms	.3300	.47139	203
dCoFr_RDuni	.2956	.45743	203

Coll_Intensity number of intense collaborations

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	49	24.1	24.1	24.1
	1.00	29	14.3	14.3	38.4
	2.00	37	18.2	18.2	56.7
	3.00	30	14.8	14.8	71.4
	4.00	32	15.8	15.8	87.2
	5.00	10	4.9	4.9	92.1
	6.00	10	4.9	4.9	97.0
	7.00	6	3.0	3.0	100.0
	Total	203	100.0	100.0	

Appendix 9 - Correlation matrix

Correlations

		Collaboration number of collaboration domains	Coll_Intensity number of intense collaborations	lnSize number of employees 2017 (log)	Food	Textile	Construction	Chemical	Machinery	Electronic	Digi_Production index of digitalization process innovations used	Digi_Product index of digital elements in products	incProductInnovation	radProductInnovation
Pearson Correlation	Collaboration number of collaboration domains	1.000	.933	.114	-.126	-.003	.013	.049	.186	-.024	.231	.235	.164	.125
	Coll_Intensity number of intense collaborations	.933	1.000	.137	-.117	.023	.005	.047	.162	-.018	.261	.245	.188	.163
	lnSize number of employees 2017 (log)	.114	.137	1.000	.094	-.075	.029	-.104	.167	-.019	.348	.200	.037	.096
	Food	-.126	-.117	.094	1.000	-.125	-.049	-.117	-.144	-.168	-.035	.101	-.024	.197
	Textile	-.003	.023	-.075	-.125	1.000	-.066	-.158	-.195	-.227	-.095	-.076	.033	-.047
	Construction	.013	.005	.029	-.049	-.066	1.000	-.062	-.076	-.088	.059	-.124	.075	-.103
	Chemical	.049	.047	-.104	-.117	-.158	-.062	1.000	-.183	-.213	.068	-.096	.057	-.183
	Machinery	.186	.162	.167	-.144	-.195	-.076	-.183	1.000	-.262	.077	.248	.008	.173
	Electronic	-.024	-.018	-.019	-.168	-.227	-.088	-.213	-.262	1.000	-.067	.055	.034	-.046
	Digi_Production index of digitalization process innovations used	.231	.261	.348	-.035	-.095	.059	.068	.077	-.067	1.000	.288	.207	-.040
	Digi_Product index of digital elements in products	.235	.245	.200	.101	-.076	-.124	-.096	.248	.055	.288	1.000	.157	.165
	incProductInnovation	.164	.188	.037	-.024	.033	.075	.057	.008	.034	.207	.157	1.000	-.331
	radProductInnovation	.125	.163	.096	.197	-.047	-.103	-.183	.173	-.046	-.040	.165	-.331	1.000
Sig. (1-tailed)	Collaboration number of collaboration domains	.	.000	.053	.037	.481	.426	.246	.004	.370	.000	.000	.010	.039
	Coll_Intensity number of intense collaborations	.000	.	.027	.049	.372	.472	.252	.011	.402	.000	.000	.004	.010
	lnSize number of employees 2017 (log)	.053	.027	.	.093	.146	.340	.071	.009	.395	.000	.002	.302	.087
	Food	.037	.049	.093	.	.039	.247	.049	.020	.009	.313	.076	.366	.003
	Textile	.481	.372	.146	.039	.	.177	.012	.003	.001	.091	.142	.322	.254
	Construction	.426	.472	.340	.247	.177	.	.193	.142	.106	.202	.040	.145	.073
	Chemical	.246	.252	.071	.049	.012	.193	.	.005	.001	.170	.088	.210	.005
	Machinery	.004	.011	.009	.020	.003	.142	.005	.	.000	.140	.000	.452	.007
	Electronic	.370	.402	.395	.009	.001	.106	.001	.000	.	.174	.220	.315	.257
	Digi_Production index of digitalization process innovations used	.000	.000	.000	.313	.091	.202	.170	.140	.174	.	.000	.002	.284
	Digi_Product index of digital elements in products	.000	.000	.002	.076	.142	.040	.088	.000	.220	.000	.	.013	.010
	incProductInnovation	.010	.004	.302	.366	.322	.145	.210	.452	.315	.002	.013	.	.000
	radProductInnovation	.039	.010	.087	.003	.254	.073	.005	.007	.257	.284	.010	.000	.
N	Collaboration number of collaboration domains	201	201	201	201	201	201	201	201	201	201	201	201	201
	Coll_Intensity number of intense collaborations	201	201	201	201	201	201	201	201	201	201	201	201	201
	lnSize number of employees 2017 (log)	201	201	201	201	201	201	201	201	201	201	201	201	201
	Food	201	201	201	201	201	201	201	201	201	201	201	201	201
	Textile	201	201	201	201	201	201	201	201	201	201	201	201	201
	Construction	201	201	201	201	201	201	201	201	201	201	201	201	201
	Chemical	201	201	201	201	201	201	201	201	201	201	201	201	201
	Machinery	201	201	201	201	201	201	201	201	201	201	201	201	201
	Electronic	201	201	201	201	201	201	201	201	201	201	201	201	201
	Digi_Production index of digitalization process innovations used	201	201	201	201	201	201	201	201	201	201	201	201	201
	Digi_Product index of digital elements in products	201	201	201	201	201	201	201	201	201	201	201	201	201
	incProductInnovation	201	201	201	201	201	201	201	201	201	201	201	201	201
	radProductInnovation	201	201	201	201	201	201	201	201	201	201	201	201	201

Appendix 10 – Regression analyses

Appendix 10.1 – Entered variables

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery[b]	.	Enter
2	incProductInnovation, Digi_Product index of digital elements in products, radProductInnovation, Digi_Production index of digitalization process innovations used[b]	.	Enter

a. Dependent Variable: Collaboration number of collaboration domains

b. All requested variables entered.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery[b]	.	Enter
2	incProductInnovation, Digi_Product index of digital elements in products, radProductInnovation, Digi_Production index of digitalization process innovations used[b]	.	Enter

a. Dependent Variable: Coll_Intensity number of intense collaborations

b. All requested variables entered.

Appendix 10.2 – Model Summary

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.255[a]	.065	.031	1.93682	.065	1.923	7	193	.068	
2	.402[b]	.161	.113	1.85376	.096	5.421	4	189	.000	2.065

a. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery

b. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery, incProductInnovation, Digi_Product index of digital elements in products, radProductInnovation, Digi_Production index of digitalization process innovations used

c. Dependent Variable: Collaboration number of collaboration domains

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.253[a]	.064	.030	1.91855	.064	1.886	7	193	.074	
2	.443[b]	.196	.149	1.79702	.132	7.747	4	189	.000	2.159

a. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery

b. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery, incProductInnovation, Digi_Product index of digital elements in products, radProductInnovation, Digi_Production index of digitalization process innovations used

c. Dependent Variable: Coll_Intensity number of intense collaborations

Appendix 10.3 – Anova

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	50.492	7	7.213	1.923	.068[b]
	Residual	723.995	193	3.751		
	Total	774.488	200			
2	Regression	125.001	11	11.364	3.307	.000[c]
	Residual	649.486	189	3.436		
	Total	774.488	200			

a. Dependent Variable: Collaboration number of collaboration domains

b. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery

c. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery, incProductInnovation, Digi_Product index of digital elements in products, radProductInnovation, Digi_Production index of digitalization process innovations used

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	48.597	7	6.942	1.886	.074[b]
	Residual	710.398	193	3.681		
	Total	758.995	200			
2	Regression	148.662	11	13.515	4.185	.000[c]
	Residual	610.333	189	3.229		
	Total	758.995	200			

a. Dependent Variable: Coll_Intensity number of intense collaborations

b. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery

c. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Chemical, Textile, Machinery, incProductInnovation, Digi_Product index of digital elements in products, radProductInnovation, Digi_Production index of digitalization process innovations used

Appendix 10.4 – Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.347	.670		2.012	.046		
	lnSize number of employees 2017 (log)	.233	.163	.102	1.432	.154	.950	1.052
	Food	-.465	.564	-.066	-.824	.411	.757	1.320
	Textile	.431	.472	.077	.911	.363	.677	1.476
	Construction	.537	.920	.043	.583	.560	.909	1.100
	Chemical	.712	.488	.122	1.458	.146	.695	1.439
	Machinery	1.108	.447	.219	2.479	.014	.622	1.608
	Electronic	.333	.417	.072	.800	.425	.599	1.668
2	(Constant)	1.242	.646		1.923	.056		
	lnSize number of employees 2017 (log)	.039	.167	.017	.233	.816	.827	1.209
	Food	-.835	.560	-.118	-1.491	.138	.705	1.419
	Textile	.381	.458	.068	.832	.407	.660	1.515
	Construction	.604	.891	.048	.678	.499	.888	1.127
	Chemical	.661	.473	.113	1.397	.164	.679	1.474
	Machinery	.694	.448	.137	1.548	.123	.567	1.763
	Electronic	.198	.409	.043	.484	.629	.572	1.750
	Digi_Production index of digitalization process innovations used	.138	.072	.147	1.927	.055	.764	1.309
	Digi_Product index of digital elements in products	.221	.128	.131	1.728	.086	.772	1.295
	incProductInnovation	.759	.358	.157	2.123	.035	.809	1.237
	radProductInnovation	.819	.326	.190	2.514	.013	.777	1.287

a. Dependent Variable: Collaboration number of collaboration domains

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.800	.663		1.207	.229		
	lnSize number of employees 2017 (log)	.294	.161	.130	1.822	.070	.950	1.052
	Food	-.398	.559	-.057	-.713	.477	.757	1.320
	Textile	.586	.468	.106	1.252	.212	.677	1.476
	Construction	.445	.911	.036	.489	.626	.909	1.100
	Chemical	.737	.484	.127	1.523	.129	.695	1.439
	Machinery	1.002	.443	.200	2.264	.025	.622	1.608
	Electronic	.377	.413	.082	.912	.363	.599	1.668
2	(Constant)	.642	.626		1.026	.306		
	lnSize number of employees 2017 (log)	.074	.162	.033	.458	.648	.827	1.209
	Food	-.827	.543	-.118	-1.524	.129	.705	1.419
	Textile	.536	.444	.097	1.206	.229	.660	1.515
	Construction	.511	.864	.041	.591	.555	.888	1.127
	Chemical	.697	.459	.120	1.520	.130	.679	1.474
	Machinery	.544	.434	.108	1.253	.212	.567	1.763
	Electronic	.242	.396	.053	.610	.543	.572	1.750
	Digi_Production index of digitalization process innovations used	.162	.070	.174	2.330	.021	.764	1.309
	Digi_Product index of digital elements in products	.204	.124	.123	1.651	.100	.772	1.295
	incProductInnovation	.932	.347	.195	2.689	.008	.809	1.237
	radProductInnovation	1.064	.316	.249	3.369	.001	.777	1.287

a. Dependent Variable: Coll_Intensity number of intense collaborations

Appendix 11 – Qualitative analysis

Appendix 11.1 – Interviewed firms

Participating firms					
	Abbreviation Company	**Industry**	**Number of employees**	**Determined size**	**Job Description(s)**
1	CF	Chemical Food	14.000	Big	Regional Innovation EAME and Technical Director Tobacco
2	CT	Chemical Textile	20.000	Big	Business Unit Manager
3	BS	Bakery semi-finished Goods	35	Small	Product Manager Quality Assurance Employee
4	FO	Food industry	140	Medium	Product Marketer
5	IE	Industrial engineering	65	Medium	Supply Chain Manager
6	PT	Equipment transport	7	Small	Director, Owner

Appendix 12 – Quotes used in qualitative analysis

Quotes used in qualitative analysis		
Innovation		**p.**
CF	Als er problemen tijdens de productie van de klant zijn, bieden we service aan om mee te denken en mee op te lossen van het probleem. Kan zijn dat we er zelfs mensen heen sturen.	7
CF	Wij doen tijdens ontwikkeling van smaakstof, op aanvraag van de klant workshops. Afhankelijk van wat ze willen doen we marketing achtige workshops, houden we lezingen, geven we informatie. We doen soms zelfs een deel van ontwikkeling van het eind product, omdat klanten steeds meer op product ontwikkeling aan het bezuinigen zijn. Hier hoeven klanten niet voor te betalen, dit zit bij het product erin. Dit doen we pas sinds een aantal jaar.	7
IE	En ja meer en deel van de innovatie die wat ik zeg dat is niet echt een specifieke strategie, die komen gewoon vanuit de fabriek zelf of vanuit de mensen op de werkvoorbereiding zelf van jongens we hebben hier veel problemen, van kunnen we het niet zo en zo doen of veranderen. Dan worden daar sessies voor georganiseerd om dat klassikaal te bespreken.	56
PT	Het voornaamste probleem met innoveren is eh mankracht, om tijd vrij te maken, naast je normale werkzaamheden. Want we zijn klein en we hebben wel nu door Corona wat meer tijd om te innoveren en sneller te kunnen innoveren.	72
Digitalization		
IE	Ehm ja wij willen de komende 5 jaar steeds verder ook die stap maken van digitalisering en automatisering aangezien dit ons onderscheidende vermogen creëert en we steeds efficiënter kunnen produceren hierdoor.	54
CF	We ontmoedigen het printen, we faciliteren binnen system dat het veel makkelijker is om documenten uit te wisselen, gezamenlijk in documenten te werken, documenten op te slaan, grotere hoeveelheid aan data die mensen tot hun beschikking hebben om documenten op te slaan, ehm HUBS waar presentaties op opgeslagen kunnen worden en daardoor heeft eigenlijk iedereen de toegang tot erg veel verschillende soorten documenten en is de noodzaak tot printen bijna tot 0 gereduceerd	6
CF	Bij onze parfum afdeling is er een nieuwe robot gelanceerd die enorm snel productie van geurstoffen mogelijk maakt, wij noemen dit de Instant Sampling Robot, een Artificial Intelligence aangedreven tool. Hierdoor kunnen de parfumeurs focussen op hun eigen creatieve werk en krijgen ze tegelijkertijd digitale ondersteuning van de robot, het is echt een aanvullende ondersteuning."	5
CT	Nou in ieder geval maakt het het mens onafhankelijk, dus als er iemand wegvalt dan is dat niet meteen een gat, maar processen lopen gewoon door. Dus het wordt betrouwbaarder	23
FC	Dus digitalisering is wel heel mooi, het levert heel veel efficiëntie op, maar ook heel onvoorspelbaar en kan heel ingewikkeld proces zijn waar je veel langer mee bezig bent of veel duurder uit valt dan je van te voren voorspelt had."	48
TC	De textiel industrie is een hele rare industrie vind ik. Aan de ene kant, zeker vanuit fashion en techniek, is het een hoog innovatieve industrie. Fashion moet elke keer weer met iets nieuws komen, techniek ook. Dus er zit heel veel innovatie aan die kant. Als ik kijk naar productie van textiel, dat doen we eigenlijk niet zo veel anders dan 50 jaar terug. Dat is echt bijna pijnlijk	21
Collaborations		
CF	Wij zitten in een aantal consortiums in Europe en Amerika. Die consortiums werken samen met startups en dat zit allemaal op het gebied van voedingsmiddel en. Die consortiums, daar zitten wij in als smaakstoffenbedrijf, maar ook bedrijven als Mille en software bedrijven, consultancy bedrijven als McKinsey en noem maar op. Om juist samen te bekijken van waar gaat de wereld heen, dus wij op het gebied van	11

	smaakstoffen, grote bedrijven als Unilever en Nestle en noem ze maar op, op het gebied van welke kant gaat de voedingsmiddelen kant op.	
IE	Nu doen we met het waterstofauto van de HAN sponseren, omdat wij als bedrijf veel toekomst zien in waterstof als duurzame energie bron.	61
CF	Je probeert met startups waarvan je denkt dat die een uniek concept in handen hebben, probeer je als eerste mee samen te werken, zodat concurrent daar niet in zit, dat we niet de boot missen.	12
CT	Er zijn een aantal van die bedrijven, die hebben hun eigen R&D afdeling afgebouwd en gaan nu veel meer samenwerken met ons om samen innovaties te creëren. Dus dat is dus de andere kant op in het kader, dat je echt met je kant samen gaat werken om iets voor elkaar te krijgen."	26
CF	We doen soms zelfs een deel van ontwikkeling van het eind product, omdat klanten steeds meer op product ontwikkeling aan het bezuinigen zijn.	7
CT	je kan niet alle apparatuur hebben, je kan niet alle mogelijkheden hebben, je moet samenwerken. Dus wij hebben een netwerk op dit moment van ik denk 5 of 6 bedrijven waarbij wij bepaalde processen laten doen die wij zelf niet kunnen.	26
PT	"Dat je kwalitatief een scherp geprijsde inkoop componenten kan realiseren en dat je de know how die je mist ook kan gebruiken van je partners. Dus echt het combineren van de sterktes van elkaar."	73
Coopetition		
CT	Door ook aan te geven wat onze competentie in zo'n samenwerking zou kunnen zijn. Het gaat altijd om benefits, altijd zorgen dat iemand ziet dat ik er ook beter van kan worden.	28
IE	Zelfs ook wel eens processen waar machines staan waar wij zelf mensen hebben die daar heel weinig ervaring mee hebben en alle ervaring uit ons bedrijf is waardoor zij opnieuw moesten leren. Toen hebben we aan onze concurrent gevraagd van kan een keer een dag iemand van jullie hier langs komen om uitleg te geven over die machines. Dus dat soort dingen worden ook wel dingen gedaan, dus zelfs trainingen van concurrenten onderling.	63
BS	Als wij een klantvraag hebben die we echt moeten kunnen beantwoorden en moeten kunnen leveren dan zouden we wellicht wel een uitvraag doen bij een concurrent om te vragen of zij voor ons kunnen produceren, maar dat zou dan wel onder strenge kwaliteitstoezicht moeten gebeuren om zeker te weten dat we dan dezelfde kwaliteit kunnen leveren.	36-37
PT	Het vertrouwen onderling, je stelt je kwetsbaar op omdat je mogelijkheden ziet om samen te werken. Als dan de informatie die je dan neerlegt wordt misbruikt door de concurrent dat is korte termijn winst voor zo'n concurrent. Dan heb je verder geen behoefte aan om daar verder mee te werken.	73
CF	ja we hebben in het verleden wel eens samen gewerkt met concurrenten, dat hebben we wel gedaan om te kijken of we gezamenlijk iets kunnen doen. Dat is ver gegaan, dat we bepaalde programma's op gezet hebben waarbij we samen dingen gingen ontwikkelen, maar dat is helaas niet succesvol gebleken. Omdat ze concurrenten waren, zowel aan beide zijde er veel argwaan was van gaan ze niet met onze innovatie lopen en dat ook in eigen producten gebruiken in plaats van alleen in het programma wat we aan het opzetten waren.	12
CT	Ja, natuurlijk start je dit soort dingen natuurlijk met NDA, Non Disclosure Agreements. Je start altijd met een NDA, waarbij je je eigen inbreng hebt waarbij de ander dat niet mag gebruiken zonder toestemming van de ander. Dus het is juridisch vast gelegd, maar de uitwerking in de dagelijkse partij is vertrouwen. Kom je dan in de problemen, dank an je altijd terug grijpen op het juridische document."	27
Relation Digitalization and Collaboration		
IE	Inderdaad waar ik net over na heb zitten te denken is dat je minder contact hebt met leveranciers waardoor je minder gezien kan worden. Als je elkaar veel ziet, kun je een positieve mening over die persoon krijgen die een band schept. Dat je minder gezien wordt. Ik merk vaak ook dat als een vertegenwoordig hier veel komt, dat is door Corona lastig, maar dat je die persoon dan wat meer vindt. Waar je een goede verstandhouding mee hebt die kan soms wel duurder zijn met dit of dat, mar die gun ik	64

	het wel omdat ik dat een fijn iemand vindt om mee samen te werken. Dit kan verdwijnen als gevolg van de digitalisering en automatisering.	
Relation Innovation and Collaboration		
BS	Nee als we een idee hebben voor een nieuw product, maar dit zelf niet kunnen, dan gaan we het ook niet doen. We gaan niet nieuwe samenwerkingsverbanden aan als het niet perse nodig is, want het gaat nu gewoon goed."	38
IE	Wij gaan voor Repeat werk of werk wat weer terugkomend in huis komt, gaan wij niet, is ons doel niet om dat bij een concurrenten neer te leggen. Dan is het ook echt zoiets van hey dit moeten wij zelf in huis halen en dan wordt op basis hiervan geïnvesteerd. Als hier niet in geïnvesteerd wordt en we moeten dit buitenshuis doen dan ben je vaak wat duurder als bedrijf zijnde als je met verschillende partijen moet gaan samenwerken, dan wordt het lastig om concurrerend te zijn aangezien alle bedrijven die meewerken er iets aan moeten verdienen. Dan kan de klant het beter direct kopen.	65
CF	Waarom zou je zelf heel veel moeite doen om iets te bedenken of ontwikkelen als een ander bedrijf dit ook heel goed kan bedenken. Je hoeft niet zelf constant het wiel opnieuw uit te vinden.	14
Relation Innovation and Coopetition		
CF	Er is gewoon niet genoeg vertrouwen om daadwerkelijk een product samen te ontwikkelen, wij doen dit dan veel liever met andere organisaties waar het vertrouwen niet zo'n belangrijke rol speelt en er minder risico aan is verbonden om samen te werken.	14