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BEYOND BOUNDARIES WITH SUPPLY CHAIN: EFFECT OF OUTSOURCING AND COLLABORATION ON ADOPTION TECHNOLOGIES

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ABSTRACT

This thesis set to examine which factors influence the adoption of digital process technologies by Dutch manufacturing firms. It does so by drawing upon the make-or-buy decision in terms of outsourcing, and by including the external context, more specially the opportunity of collaboration within the production domain. The relationship between outsourcing production and adoption of digital process technologies in this study is proposed to hinge upon one contextual factor: collaboration in production. Five semi-structured interviews were conducted, and an analysis of 152 Dutch manufacturing firms from 2018 were under investigation to provide answers.

The study finds that outsourcing production does not lead to a higher adoption rate of digital process technologies. Other results this study found are that collaboration in the production domain, trigger firms to engage in several collaborative partnerships to gain access to digital process technologies. However, the study found that when collaboration is narrowly defined, the relationship does not receive significant evidence.

Finally, collaboration was found to play a moderating role in the relationship between outsourcing production and adoption of digital process technologies. Adding to this, outsourcing production only has a positive effect on this adoption of technologies when firms collaborate beyond mere transactions.

In light of the results, this study contributes to theory on collaboration and adoption digital process technologies by concluding that collaboration, in the production domain, provides access to new knowledge, and stimulates firm’s competitive advantage.

PREFACE

I present to you my master's thesis "*Beyond boundaries with supply chain: Effect of outsourcing and collaboration on adoption technologies"*. It has been written to fulfill the graduation requirements of the MSc Strategic Management at Radboud University. I was engaged in researching and writing this dissertation from January to June 2023.

In this section I would like to thank several people who supported me throughout the duration of this master's program. Firstly, I would like to thank my supervisor dr. Ligthart for his academic assistance and great feedback and support during my thesis. Subsequently, I would like to extend my gratitude to the manufacturing firms that have greatly contributed to my understanding of their practical operations. I also want to thank my family who supported me throughout the writing process of this thesis. Lastly, I would like to thank my friends for all the positive feelings and help throughout the year, in addition to the discussions that have caused me to think about aspects from another perspective.

CONTENTS

1. INTRODUCTION

This chapter will provide a background to the research topic and will specify the central research question, the relevance of this study, the research questions and finally the structure for the remaining of the report.

Over the past decade, the manufacturing industry has undergone big and many transformations. Nowadays, the industry is once again facing new challenges related to digitalization and advanced technologies (Frank et al., 2019). Digitalization has emerged as a critical concern for these firms, and the adoption of digital process technologies has become a strategic necessity for firms to stay competitive (Ligthart & Vaessen, 2020). With connectivity platforms provided by Internet of Things (IoT) and cloud computing, a new digitalized era is rising. This digitalized era revolutionizes global value chains by transforming isolated manufacturing processes into automated, and fully integrated product and data flows (Strange & Zucchella, 2017). Firms need to prepare themselves for the changes that this way of production brings with it (Bauer & Wee, 2015). However, firms don't yet make sufficient use of digital process technologies in their production processes (Van Helmond, Kok, Ligthart & Vaessen, 2018). To keep up with technological developments, it's crucial to engage with the external environment to gain access to new knowledge, because no single firm can possess expertise in every area of technology anymore. By establishing external linkages, firms can tap into specialized knowledge and expertise that may not be available within their own organization (Lewin, Massini & Peeters, 2011). In situations where firms lack the required expertise to certain digital process technologies, outsourcing can be a viable option. Although outsourcing is primarily associated as a cost advantage strategy, evidence shows that many firms now outsource to access new knowledge, expertise, or technology (Sen & MacPherson, 2009). Conversely, the dimension of core competencies can be lost over time as external suppliers assume control over critical processes and technologies, which can pose problems for firms in maintaining their competitive advantage (Winroth, 2004). To counteract this potential loss of core competencies, collaboration with partners can serve as a tool of continuous learning and knowledge exchange. By working intensively with partners, firms can gain insights into technologies, while still maintaining a level of control and understanding of their core competencies. On the other hand, integrating collaborative relationships into operations comes with its own set of challenges. One such challenge is the issue of information hoarding, where firms may be reluctant to share critical information or knowledge with their collaborative partners. Therefore, firms must critically analyze various determinants that can make or break a collaboration successful. This study will focus on the debate between outsourcing and/or collaboration within the production domain in the context of adopting digital process technologies, which represents a strategic choice that firms encounter when considering their business operations, while lacking the necessary knowledge, skills, and expertise. The decision between outsourcing and/or collaboration arises as firms seek to leverage external resources and expertise to bridge their knowledge gaps and effectively adopt digital process technologies. Both outsourcing and collaboration have their pros and cons. By carefully weighting these factors, firms can determine the most suitable approach or combination of outsourcing and collaboration that aligns with their goals and circumstances.

1.1. Problem Statement

The Dutch manufacturing industry is witnessing a gradual adoption of digital process technologies, but not all firms are still fully embracing these technologies (Van Helmond, Kok, Ligthart & Vaessen, 2018). The businesses of today are facing increasing international competition though globalization, diversifying customer needs, and the rise of advanced technologies. The adoption of digital process technologies has the potential to revolutionize and improve value chains. The transition to this revolutionized value chain is crucial to move towards a manufacturing industry with higher level of production, increased volumes, efficient time-management, and resource efficiency (Huizinga, Walison & Bouws, 2014). By integrating more technologies across the supply chain, businesses can collect real-time data from various points or partners. As a result, businesses generate value, and can make more informed decision in terms of accurate demand forecasting, inventory risk management, and optimize resource allocation (Yang, Fu & Zhang, 2021). Supply chains will become more integrated, and this integration facilities more communication between suppliers, customers, and competitors. The growth of technology and digitalization has already had an impact on supply chains, and this digitization trend is likely to continue. However, the adoption of digital process technologies in the Dutch manufacturing industry in still in the early stage, and Dutch businesses apply a few technologies across various industries (Van Helmond et al., 2018). It’s worth nothing that existing studies have shown that the adoption of digital process technologies can help firms improve their performance in terms of efficiency, resilience, and reduce supply chain risks (Yang et al., 2021). While some forms have been early adopters of digitalization, the average manufacturing businesses are still at the beginning stages of digital transformations in their production processes. Therefore, firms may face difficulties when initiating their adoption operations for new technologies. The adoption can be influenced by various factors, namely technological, organizational, and environmental aspects (Yadegaridehkordi et al., 2018). Firms should assess the specific technology they are considering (technological), how they are going to implement it within the internal organization (organizational), and the potential relationships they want to establish when considering technology adoption. When an organization lacks the necessary technical capabilities, expertise, skills, or knowledge, it can hinder the effective adoption of digital technologies. As a result, firms should consider expanding their boundaries and seeking potential relationships to overcome these limitations. Outsourcing and collaborations emerged as potential solutions to these issues both with their own characteristics. Outsourcing can offer several short-term advantages, and lead to cost savings and increased economic efficiency for organizations. Moreover, it allows businesses to focus on their core competencies and allocating their scarce resources more effectively (Gilley & Rasheed, 2000). However, there are concerns about the long-term implications, particularly related to knowledge and organizational learning (Edvardsson & Durst, 2019). Firms can lack in-house knowledge or expertise regarding core competencies, which can be the case for adoption digital process technologies. Then outsourcing can be an effective strategy, but the core competencies comprise the collective learning of organizations (Kumar et al., 2010). A potential drawback could be the loss of touch with the technological and organizational know-how which can offer opportunities for development of technologies (Martínez-Sánchez et al., 2007). As a result, outsourcing undermines the knowledge base of firms, and firms could eventually lose their understanding of core markets (Quintas, 2001). Therefore, the impact of outsourcing on knowledge and organizational learning is an important topic for both academic research and practical implications (Edvardsson & Durst, 2019). In addition to outsourcing, firms can choose for more intensive collaboration as an alternative strategy. Collaboration is driven by the need to access knowledge that can't be obtained via in-house investments (Sen et al., 2009), and provides opportunities to gain access to new technologies (Lightart & Vaessen, 2020). Collaboration complements outsourcing as a strategy because it brings multiple benefits such as creating new knowledge (Belderbos et al., 2004), and learning more effectively from partners (Dyer & Nobeoka, 2000). As with outsourcing, collaboration also has some drawbacks. Collaboration can be ineffective when there is a lack of shared vision, unequal sharing of information or lack of formal agreements. While outsourcing and collaboration may appear similar at first glance, they can be seen as rival strategies in terms of establishing external linkages to adopt digital process technologies.

1.2. Objectives, Research Question & Relevance

The main objective of this study is to provide insights into how businesses in the manufacturing industry can properly achieve the expected outcomes of adopting digital process technologies. Many firms in the manufacturing industry are currently in the process of adopting digital process technologies to improve their operations and stay competitive in today's digital age. Two commonly familiar strategies that firms can utilize to tap into specialized knowledge and expertise from external sources are outsourcing and collaboration. To bridge the gap between academic literature and practical implementations, it's important for businesses to consider the potential benefits, risks, and long-term strategic implications associated with each option. Firstly, this study describes the main effect of outsourcing, in the domain of production, on the adoption of digital process technologies. Secondly, the study aims to explore the added role of collaboration as a moderator and examine what additional risks of benefits collaboration brings to the interaction effect. The following research question is formulated, regarding the research objective: *"How does outsourcing production affect the adaptation of digital process technologies, and to what extent is this influenced by collaboration in production?"*

1.3. Structure and division of chapters in Thesis

As the first chapter has introduced the subject and the relevance of this study to the subject, the next chapter, chapter 2, will introduce the theoretical part of the thesis. In this chapter relevant literature will be provided that explains the main constructs in this thesis, starting with the meaning of outsourcing. Chapter 2 also introduces the conceptual model of this paper connected to these main constructs. Furthermore, the different relationships between the constructs will be described from which the hypotheses arise. Chapter 3 will introduce the methodology. Next, chapter 4 will tell the results and whether the hypothesis can be answered with significant effects. Chapter 5, 6, and 7 will respectively contain the conclusion, discussion, and future research implications.

2. THEORETICAL PART OF THE THESIS

This chapter aims to gain more insight into the various concepts that play a role in finding an answer to the research question. This chapter provides multiple perspectives of outsourcing and provides the implications it has on firms. Furthermore, this chapter highlights the importance of taking collaboration into account. It delves into the benefits, challenges, and best practices of collaboration. Finally, a comprehensive overview of the concept of adoption of digital process technologies by firms will be given.

2.1. Outsourcing

Increasing global competition and world connectivity has led to a rise in the outsourcing of manufacturing business. The ongoing outsourcing trend has brought a change in how firms develop their activities. Initially firms started outsourcing focused on relatively simple assembly and support activities to external suppliers. This was later followed by outsourcing of manufacturing processes, but outsourcing of today is used for a variety of business processes (Uygun et al., 2022). Firms realized that external suppliers performed certain activities better due to specialization. Outsourcing has increasingly become an essential requirement for achieving efficient and cost-effective production processes. It's one of the fastest spreading and globally adopted forms of international trade in most of the industrial sectors. Nowadays, outsourcing has become increasingly common as a strategic decision for many organizations in today's business landscape and continues to gain momentum in many industries. The literature on outsourcing reflects a wide range of definitions in different business processes. In the literature review of Ishizaka et al. (2020) the authors examined existing literature about outsourcing from 1994 to 2020 and came to a general and broad definition: *"Outsourcing is a business agreement, either domestic and/or international (known as offshoring), and strategic management initiative for gaining a competitive advantage of a firm by contracting out their existing internal and/or external non-value-added functions, and/or value-added functions, and/or core competencies to competent supplier(s) to produce products and/or services efficiently and effectively for the outsourcing firm"*

This definition of Ishizaka et al. (2020) consists of multiple elements, namely business agreement, and strategic management initiative. Outsourcing implies an inter-organizational business relationship between two parties. The firm that makes the decision to outsource is called the buyer or client, whereas the external partner that provides the product is known as supplier or subcontractor (Dolgui & Proth, 2013; Arnold, 2000). The buyer and the supplier typically establish a contract to formalize their outsource agreements and to align on terms and conditions. The core of outsourcing lies in the decision to accept or reject performing an activity in-house (Gilley & Rasheed, 2000). Firms can outsource activities that were previously performed internally or outsource activities that may not have been performed in-house earlier. Outsourcing previously performed activities allows firms to focus on core competencies. Firms can choose to outsource activities despite having the capability to perform them internally for cost advantage, flexibility, capability, and external expertise (Gilley & Rasheed, 2000). Within this view of vertical disintegration, outsourcing can be seen as a make-or-buy decision. In most cases, it's about outsourcing general business processes, such as manufacturing, IT, or logistics processes (Gilley, McGee & Rasheed, 2004). The outsourced objects are typically customized or designed according to the specific requirements and instructions provided by the client. In other words, the client retains control over the outsourced process, but the execution is performed by the supplier (Kimura, 2002). Therefore, the purchasing of standardized components is not considered as outsourcing, but rather a form of purchasing. Furthermore, outsourcing can be a strategic management initiative (Ishizaka et al., 2020). Traditional outsourcing involved contracting out non-core functions.
As a result, firms can focus on their core competencies. Some firms have started to explore outsourcing core competencies as well, which means that firms are aiming for more specialized expertise to gain access to new technologies (Pang, Zhang & Jiang, 2021). Furthermore, by outsourcing certain business processes to qualified suppliers, a firm can achieve more efficient and effective products that can help to improve its position in the market.
In addition to outsourcing, offshoring is a different practice that goes beyond national borders. While both outsourcing and offshoring involve delegating tasks or activities to external partners, offshoring specially refers to the movement of business operations to a foreign country according to Lewin et al. (2009): *"The process of sourcing and coordinating tasks and business functions across national borders"*

This definition has two elements that differentiate offshoring from outsourcing. Offshoring does have a geographic aspect which involves moving specific activities to a foreign location, whereas outsourcing is more focused on ownership of processes regardless of their location. The second element of offshoring is that it is aimed at supporting a firm's existing business, which can be driven by costs reduction or labor availability (Mihalache & Mihalache 2016). In other words, with offshoring firms take advantage of foreign countries competitive advantages. Outsourcing and offshoring are not mutually exclusive, and firms can adopt partial strategies that involve both outsourcing and offshoring elements.
In this thesis, the focus is specifically on outsourcing production, which refers to the practice of firms contracting out production related processes to a supplier (Gomez, Salazar & Vargas, 2022). This outsources arrangement involves the supplier's responsibility for some or all the manufacturing activities involved in making the product. The general decision is explicitly linked to manufacturing outsourcing.

2.1.1. Motivations of outsourcing

Three common theories have been used to gain a deeper understanding of outsourcing decisions, namely *Transaction Cost Economics (TCE), Resource-Based Theory (RBT), and Theory of Core Competencies (TCC).* These theories provide a framework for understanding the motivations and factors that influence the decision to outsource activities.

Transaction Cost Economics

The TCE theory of Williamson (1979) is a combination of economic theory and management theory with a strong emphasis on the rational economic perspective. The TCE is a theoretical framework that focuses on analyzing the decision to make or buy goods in economic transactions. Williamson's work emphasized the role of transaction costs, which include costs associated with purchasing orders, quality inspections, and the transfer of goods, among other things. The comparison between transaction costs and operating costs is a fundamental aspect of TCE. By reducing total costs, firms can improve their profitability and performance.
If the transaction costs of outsourcing are lower than the operating costs of performing the activities internally, then outsourcing becomes a more attractive option for the firm.
According to Williamson (1979) activities which are routine and standardized, and do not require firm-specific assets or knowledge, can be effectively outsourced to third-party suppliers. While TCE provides a valuable framework for understanding the make-or-buy decision, TCE has faced some critiques, and one of the common criticisms is that it simplifies

the economic situation of firms and place strong emphasis on the operational side (Bolumole et al., 2007). In line with this, Holcomb & Hitt (2007) identified criteria such as uncertainty in demand, asset specificity, and frequency of transactions as factors that influence decision about decision. While cost saving has traditionally been a primary motivation for outsourcing, recent studies have shed light on alternative perspectives and motivations for outsourcing.

Resource-Based View

The resource-based view (RBV) perspective is a theoretical framework that implies that a firm's competitive advantage is derived from its unique and valuable resources (Espino-Rodríguez & Robaina, 2006). Within the RBT perspective, scholars analyze a firm based on its in-house resource availability, which includes various dimensions such as technology, financial capital, and human capital capabilities. Outsourcing can be considered when a firm lacks specific unique resources that are essential for its competitive advantage. The RBT perspective primarily focuses on analyzing a firm's internal resources and capabilities (Dekkers, 2011). The uniqueness of assets possessed by firms can have implications for power dynamics and trust in buyer-supplier relationships. Medcof (2001) highlights that when one firm has unique assets or resources that are critical to the relationship, it can create an imbalance of power between the buyer and the supplier. Buyers can become highly dependent on certain suppliers, when those suppliers possess unique capabilities that are critical to the production process or quality of the final product. This can lead to a shift in the approach to outsourcing from an operational level to a more tactical or strategic level.

Theory of Core Competencies

The theory of core competencies (TCC) suggests that firms should focus on developing their unique strengths and capabilities, known as core competencies, to achieve competitive advantage (Hamel & Prahalad, 1990). The TCC framework provides a useful perspective for evaluating which activities should be kept in-house as core competencies, and which activities can be outsourced to external partners (Gilley & Rasheed, 2000). Core competencies are the unique skills, activities or assets that differentiate a firm from its competitors, and contribute to its competitive advantage (Parry, Graves & James-Moore, 2006). These competencies are typically specific to the firm, and difficult for competitors to replicate. Identifying core competencies is crucial for achieving optimal performance (Insinga & Werle, 2000; Quinn & Hilmer, 1994). The key issue behind TCC is to develop core competencies internally, while outsourcing non-core activities to external parties. The shift has led to a transformation in the traditional vertical integrated production model, towards a more networked model. However, in today's rapidly changing economy, core competencies can become outdated due to the emergence of new technologies and shifts in market dynamics. Therefore firms need to continuously refine their skills, resources, and core competencies (Hätonen & Eriksson, 2009).

2.1.2. Risks of outsourcing

While outsourcing can offer several advantages, there are also downsides associated with this business practice. It's important to consider both the pros and cons before deciding to outsource certain processes. Despite the many potential benefits, a downside of outsourcing is the potential loss of important skills and market performance due to increased reliance on third-party suppliers (Broedner, Kinkel & Lay, 2008). When firms outsource their core competencies, which are unique capabilities, it may transfer critical knowledge and expertise to suppliers, and these suppliers become stronger. Firms need to continuously develop a comprehensive understanding of new technologies and possibilities to stay competitive. Failing can result in falling behind on leading technological advancements and missing out on potential process opportunities (Gilley & Rasheed, 2000). On the hand, third-party suppliers who gain production knowledge through outsourcing relationships can implement that knowledge, and eventually launch their own products to compete with the firms they previously served. Williamson (1979) referred to opportunistic behavior by third-party suppliers, which arise from their self-interest and the goal of maximizing their own benefits. Secondly, the potential impact of transaction costs can sometimes be significantly high (Gilley & Rasheed, 2000). Finally, outsourcing can lead to spatial dispersion and introduce certain challenges, as highlighted by Levy (1995). These challenges include longer lead times, larger inventories, and communication problems. Overall, the risks associated with outsourcing can impact the success or failure of an outsourcing decision

2.2. Collaboration

Collaboration can take on different firms, such as strategic alliances, partnerships joint ventures, networks, joint ventures, cooperation, etc. In the simplest form, collaboration involves "*individuals of groups working together across organizational boundaries*" (Huxham & Vangen, 2005). Collaboration can be defined as a "long-term partnership where the parties work together, exchange information, share risks and resources, and make joint decisions to accomplish mutual beneficial outcomes" (Bowersox, Closs & Stank, 2003). In other words, firms voluntarily come together to combine human, financial, or technical resources to create better business models. Collaboration goes beyond regular formal transactions and facilitates the exchange of information and knowledge, which in turn leads to competitive advantage (Matapoulous et al., 2007). Firms are engaging in partnerships when they acknowledge that individual efforts alone are insufficient in tackling common problems and achieve their desired goals (Wagner, Macbeth & Boddy, 2002). Collaboration can take different forms and involve several partners within the supply chain, meaning that firms also work with partners beyond the supply chain.

2.2.1. Supply chain collaboration

Before determining supply chain collaboration, supply chain is briefly described as all the steps from raw materials to the finished product, so everything that happens, and all the goods that are moved between a supplier and a customer (Chopra, Meindl & Kalra, 2007). The presence of supply chains is a requirement for supply chain collaboration. Supply chain collaboration implies that "*two or more chain members become involved and actively work together in coordinating activities that extend beyond the boundaries of their respective organizations*" (Matapoulous et al., 2007). Firms work together along in the supply chain to ensure the end product to customers (Simatupang & Sridharan, 2008). Within supply chains there are several activities where collaboration is possible: purchasing, production, distribution, and R&D. In this study, the focus is on collaboration production as the primary subject. Supply chain collaboration can take place in both vertical and horizontal dimensions. Vertical collaboration focus on the collaborative relationships and activities that occur between actors at different levels of the supply chain, such as buyers and suppliers, in which they work together by sharing information and resources (Bahinipati & Deshmukh, 2012). This type of collaboration offers advantages such as lowering transaction costs, knowledge exchange and sharing of resources. An example of vertical collaboration in manufacturing is when manufacturers work closely with suppliers to ensure a consistent and punctual supply of purchased components and sub-assemblies. On the other hand, horizontal collaboration takes place between partners who operate at the same level (Bahinipati, Kanda, Deshmukh, 2009). Horizontal collaboration primarily involves collaboration with competitors. Benefits of this type of collaboration are costs savings resulting from the combined utilization of manufacturing systems, capacity compensation, reduced supply risks, and establishing valuable network connections (Bahinipati, Kanda & Deshmukh, 2009). In the area of production, firms can share machines or personnel by jointly utilizing organizational infrastructure of each other. By sharing machines, firms can expand their production capacity without high capital investments. In addition to horizontal collaboration, co-opetition is another form of collaboration that can occur between similar firms in the supply chain. Collaboration with a competitor, also known as co-opetition, refers to a situation where two or more competitors simultaneously cooperate and compete (Yang et al., 2023). The difference with horizontal collaboration is the simultaneously nature of both cooperation and cooperation. Co-opetition can be seen as a dynamic hybrid strategy because firms combine elements of both cooperation and competition to create value (Hafezalkotob, 2017). Just like horizontal collaboration, firms operating within the same market often collaborate in discovering new knowledge and new technologies. In contrast to horizontal collaboration, firms maintain competitiveness and strive to outperform competitors in terms of market share and attracting more customers. In addition, firms can also collaborate by creating relationships with various other non-industrial entities beyond the supply chain. These include universities, consultants, research institutes, and other associations. These research institutes play an important role in providing scientific and technological knowledge and can create new insights.

2.3. Adoption of digital process technologies

The third and last concept in this study refers to the adoption of digital process technologies by manufacturing firms. Over the past decade, firms have explored the integration of digital process technologies into their production processes, such as Internet of Things (Iot), big data analytics, and artificial intelligence (Yang, Fu, Zhang, 2021). The emergence of new digital process technologies can have a significant impact on firms in the industry. The adoption of a new technology has the potential to drive positive changes and improvement within an organization (Miranda et al., 2016). Firms that fail to adopt these technologies can face the risk of being forced out of business. While certain firms strive to be an innovation leader and want to achieve first mover advantages by adopting new technologies earlier, other firms wait and potentially learn from mistakes made by these pioneers (Oster, 1995). The adoption of new technologies is commonly described as a process that involves a series of connected stages that organizations go through. In the context of the diffusion theory of Rogers (1995), there are five stages when firms adopt a new technology: knowledge, persuasion, decision, implementation, and confirmation. The confirmation or use of a new technology is typically the last step in the process of adopting digital process technologies. In this study, adoption is defined in a broader context and as overall use, rather than focusing on different stages of the process itself. Therefore, adoption of digital process technologies can be defined as "*the act of a person, business, or another agent's first use of new technology"* (Forman, Goldfarb & Greenstein, 2018). The process of adopting new technologies is complex, social, and developmental and is subject to several factors that influence whether a firm chooses a technology (Straub, 2009). The Technology-Organization-Environment framework, identified by Yadegaridehkordi et al. (2018), is a conceptual model that explains these three factors that significantly influence the adoption of digital process technologies. Technological factors relate to the characteristics of the technology itself; organizational factors focus on the internal structure and resources of the firm, and environmental factors consider the external context and conditions in which the firm operates. Furthermore, the process of adoption can occur at two distinct levels, namely the individual and the firm/organizational level (Hameed, Counsell & Swift, 2012). Adoption at the individual level refers to acceptance and willingness of individuals to adopt new technologies. Although the individual level of adoption is an essential part, the primary focus is on the adoption at the organizational level. The adoption process at the organizational level refers to the decision-making process with the entire organization selecting a technology. Top management has the responsibility to determine the required action of adopting a new technology.

2.3.1. Drivers of adoption

Adoption of digital process technologies is an important agenda for business aiming to improve their firm performance. Understanding the key determinants for the adoption of digital process technologies is crucial for businesses. The increasing complexity of operations and the rising costs of labor make it less efficient to rely purely on manual work in the manufacturing industry (Yang, Fu, Zhang, 2021). The adoption of technology creates process improvement within organizations which leads to several benefits, such as saving labor costs, minimize human errors and accelerate speed of production (Lee, Falahat & Sia, 2021). Secondly, strategic considerations play a role in determine whether adopting digital process technologies. The digitization of process technologies has become a fundamental pillar for business strategies both in the present and for the future. On the other hand, the adoption of technologies by competitors can serve as a trigger for firms to accelerate their own digital transformation, because the fear of being left behind is a concern for these firms (Yang et al., 2021).

2.4. Hypothesis development

In the past decade, outsourcing production has experienced widespread adoption in different industries (Lai, Liu & Xiao, 2021). The time that firms are operating as independent entities is no longer feasible in the current environment (Vandchali et al., 2020). As described earlier, the decision to outsource activities often depends on the principles of value creation, core competencies, and primarily on transaction costs. Firms will choose to externalize production activities when other suppliers do have a cost advantage and offer a price that's less expensive than replicating the technology within internal production (Chang, Kuo & Chen, 2008). In other words, firms decide to outsource production to take costs advantage of effective production capabilities offered by other firms. Such costs advantages occur when suppliers possess superior production technology (Pierce & Sen, 2011). Firms can possess highly advanced machines or highly skilled labor forces. For this reason, outsourcing can be seen as a strategy to access new technologies, increase efficiency, and reduce costs (Weigelt, 2009). Conversely, when firms outsource their production activities, there is a potential risk of hollowing out a firm's internal capabilities (Bettis, Bradley & Hamel, 1992). Hollowing out refers to the loss of a firm's resources, skills, and knowledge because of outsourcing. Steensma & Corley (2000) argues that although outsourcing activities to external suppliers provide access to new technologies, this access does not guarantee effective adoption within firms. The successful adoption of new process technologies relies on the integration with the existing ongoing business processes and workflows (Purvis, Sambamurthy & Zmud, 2001). Thus, while outsourcing production provides access to new technologies, it brings challenges in the successful adoption of digital process technologies.. These pros and cons of outsourcing demonstrate that the adoption of digital process technologies is a complex process influenced by a wide range of factors. As a result, the following hypothesis can be formulated

Hypothesis 1 (H1): *Outsourcing production will have an effect the adoption of digital process technologies*

As discussed earlier, technologies and supply chains will continue to evolve in the future and become more complex (Melnyk et al., 2009). To stay competitive in the rapidly changing business environment, manufacturing firms must adopt and integrate new technologies. If firms fail to implement the appropriate technologies, they face the risk of falling behind competitors and eventually losing market share. According to Benitez et al. (2020) many small and medium-sized enterprises (SMEs) face difficulties in implementing new advanced technologies. The high expenses and required knowledge of new technologies present a major barrier and restrict access to the latest technologies. To access these technologies, firms can choose to collaborate with partners. Collaboration can provide opportunities by working together with other individuals, organizations, or institutions to overcome the lack of knowledge and gain access to new technologies (Ligthart & Vaessen, 2020). Firms can have different objectives or goals which reflect the motivations behind inter-organizational collaboration. In line with collaboration literature, firms can be distinguished between supply chain collaboration and R&D collaboration. Firms can collaborate within the supply chain to acquire complementary assets, i.e. expertise, resources, and capabilities to use in their own operations. By collaboration with suppliers, competitors or customers, firms can strength their technological capabilities and knowledge to gain competitive advantage. Secondly, firms can collaborate to stimulate their growth or market power (Ligthart & Vaessen, 2020). This often leads to R&D collaboration with suppliers, firms and research institutions that can help to innovate new products, technologies, or business processes (Tether, 2002). Through these collaborative R&D partnerships, manufacturing firms can accelerate the development of new technologies and gain more market share. In this research, the focus is specifically on collaboration production within the supply chain. In their study, Ligthart & Vaessen (2020) found evidence that there is a significant positive relation between both supply chain collaboration and R&D collaboration with digitalization. In conclusion, the effect of adoption of digital process technologies is stronger when it is influenced by collaboration regarding production within the supply chain.

Hypothesis 2 (H2): *Collaboration production will have a positive effect on the adoption of digital process technologies*

Outsourcing and collaboration are two strategies that firms use to access external resources and expertise. Both strategies share a common purpose of extending beyond organizational boundaries. However, it’s important to note that their execution and nature differ significantly. Both strategies are driven by cost’s considerations (Sen et al., 2009). Cost considerations are the key driver whether to outsource business activities or to keep them in-house, but this can lead to a limited scope and overlook other important considerations. By outsourcing, firms can seek external expertise that can contribute to minimizing transaction costs. With outsourcing the firm allocates resources to external suppliers but is still in control over the work being performed. The relationship between the firm and the supplier is typically governed by formal contracts that outline performance expectations, price, and therefore considered as a transactional relationship. While collaboration does consider costs consideration, the primary motivation for engaging in collaborative partnerships, is the need to access knowledge that can’t be generated through in-house capabilities (Sen et al., 2009). Outsourcing can bring short-term costs benefits in terms of reducing vertical integration (Winroth, 2004), but there is a potential risk of losing core competencies, control over the processes, and limit the firm’s ability to learn and utilize external knowledge effectively (Hoecht & Trott, 2006). If the firm relies solely on outsourcing without active management and control over the processes, this can lead to more potential problems, because firms lack the knowledge and understanding of the outsourced processes. Where outsourcing may fall short, collaboration can provide new opportunities and advantages. It enables a mechanism of efficient learning from and by partners (Dyer et al., 2000) and facilities the creation of new knowledge and skills (Verespej, 2002; Belderbos et al., 2004). Still collaboration efforts can fail for a variety of reasons. In comparison with outsourcing, most collaborations lack formalized collaboration agreements (Daugherty et al., 2006). Moreover, collaboration entails a loss of complete control for firms, as decision making, and goal alignment processes take longer due to the need for consensus among partners within the relationship (Masten, 2016). Thirdly, if firms don’t possess superior knowledge or resources, it impacts a firm’s ability to bargain effectively to achieve favorable outcomes. Based on the benefits and risks of collaboration, the effect of outsourcing on adoption of digital process technologies is highly context sensitive. That’s why the hypothesis is two-way formulated that take into account both directions of effect:

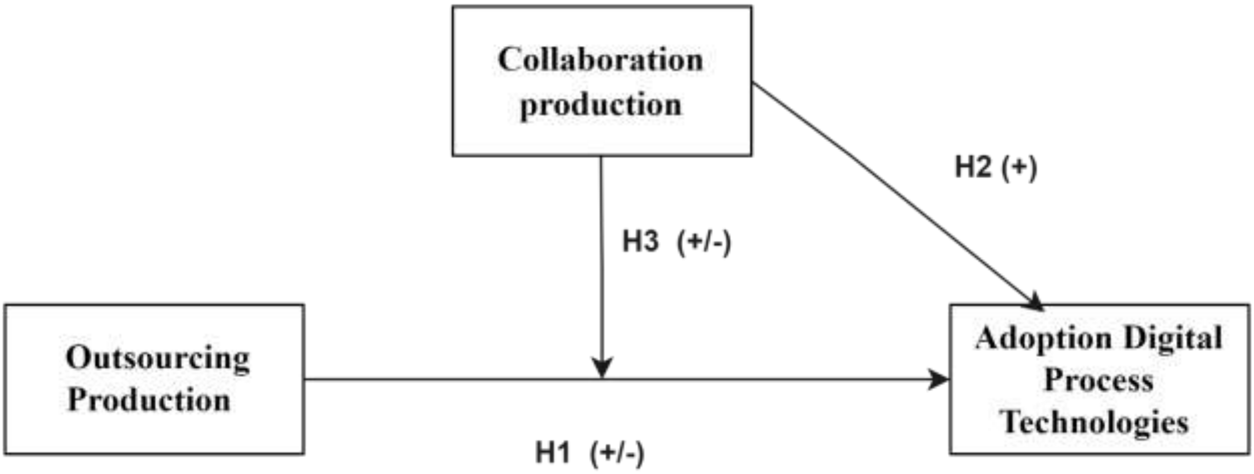
Hypothesis 3 (H3): *There is an effect of outsourcing production on adoption of digital process technologies when is moderated by collaboration production*

2.5. Conceptual model

The conceptual model examines the dependent variable adoption of digital process technologies with the independent variables outsourcing production and collaboration production. In addition to the direct effect, collaboration production is also included as moderator that helps to explain the underlying mechanism of the direct relationship between outsourcing production and adoption of digital process technologies. The conceptual model is presented in figure 1.

Figure 1

Conceptual model hypothesis 1, 2 and 3



3. METHODS

This chapter will outline the methodology, specifying how the research aims to test the hypotheses. This section includes clarifications about the research design, followed by the data collection method, operationalization, and the reliability and validity of the research.

3.1. Research design

The aim of this study is to investigate the relationships between outsourcing production, collaboration production, and the adoption of digital process technologies. This study is based on a so-called convergent mixed method study design, meaning that both quantitative and qualitative research methods have been used. A mixed method approach is used, because it combines the strengths of both methods, resulting in a more comprehensive and robust study. Quantitative research is valuable for testing the significance of hypotheses with numerical data derived from the data set. With quantitative samples, the results are more generalizable and can have higher validity compared to quality research. On the other hand, qualitive research is used for gathering deeper insights of relationships between the constructs. As a result, both research methods are complementary to each other and improve the reliability and validity of this study. Furthermore, the study is conducted as deductive research, which formulates that the research question of this study is derived from existing theory. Therefore, a literature review was conducted using various online databases and search engines, such as Google Scholar and Business Source Complete. Current literature about outsourcing, collaboration, and adoption of digital process technologies has been reviewed to develop the conceptual framework.

3.2. Research instruments

The quantitative data was collected using a postal survey research to test the generic effects of the formulated hypotheses. The quantitative research is done based on the European Manufacturing Survey (EMS), which provides insights into the determinants that drive innovation in the manufacturing industry. The EMS is a survey conducted by a consortium of research institutes and universities from and across Europe and collects data on techno-organizational innovations within the manufacturing sector. For this study the latest version of EMS has been used, which was conducted in 2018. Data collection for this survey is done by using a pretested questionnaire that has been through a process of translation and back-translation. A representative set of manufacturing firms in different private sectors, consisting of firms with 10 or more employees, received the survey for participation. The sample includes 152 Dutch manufacturing firms in the following industries: metal, food, textile, construction, chemical, machinery and electronic industry.

Qualitive research is used to obtain an understanding of the proposed relationships between the variables. The qualitative data were collected by semi-structured interviews which have been conducted with respondents of different firms within the Dutch manufacturing industry. To ensure a diverse representation of firms, it’s important to place emphasis on contacting firms in several industry sectors. The respondents were contacted through a combination of email and phone. Their contact information was sourced from their websites or obtained through the researcher’s network. A total of five respondents were interviewed for the study. Table 1 provides the details of their firm sizes, industry sectors, and job descriptions. These semi-structured interviews are based on a predefined interview script that is used in every interview, and which is available in appendix 5. All these questions are related to a construct of a relation between constructs. All constructs can be found in the operationalization table in table 2. Although the predefined questions, the interviewer is free and flexible to ask additional spontaneous follow-up questions, to enable a more detailed exploration of answers. Before the interviews, respondents are asked for permission to record the session. The recordings can then be better edited and transcribed for better results, so that the most valuable insight from the interviews is obtained (Linneberg & Korsgaard, 2019). To identify the most relevant quotes related to the concepts being investigated, the study uses a theory-based coding scheme. The first step of this analysis is to select the most relevant quotes of all the respondents. These quotes are carefully reviewed and ranked on a three-point Likert scale ranging from 1 (most relevant) to 3 (least relevant). The process of ranking the quotes on the Likert scale applies to all the concepts and their inter-concept relationships that were formulated by the hypotheses. With this method the most relevant quotes create a comprehensive understanding of the concepts and their relationships to each other to the hypotheses in this study. The results will be presented in Chapter 4 of this study.

Table 1

Samples companies

Company name	Firm size	Industry	Job description
EC	2200	Electronics	Global Process Owner PCBA/SMD
MC	80	Machinery	Head of Business Office & IT
HM	515	(Hydraulic) Machinery	Director Operations
FD	275	Food	Manager Sales & Operational Planning
IP	30	Electronics (Industrial Products)	Managing Director

3.3. Operationalization Quantitative study

In the theoretical part of this study, the concepts were defined based on current literature. In this part of the study the theoretical abstract concepts are turned into measurable observations. The EMS dataset contains a comprehensive collection of core indications that are specially designed to measure the constructs addressed in this study. By developing specific measures or indicators for each of three concepts, it collects empirical data from EMS that can be analyzed to test the hypothesis and draw conclusions. Table 2 provides an overview of all constructs, and each construct is elaborated further in detail in the next paragraphs.

3.3.1. Outsourcing production - independent variable

The first independent variable is outsourcing production, which is measured in the EMS dataset as outsourcing parts of production. These variable measures the extent to which a firm does or does not outsource parts of production. Firms that choose to keep parts of production in-house and don’t outsource receive a score of 0, while firms that opt for outsourcing their production receive a score of 1.

Table 2
Operationalization table

Variable	**Construct**	**Dimension**	**Measurement (items used from EMS, 2018)**
Independent variable	Outsourcing production	Production abroad	*Has your factory moved parts of production abroad (offshored) or to foreign locations?* - Dummy variable (0 = no, 1 = yes)
Independent variable	Collaboration production	Co-operation production	*Does your factory co-operate in production* - Dummy variable (0 = no, 1 = yes)
Dependent variable	Adoption of digital process technologies	Number of used digital process technologies	*Which of the following technologies are currently used in your factory?* - Mobile/wireless devices for programming and controlling facilities and machinery - Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor - Software for production planning and scheduling - Digital Exchange of product/process data with suppliers / customers - Near real-time production control system - Systems for automation and management of internal logistics - Product-Lifecycle-Management Systems (PLM) or Product/Process Data Management - Virtual Reality or simulation for product design or product development - Industrial robots for manufacturing processes - Industrial robots for handling processes - 3D printing technologies for prototyping - 3D printing technologies for manufacturing of products
Control variable	Firm size	Number of employees	*Please characterize your factory regarding the number of employees.* - Log number of employees
Control variable	Firm industry	Industry sector: 1. Metal 2. Food 3. Textile 4. Construction 5. Chemical 6. Machinery 7. Electronics	*Which main industry do you supply?* - Dummy variable for each sector (0 = no, 1 = yes) - Reference category Metal

3.3.2. Collaboration production – independent variable

To cover the concept of collaboration, it is important to consider the field in which firms collaborate. Based on the EMS, collaboration is described as co-operation which implies a voluntary inter-firm relationship beyond pure business relations. Collaboration can take place in the following areas: purchasing, production, sales/distribution, service, and R&D co-operation. The research examines whether there is a relationship at all between the collaboration production of firms and the adoption of digital process technologies. Collaboration production will be selected as an item to measure the construct of collaboration. Firms that don't collaborate with other businesses receive a score of 0, and firms that collaborate receive a score of 1.

3.3.3. Adoption digital process technologies – dependent variable

Adoption of digital process technologies was measured as a composite counting the number of digital process technologies that are in use by manufacturing firms. Determining the use of a technology relies on the question of whether a particulier technology is applied or not. A set of 12 items were used as indicators to measure the construct of adoption of digital process technologies. A score of 0 represents the absence of any digital process technologies and a score of 12 indicates that a firm has implemented all the digital process technologies.

3.3.4. Control variables

Adoption of digital process technologies can be influenced by various organizational characteristics. These characteristics can play a role in determining the strategic choices that organizations make regarding implementing digital process technologies. To eliminate any potential influence of the independent variables on the dependent variable, the firm size and industry sector were utilized as organizational characteristics and are represented as control variables. A control variable is a variable that is held constant or adjusted and unlike independent of dependent variables control variables are not the focus of the study (Field. 2018). By including control variables in a statistical model, researchers can minimize the impact of these variables on the overall analysis and allow for a more accurate assessment of the relationship between variables of interests. Regarding the first control variable, a way to quantify the firm's size is to measure the number of full-time equivalent (FTE) employees it employs. The second control variable industry sector is designed to measure the industry sector specially within the EMS. The industry sector control variable is operationalized using a dummy codification method to represent a sector's presence or absence. When utilizing dummy variables, it’s necessary to exclude one category to compare different categories. Throughout the analysis, the metal industry will serve as the base- reference category.

3.4. Validity & reliability

As noted earlier, using a mixed method study can increase the validity and reliability of this study by triangulating the findings from both quantitative as qualitive methods (Bryman, 2006). To determine whether the operationalization of the concepts is valid and have consistent responses, it’s important to take both validity and reliability into account. A study with high validity and reliability is essential for ensuring the quality of the research.

3.4.1. Validity

To evaluate the validity of this study, both internal and external validity need to be considered. Internal validity is primarily concerned with the consistency of measurement which means that a research study accurately measures what it intends to measure, regardless of any other factors that influence the results. In other words, the degree of confidence that the relationship between variables is real and not influenced by other variables (Hair et al., 2018). To ensure the internal validity of this research, it’s important to start with a solid theoretical literature review to get a comprehensive understanding of the relevant concepts and their relationships to each other. In addition, using a high-quality dataset evaluated by academics is also an important element to ensure the internal validity. Furthermore, by controlling the selected control variables, the risk of confounding influences is minimized. External validity refers to the extent to which research findings can be generalized and replicated in a broader context, i.e., beyond the original study with other settings and conditions (Hair et al, 2018). To increase the external validity of this thesis, it’s important to use a representative sample size in both the quantitative EMS data set and interviews. By using a relatively large sample size of approximately 150, the research provides findings beyond a specific case of company and are considered large enough.

3.4.2. Reliability

Reliability is a critical aspect in a research study. Reliability refers to the consistency of the data collection methods used. According to Hair et al. (2018) reliability is the extent to which the observed variables accurately capture the true value without any errors. If a study is repeated multiple times in different circumstances, it’s important to see the same results. In quantitative analysis, it’s necessary to assess the reliability of the constructs that possess multiple items (Hair et al., 2018). In this research, only the dependent variable adoption of digital process technologies consists of multiple items, namely 12 items. The most used measure of reliability is Cronbach’s Alpha. The variable of adoption of digital process technologies has a coefficient of 0.608 (see appendix 1) and so the reliability of the construct is feasible. A way to increase the reliability of the qualitative part is to use a reliable measurement tool in terms of setting a guideline for the conducted interviews. By using this guideline, each respondent of different firms can answer the same set of questions, which minimizes the risk of potential biases. By providing a uniform introduction to the constructs for all respondents, it ensures that everyone perceives the constructs in a consistent manner. The same is applicable in terms of coding answers of respondents by using a systemic approach. However, it’s also important to strike a balance between the interview guideline and being flexible with follow-up questions to dive deeper into some possible subjects. Furthermore, it’s important to consider the research context that can change over time and have an impact on the findings obtained in the study regarding reliability. Especially in some industries such as electronics, changes can occur rapidly and frequently, which can have implications for further research studies conducted in this field.

4. RESULTS

This chapter will discuss the results from both the quantitative and qualitative research methods to answer the research question and test the formulated hypotheses. The quantitative analysis encompasses a multiple regression analysis, while the qualitative part is based on semi-structured interviews with employees of Dutch manufacturing firms within different industry sector.

4.1. Quantitative analysis

In the quantitative analysis the concept of adoption of digital process technologies has been examined by conducting a multiple regression analysis. For this research several hypotheses have been formulated. These hypotheses includes whether different independent variables (outsourcing production, collaboration production, firm size, and industry sector) have a significant influence on the dependence variable adoption of digital process technologies of Dutch manufacturing firms. This thesis leverages a dataset of contacting the European Manufacturing Survey (EMS) data from the year 2018. The sample size consists of 152 valid samples which specially consists of only Dutch manufacturing firms. With the rules of thumb regarding sample size, the minimum ratio of observations of each independent variable is 5:1, but the preferred and desired ratio in this thesis is 20:1 (Hair et al., 2018). In total there are 5 variables including control variables, so this is far above the preferred ratio.

4.1.1. Descriptive statistics

First the descriptive data of the EMS 2018 will be analyzed using a univariate approach to provide an initial overview of each variable individually. An overview of the descriptive statistics of the variables is presented in table 3. The firms are distributed across various industry sectors as follows: 20,9% in the Metal industry (base category), 7,8% in Food, 13,7% in Textile, 1,97% in Construction, 13,7% in Chemical, 17,0% in Machinery, and 24,8% in Electronics. The second control variable under consideration is the size of the firm with a value of 3.77. The firm size measure has been log transformed to correct for highly skewed distributions. The primary focus of this research is the dependent variable of adoption of digital process technologies. From the selected predefined 12 digital process technologies, the average use of technologies is 2.8. Software for production planning and scheduling holds the highest adoption rate among firms, with approximately 62% of firms indicating its usage. Conversely, the least utilized technology appears to be Product-Lifecycle-Management (PLM) systems, a mere 9.5% of the firms reporting its implementation (see appendix 1, table 2). The Cronbach's Alpha coefficient of 0.608 (see appendix 1, table 3) suggests a moderate level of reliability for this construct according to Hair et al. (2018). The second concept of this study is outsourcing production, which indicates whether firms engage in outsourcing or not. It became clear that a small proportion of firms, with a percentage of 18.95, engage in outsourcing production. The same measurement is applicable for the third construct, collaboration production, whether firms collaborate regarding production or not. The results suggest that approximately 31% of the firms collaborate with other companies to share production processes. This indicates that a significant portion, roughly one-third, of the companies are open to collaboration by sharing their production capabilities. When examining the interaction between outsourcing and collaboration in production, it becomes clear that only 8.5% of the total sample engage in both practices simultaneously. In this section, a univariate analysis was used to examine the individual concepts. In appendix 3, the correlations between these concepts will be shown.

Table 3

Descriptive statistics

Independent variables	**Mean**	**Std.**	**Min**	**Max**
Industry (base: Metal)	20.9%		0	1
Food, Beverages, Tobacco	7.8%		0	1
Textiles	13.7%		0	1
Construction	1.97%		0	1
Chemical	13.7%		0	1
Machinery	17.0%		0	1
Electronics	24.8%		0	1
Size (log number of employees)	3.7725	0.938	2.3	8.41
Digital Process Technologies	2.8235	2.080	0	8
Outsourcing Production	18.95%		0	1
Collaboration Production	31.37%		0	1
OutColl Interaction Production	8.50%		0	1

Notes: N= 152

4.1.2. Multiple regression analysis

Multiple regression analysis will be used to examine the relationship between a single dependent variable, namely the adoption of digital process technologies, and several independent variables and control variables (Hair et al., 2018). In multiple regression analysis, there are five common assumptions that researchers typically consider. These assumptions are explained and tested in appendix 2. The hypotheses are formed in a specific direction (positive relationship), so a one-tailed regression analysis is conducted. The regression analysis followed a three steps enter-method model within SPSS. The first model can be defined as the basic model and consists of the control variables firm size and industry sectors. In addition to Model 1, the independent variables of outsourcing production and collaboration production are added in Model 2. At last, within Model 3 the interaction effect has been added with in total all 10 independent variables.

Table 4

Model fit summary

Model fit evaluation – Adoption digital process technologies							
Model	**R Square**	**Adjusted R Square**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**
Model 1	0.138	0.096	0.138	3.308	7	145	0.003
Model 2	0.149	0.095	0.011	0.922	2	143	0.400
Model 3	0.149	0.089	0.000	0.65	1	142	0.799

Model fit

The model fit measures the extent to which the established model can explain the variation in the dependent variable adoption of digital process technologies. The results of the model fit are shown in table 4. In this research the adjusted R Square is used to have a better result. The reason behind is that including additional variables in a regression model will always lead to an increase in the R square, regardless of whether additional variables have a significant effect on the outcome. Model 1 has an Adjusted R Square of 0.096, which means that the model explains approximately 10 percent of the variation in the dependent variable adoption of digital process technologies. Model 1 has a significance level of 0.003 ($F = 3.308$, $p \leq 0.05$), and therefore is statistically significant which indicates a good overall model fit. Having a look at Model 2 and 3 the Adjusted R Square decreases, and both models are not significant regarding a significance level of 0.05 ($F = 0.922$, $p \geq 0.05$) and ($F = 0.065$, $p \geq 0.799$). The values of the Adjusted R Square are respectively for Model 2 0.095 and for Model

3 0.089. The F-test of ANOA will also be used as a method to evaluate the overall model fit. The ANOVA output in appendix 4 confirms that the third model, including all 10 independent variables, is a significant model for the dependent variable adoption of digital process technologies. Having a look at the model fit, the F-values for models 1, 2, and 3 are significant, because all the p-values are below the tolerance value of 0.05 ($F = 3.308$, $p \leq 0.01$) ($F = 2.775$, $p \leq 0.01$) ($F = 2.487$, $p \leq 0.01$). The conclusion is that the model has a good overall strong fit, and that the variables included in the model are significantly compared to the dependent variable.

Table 5

Coefficient of regression

	Model 2 (B)	**Robust SE**	**Model 3 (B)**	**Robust SE**
(Constant)	0.106	[0.756]	0.099	[0.759]
Industry (base: Metal)				
Food, Beverages, Tobacco	-0.678	[0.677]	-0.666	[0.681]
Textiles	-0.347	[0.558]	-0.345	[0.560]
Construction	0.132	[1.206]	0.146	[1.211]
Chemical	0.405	[0.559]	0.393	[0.563]
Machinery	0.143	[0.529]	0.144	[0.530]
Electronics	-0.238	[0.476]	-0.253	[0.481]
Size (log number of employees)	0.722**	[0.181]	0.729**	[0.183]
Outsourcing Production/ production abroad	0.579	[0.428]	0.483	[0.569]
Coll_production Production co-operation, capacity compensation, joint utilization of machinery	-0.126	[0.356]	-0.176	[0.406]
OutColl Interaction Outsourcing and Coll_Production			0.223	[0.873]
Model statistics				
Observations	152		152	
Adj. R-Square	0.095		0.089	
F	2.775		2.487	
p-value	0.005		0.009	

Dependent variable: adoption of digital process technologies
Notes: *p <,05; **p <,01

4.1.3. Hypotheses

For individual coefficients to be considered statistically significance, their associated p-values should be below the significance level of 0.05. The coefficients are shown in table 5. H1: *Outsourcing production will have an effect the adoption of digital process technologies.* The first concept is about the impact of outsourcing production on the adoption of digital process technologies. The assumption is that when firms outsource (parts) of production to third-party suppliers, the adoption rate of technologies will change. The hypothesis is tested in the second model, and the coefficient of outsourcing production ($B = 0.579$, $p = 0.179$) gives no support for hypothesis 1, meaning that outsourcing production not significantly influence the adoption of digital process technologies. Therefore, hypothesis 1 is rejected.

H2: Collaboration production will have a positive effect on the adoption of digital process technologies

The second concept looks at whether a firm collaborates within the production domain and whether this influence the adoption of digital process technologies. Looking at the results in model 2, they show collaboration production does not have a significant positive effect on the adoption of digital process technologies. With the coefficient ($B = -0.126$, $p = 0.723$), the second hypothesis doesn't have support. As a result, hypothesis 2 is rejected.

H3: There is an effect of outsourcing production on adoption of digital process technologies when is moderated by collaboration production.

Collaboration production could have a moderating effect on the relation between outsourcing production and the adoption of digital process technology. Like the other hypotheses, the coefficient of hypothesis 3 doesn't have a significant effect on the adoption of digital process technologies. Within model 3 the coefficient does have a p-value above the critical 0.05 ($B = 0.23$, $p = 0.799$), and resulted in a rejection of hypothesis 3.

In addition to the independent variables within the conceptual model, the control variables are also tested for a possible significant effect. It appears that the control variable firm size is found to be statistically significant, and that there is a positive relationship between firm size and adoption of digital process technologies ($B = 0.722$, $p < 0.001$). This means that larger firms have access to more technologies. The second control variable industry sector is not significant as all the values are above the critical value of 0.05. Therefore, it can be concluded that a specific industry sector doesn't influence the adoption of digital process technologies.

4.2. Qualitative analysis

The qualitative analysis allowed for a deeper understanding of the different relationships based on theory. The sample is based on manufacturing firms that have different sizes, with some firms having 30 employees and other firms have 2200 employees. For each concept and inter-relationship, the most important quotes are provided in the next tables. All other relevant quotes that are used for the analysis can be found in the appendix. Alle quotes are labeled with abbreviations and numbers as reference.

4.2.1. Individual concepts

The first concept is outsourcing production. Outsourcing can be defined as contracting out existing internal and/or external functions, and/or core competencies to competent supplier(s) to produce products (Ishizaka et al., 2020). The most relevant quotes are shown in table 6.

Table 6: Quotes outsourcing production		
Company	**Quote**	**Open code**
EC1	"Binnen het bedrijf hebben we nogmaals wel echt altijd de drive gehad en ook nog steeds om wel echt zoveel mogelijk van de productie in-house te doen. Soms ben je dan te erg gefocust op dingen in-house ontwikkelen terwijl een andere partij allang het wiel heeft uitgevonden en veel efficiënter of veel sneller bepaalde producten kan leveren. Dus ja, het is niet altijd de beste strategie."	Maximum production in-house
MC1	"Wij hebben zelf geen lasersnijmachine en kantbanken en alles wat daaraan toe behoort. Dus al het plaatwerk wat we in onze machines gebruiken, besteden wij uit extern. Daarnaast geldt hetzelfde voor draaien en draaien en frezen voor zowel kunststof als metaal. Voor het lassen uitbesteden of het stralen of het verpakken is het vaak met name capaciteit issues. Zo doen we het liefst zoveel mogelijk zelf, tenzij het vanwege de capaciteit niet kunnen."	Capaciteit
HM1	" Kijk, we hebben een make-or-buy strategie en dat betekent dus als we het hebben over cilinders, toch wel de hoofdmotor van de producten die we hier maken, waarvan we zeggen: wat zijn nou standaard competenties, wat zijn key competenties en wat zijn core competenties en eigenlijk de core competenties willen we zo min mogelijk uitbesteden."	Core competencies
FD1	Wij werken ook veel in ketens. Dus wij doen dan het slachten en het uitbenen en we hebben een ander bedrijf dat bijvoorbeeld het verpakken en het marineren doet. Maar dat zijn wij wel, ja zeg maar contractueel afgesproken."	Ketens
IP1	"Uitbesteding noem ik echt op tekening van ons iets ontwerpen en dan laten maken. Dus het is ons design, onze tekening, et cetera. We besteden het gieten uit, vervolgens wordt het opgestuurd naar een zusterbedrijf van ons waar de machinale bewerking, nou het frezen, draaien, tappen, boren, slijpen, noem maar op, totdat het product klaar is. En van daaruit gaan wij het dan uiteindelijk in een assemblage gebruiken als een eindproduct."	Ontwerp

The interviews showed that all firms are engaged in some form of outsourcing, but the meaning of outsourcing lack clarity among the respondents. This variation is not uncommon, as different respondents emphasize different aspects of outsourcing based on their experiences and industry sector. On the one hand, one respondent (EC6) sees outsourcing in terms of purchasing components, but this doesn't link with the definition of outsourcing as provided in chapter 2. On the other hand, one respondent refers to the make-or-buy decision (HM1), whether to produce goods or acquire them from external partners. "*I specifically define outsourcing as the process of designing something based on our own drawings and specifications (IP1)".* In this context, the firm retains complete ownership and control over the design, which links with the definition of outsourcing in this study. Subsequently, the extent of outsourcing varies among the firms. The decision of how much to outsource is influenced by several factors mentioned by the respondent, such as labor costs (EC3), focus on core competencies (HM1) and efficiency (FD3). Capacity as reason was mentioned by 4 out of 5 firms (EC2, MC1 & FD). "*I won't just outsource it once we can build it ourselves. If we have capacity on the machine, then the first step is to do it yourself (HM2)".*

Besides the advantages, the respondents acknowledge that outsourcing also carries inherent risks and challenges. One of the most given examples of risk was the dependence on external parties (EC4, FD4), such as quality issues that fall outside the tolerance standard (HM3), delay in lead time (EC3), and loss of traceability (FD5). Furthermore, investing in new machines to keep all processes in-house is of great size and may not always be profitable for most firms (EC5, HM4). It's important to note that the impact of these risks may vary depending on the firm's scale and its corporate level of operation. For instance, the firm (IP) is part of a larger parent company and outsources all their other production processes to subsidiaries. *"When outsourcing is performed internally, it generally does not present a big issue (IP2)".* Finally, outsourcing can potentially make suppliers stronger, particularly in situations where they become more specialized and potentially becoming competitors (HM5) which make negotiations more challenging (FD4).

Collaboration production

The second concept is collaboration in production. Collaboration is a long-term partnership where parties work together, share information and resources, and make decisions together (Bowersox, Closs & Stank, 2003). As the quantitative part included collaboration regarding production, firms were asked how they collaborate with partners in relation to their production processes. Respondents were also asked about the underlying reasons and whether they perceive any potential disadvantages. Table 7 presents a selection of the most relevant quotes. Suppliers are partners that all firms collaborate with (EC1, MC2, HM1, FD1, IP1). Via service contracts, the suppliers provide their specialized expertise in maintenance and troubleshooting (EC1). Another example could be collaboration with customers: *"The customer's request for us to develop something is driven by customer demand, and that demand serves as the primary motivation for establishing a partnership with them (MC1)".* One of the firms gave the example of partnering with an educational institution for the production process, while collaboration with these institutions often tends to be R&D focused. As part of the collaboration, the firm can offer welding training programs or apprenticeships to interested individuals (IP2). A last example of collaboration can be seen through the partnership between the food manufacturer and its suppliers (FD2). To prevent waste, the firm is actively involved in establishing supply chain collaboration that connects groups of farmers directly to groups of customers that helps to create a more balanced demand in the market.

Table 7: Quotes on collaboration production		
Company	**Quote**	**Open code**
EC1	"Nou, we hebben sowieso een hoop leveranciers van alle verschillende machines, dus je hebt daar altijd servicecontracten lopen. Ja, Ik denk dat je die samenwerking altijd wel blijft houden, vooral in deze branche."	Leveranciers
MC1	"Ja, dat begint eigenlijk al de manier hoe wij werken. Dus wij verkopen aan een tussenpartij, zoals ik het even noem zo'n GEA of een Multipond. Daar moet eigenlijk al gewoon vanaf moment één mee samengewerkt worden.	Klanten
MC2	"Als je zo'n project loopt, zit je iedere week wel samen, zeg maar. En eigenlijk loopt dat binnen heel de bedrijfsvoering door, net als bij onze leveranciers."	Leveranciers
HM1	"Op allerlei gebieden. Ja, dat doen we aan de technologie kant. Zeg maar de engineering kant, werken we met allerlei engineering bureaus."	Leveranciers
HM2	"Als ik operations kijk, werken we met allerlei leveranciers natuurlijk samen. Ook in de zin van partnership om dingen uit te besteden. Mijn beleving is dat op dit moment echt een onmisbare toevoeging is."	Engineerbureaus
FD1	"Ja, dit is ook letterlijk de kern van onze strategie. Ja, wij willen dus in ketens werken, dus je wil eigenlijk dat er uiteindelijk een groep boeren, een groep leveranciers zou je kunnen zeggen, precies aansluit bij een groep klanten of een klant hè?	Leveranciers
IP1	Eigenlijk, ja heel breed, dus je kunt eigenlijk kijken van. Productie werkt men heel veel samen, bijvoorbeeld met robot leveranciers. Dus dat is een voorbeeld."	Leveranciers
IP2	"Maar ook aan de andere kant, het opleiden van de vakmensen voor de productie. Kijken we bijvoorbeeld samen met Summa college als voorbeeld. Lassers is een probleem, dus wij hebben nu een eigen bedrijf X Academy opgericht waar wij lassers opleiden."	Onderzoeksinstituut

All respondents recognize collaboration as an essential and valuable addition to their business operations (EC2, MC3, HM3, FD3, IP3). The reasons for collaboration vary among the firms. A reason mentioned by a firm is the specialized knowledge of suppliers (EC2), while another firm sees collaboration as a necessity due to their small size and the diverse range of products they offer (HM3). "*Any kind of collaboration is often useful as it helps to get sub-optimality's within the supply chain. Instead of taking a bigger bite out of the pie, you do want to make the whole pie bigger (FD2)".* In the end, it's about mutual benefits and positive outcomes for all parties which ultimately strengths the relationships (IP4).

Adoption of digital process technologies

The third and last construct is the adoption of digital process technologies. The adoption of digital process technologies is defined as the utilization of digital process technologies. To determine the level of adoption, firms were asked which specific digital technologies they have implemented. The results of the interviews are summarized below in Table 8.

Table 8: Quotes on adoption of digital process technologies		
Company	**Quote**	**Open code**
EC1	"We hebben sowieso een hoop externe software pakketten draaien. Heel je inventory management loopt via SAP."	Software pakket
EC2	"Robots zijn ook niet heilig, maar over het algemeen, als je iets automatiseert en dan staat een stabiel programma op, dan maak je minder fouten dan dat met menselijk handje gebeurd."	Robots
MC1	"Als ik echt naar onze productieprocessen kijk, dan zit de automatisering met name in op dit moment het overstappen van geprinte werktekeningen naar 3D files die bijvoorbeeld de monteurs kunnen inzien."	3D tekeningen
MC2	" Ja, we hebben nog maar een jaar of 6 of 7 een ERP systeem. Dus dat was voor ons al een flinke stap richting digitalisering, zeg maar.	Software pakket
HM1	"Wij hebben op elke werkplek, 1 grote tv geplaatst met een losse monitor ernaast, waar de operator zelf ook een inlog account heeft.. Hij heeft digitaal werkinstructies tot zijn beschikking."	Digitale werkplekken
HM2	"Zeg maar een digitale productieplanning doen wij digitaal, het begint met ons ERP systeem.	Software pakket
FD1	"Wij bouwen onze eigen planning systeem, dus dat is echt wel een goed geïntegreerd hè? Dat is een gewoon cloud based en gestandaardiseerd over vestigingen en dergelijke."	Software planning
FD2	"We doen echter ook nog bijvoorbeeld in de fabriek nog veel op papier; audits, steekproeven, dat soort gekkigheid."	Papierwerk
IP1	"En met één druk op de knop komt er niemand aan, wordt de productie opgestart als wij akkoord gegeven, dus er gaat niemand calculeren, behalve de software. Er gaat niemand plannen, behalve de software. De machine wordt aangestuurd rechtstreeks zonder dat iemand er aankomt."	Plansoftware
IP2	"En dan met de AV voertuigjes het product uit de machine gaat naar het logistiek en snel naar de klant."	AV voertuigjes

By far, the most used technology is digital production planning and scheduling in terms of ERP software or SAP planning systems with a cloud-based infrastructure across different departments and locations (EC1, M2, HM2, FD1, IP1). Furthermore, the interviews showed that manufacturing firms differ in their degree of adoption of other digital process technologies. Firms in the machinery industry and food industry use basic technologies such as cameras, sensors, or digital workplaces (FD3, HM1). The two electronics firms are particularly dedicated to a strong commitment to digital process technologies, for example robots (EC2). One firm recognizes the importance of digitization in securing its future: "*We think that without digitization in the future, we'll miss opportunities, so we have to (IP4)".* The increased use of technologies brings greater availability of up-to-date data, which is very important (IP3). Based on the analysis of the collected data, firms can monitor and define actions (HM3). Secondly, firms have reduced the amount of paperwork in their operations through the adoption of 3D working drawings (MC1), which enables mechanics and other personnel to access the design in a digital format. Despite the existence of a planning system, the firm in the food industry continues to work with paper-based processes: *"We still do a lot on paper in the factory, for example with audits, controls, that kind of stuff (FD2)".* In the two electronic manufacturing firms more advanced technologies are used, including robots and full automation. The firm specialized in industrial products has implemented a system that utilizes 3D file input, and with a push on the button, production can be initiated without the need for manual calculations or planning (IP1). The software takes care of these tasks, and the machines are controlled without any human intervention. Lastly, the automated guided vehicle facilitates the transportation from the machine to the logistics and eventually will be delivered to customers (IP2). Besides the inevitable use of technologies and data enrichment, two respondents also highlight efficiency as the driver for the adoption of these technologies (EC2, IP4) by eliminate weak links within their operations. Adoption of digital process technologies can also result in a reduction of FTE positions: *"We'll always look very actively at automation in production, how it can be made easier, and above all how you can simply save FTEs (EC3)".* Conversely, there are also risks and barriers that complicate the adoption of digital process technologies. The firms that operate in the machinery sector commonly adopt the so-called 'Engineer to Order' approach in their operations (MC3, HM6). Due to the nature of this approach, products are unique, and it becomes difficult to standardize and automate the production processes entirely. A second reason why firms don't have adopted more technologies is resistance among employees. When introducing new technologies, it's important to get people on board and provide clear explanations of functionalities and the benefits it can bring (HM4). "*You should not underestimate the challenges involved, as it requires undertaking different tasks, potentially restructuring the organizations, and potentially hiring new personnel. So the acquisition of knowledge and expertise is a crucial aspect (FD4).*" As mentioned earlier, the adoption of digital process technologies is not only influenced by the industry sector but also the size of the firm. Investments in new technologies can be expensive. Due to the larger size of the firm, a higher budget is generally available to spend, and provides more flexibility and opportunities for investments (HM5, FD5).

4.2.2. Inter-concept relations

Firms are constantly seeking competitive advantage when they decide to outsource certain aspects of their operations. According to Pierce & Sen (2001) competitive advantages arise when firms possess superior production technologies. The formulated hypothesis suggests that there is a relationship between outsourcing production and adoption of digital process technologies. The results of the relationship are shown in table 9.

Table 9: Quotes on relation outsourcing and adoption		
Company	**Quote**	**Open code**
EC1	"Dus uiteindelijk als je ziet nou volumes het loont om daar gewoon zelf een machine voor aan te schaffen, dan doe je dat."	Terugverdienen
MC1	"Je kan die informatie hoe zo'n frame gelast moet worden, zou je zeggen prima op een digitale tekening kwijt, maar op een of andere manier lukt het ons niet om als hun het maken, dezelfde kwaliteit te krijgen als dat wij het maken."	Kwaliteit
FD1	"Ik wil eigenlijk, als jij iets, een bepaald proces of whatever ziet als een concurrentievoordeel, dan moet jij het zelf doen."	Concurrentievoordeel
IP1	"Nou, wat je ziet is als wij uitbesteden, dan ga je de voordelen zien van een bedrijf wat digitaliseert. Dus als wij leveranciers hebben die eigenlijk totaal niet meegaan met het stukje digitalisering, zullen ze in de toekomst bij ons de boot gaan missen, omdat wij waarschijnlijk doorgaan op dat soort dingen."	Vermogen leveranciers

The current outsourcing arrangements between firms and suppliers can potentially have a negative impact on the adoption of digital process technologies. The example of the digital design that doesn't achieve the desired quality by the supplier, and it becomes necessary for the firm to physically check it (MC1). Therefore, outsourcing doesn't lead to more adoption of digital process technologies by this firm. In line with this, the firm IP1 switches to other suppliers, if their current suppliers don't possess adequate technologies. However, this negative relationship is moderated by the capabilities of their current suppliers. The other two respondents (EC1, MC2) give other explanations that could initially be a reason to outsource certain activities to gain access to new digital process technologies, such as costs or competitive advantages. The findings show that there is no consensus on whether there is a relationship between outsourcing production and adoption of digital process technologies. The relationship tends more towards the negative, but this depends on other factors. As a result, hypothesis 1 must be rejected based on the qualitive data.

Relationship Collaboration and Adoption

The initial hypothesis stated that collaboration outsourcing positively influences the adoption of digital process technologies (Ligthart & Vaessen, 2020). Within the quantitative analysis, the hypothesis was rejected. Table 10 presents the relevant quotes for this hypothesis.

Table 10: Quotes on relation collaboration and adoption		
Company	**Quote**	**Open code**
EC1	"En ja als iets geüpgraded moeten worden of het is tijd voor iets nieuws, dan komt er gewoon via die leverancier weer iets nieuws en dan gaan we daar naar kijken."	Interesse leveranciers
EC2	"We hebben wel ooit experts van ons uit overgeheveld naar een concurrent. Dus dat gebeurt, alleen niet heel vaak"	Kennis transfer
MC1	"Ja, als een klant het idee heeft van he, dit is nu in de markt en dat is voor jullie ook wel interessant. Dan wordt dat echt gewoon met ons gedeeld, maar dat is dan wel vanuit hun eigen belang."	Interesse klant
MC2	"Alleen het is niet zo denk ik, dat wij bijvoorbeeld naar een concurrent of concullega kunnen gaan om te kijken hoe hun, die dezelfde machines maken als, hoe hun dan aanpakken, want dat is natuurlijk een beetje concurrentie en dat ligt heel gevoelig."	Concurrent
HM1	"Nou mocht het zo zijn dat er een partner is die aan de andere kant van de wereld voor ons cilinders gaat realiseren en gebruik moet maken van werkinstructies know how die wij hebben, dan denk ik.. Is het handig dat we dat aan elkaar connecten en dan het liefst zou ik zeggen, van bel dan in op ons systeem of dat ook werkt voor zo'n partner."	Online platform
HM2	"Nou, als het andersom moet zijn, als het een klant is, ja, dan pas ik me ook graag aan een klant."	Wensen klant
FD1	"Juist met die bedrijven in andere sectoren maakt eigenlijk wel dat we in ieder geval sneller kennismaken met nieuwe technologieën en dat we daar ook makkelijker voor openstaan."	Kennisverbreding
IP1	"Doordat wij zeg maar op corporate niveau bij de groep terug kunnen vallen op een bedrijf X Digital zeg maar, die dan eigenlijk een club mensen heeft die daar allemaal op verschillende fronten zeg maar hun expertise hebben."	Expertise zusterbedrijf
IP2	"Maar ook wel buiten de groep als het om heel specifieke kennis gaat."	Externe kennis

Table 10 shows that firms confirm that collaboration leads to quicker adoption of digital process technologies. Collaboration with suppliers, customers, or sometimes competitors, can strengthen the adoption of digital process technologies. Suppliers are often at the forefront of technological advancements and allow firms to gain access to new technologies (EC1). A similar principle applies to collaboration with customers when technologies are new on the market, and the customer is interested in having that technology (MC1, HM2).

Collaboration with competitors is slightly different according to two respondents. Firms can transfer knowledge to each other (EC2), but it's still competition and remains a sensitive aspect of business (MC2). One of the firms stated that collaboration with worldwide partners can facilitate the implementation of a cloud-based software system that provides access to each other's work instructions (HM1). Another firm goes beyond collaborating within its supply chain and collaborate with companies from other sectors. This collaboration helps in staying informed about the latest technologies and helps to reduce the risk of lock-in syndrome (FD1). Lastly, one firm operates as a subsidiary within the parent company and collaborates with their subsidiary Digital to adopt new digital process technologies (IP1, but also collaborates with external partners to gain specific knowledge (IP2). Even though collaboration occurs within the parent company internal structure, it can still be regarded as collaboration. This shows that all the firms collaborate in different forms, and that contributes to a higher adoption of digital process technologies. Based on the findings, hypothesis 2 can be accepted.

Relationship Collaboration and Outsourcing X Adoption

Table 11: Quotes on relation collaboration and outsourcing X adoption		
Company	**Quote**	**Open code**
EC1	"Het is eigenlijk dat stukje kennis en bij elkaar een kijkje in de keuken nemen."	Kennis
MC1	"In de basis is het denk ik toch belangrijk dat je niet zozeer dingen over de schutting gooit zonder enige communicatie."	Communicatie
FD1	"En soms wil je iets uitbesteden wat wel een concurrentievoordeel kan worden, maar dan kan je beter voor de vorm co-creëren kiezen en dan moet je dat aan de voorkant gewoon goed afspreken contractueel, dat je daarmee mede eigenaar van bent of whatever."	Co-creatie
IP1	"Dus ja, die kennis en kunde die proberen we zoveel mogelijk weer te halen bij in ons geval, de uitbesteedt adressen zijn dan vaak de zusterbedrijven."	Kennis

Table 11 shows that four of the five companies have not directly confirmed that collaboration positively influences the interaction effect between outsourcing and adoption of digital process technologies, but it helps to go beyond the transactional nature of outsourcing. The findings highlight the importance of knowledge sharing and effective communication. The knowledge aspect (EC1, IP1) was not mentioned in the relationship between outsourcing and adoption. The respondents express a positive sentiment towards collaboration in the context of outsourcing. Earlier, the challenges and concerns that can be associated with outsourcing were discussed. Collaboration involves a more interactive and cooperative relationship between the firms and the suppliers. *"I think it's important that you don't throw things over the fence* *without any communication (MC1)".* Instead of traditional outsourcing arrangements, the firms are willing to choose for co-creation (FD1) or a form of collaboration beyond transactional relationships to achieve competitive advantages. Based on the critical aspect of effective knowledge sharing and communication, hypothesis 3 is accepted.

4.2.3. Hypothesis overview

The results of both analyses are shown in table 12. The quantitative analysis shows no support for each of the three hypotheses. In both analysis hypothesis 1 is rejected, which means that there is not a significant effect between outsourcing production and adoption of digital process technologies. Secondly, collaboration within production positively influences the adoption of digital process technologies. Although hypothesis 2 is rejected within the quantitative analysis, all the respondents see collaboration as a positive influence on the adoption of digital process technologies. Additionally, the analysis supports the idea that the positive effect of outsourcing production on adoption is enhanced when it's moderated by collaboration production.

Table 12
Hypothesis overview

Hypothesis	Conclusion quantitative	Conclusion qualitative
H1. Outsourcing production will have an effect on the adoption of digital process technologies	Rejected	Rejected
H2. Collaboration production will have a positive effect on the adoption of digital process technologies	Rejected	Accepted
H3. There is an effect of outsourcing production on adoption of digital process technologies when is moderated by collaboration production	Rejected	Accepted

4.2.3. Conceptual findings

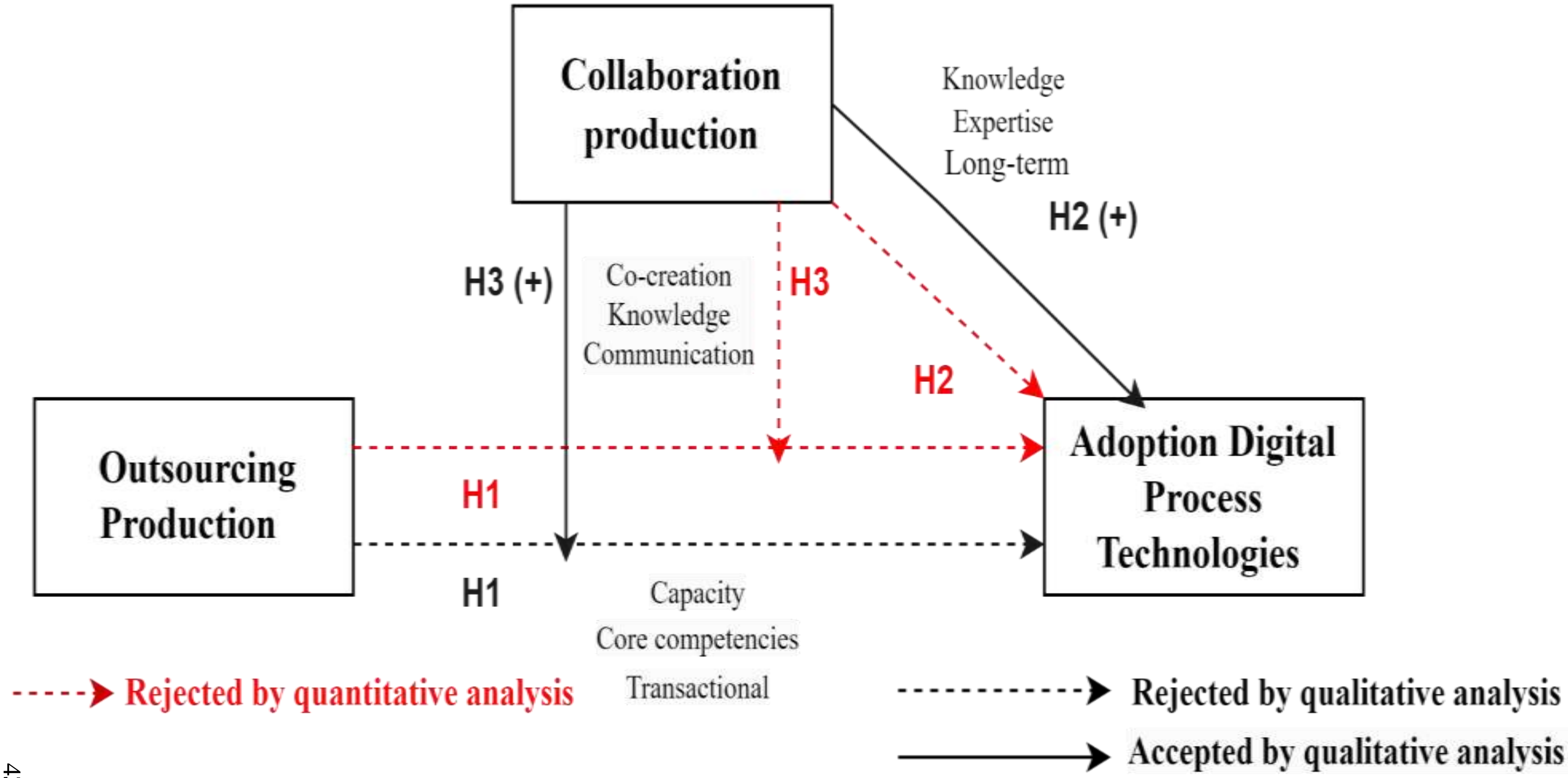
Although outsourcing and collaboration are in some way similar, the findings show that these two strategies have distinct characteristics and outcomes. The complete conceptual model is shown in figure 2. It's important to understand the differences between outsourcing and collaboration in the context of adoption of digital process technologies. Outsourcing is primarily utilized for capacity-related reasons. Many firms lack the internal resources, capacity, or employees to produce goods themselves, and therefore choose to outsource their production processes. This practice mainly applies to standardized processes. On the other hand, core competencies, such as product design and unique selling points, are generally kept in-house whenever possible. Firms strive to handle as many tasks as possible internally, even when there are other companies capable of performing certain tasks more efficiently. Otherwise firms are increasingly developing a high level of dependency on suppliers. In summary, outsourcing does not effectively facilitate the desired adoption of digital process technologies. It lacks the exchange of knowledge and remains primarily transactional in nature, and it does not typically involve the expansion of long-term collaboration between businesses.

Unlike outsourcing, collaboration is recognized as a valuable source of knowledge transfers and expansion. Each firm out of the sample engages in various collaborations with different partners across different domains. These collaborations often involve suppliers who possess specialized knowledge in technologies, which is actively shared and discussed. Moreover, collaboration goes beyond mere financial transactions, sometimes involving personnel exchange and frequent agreements between partners. The relationships formed through collaboration tend to be long-term in nature. In the context of digital process technologies, firms proactively seek out new technologies, not limited to their own industry but also from external sectors. Collaboration is widely regarded as an essential concept in business operations, whereas outsourcing may not emphasize it to the same extent.

Finally, the combined effect of outsourcing and collaboration positively impacts the adoption of digital process technologies. While outsourcing primarily involves transactional relationships, collaboration adds crucial elements of knowledge sharing and communication. It is these aspects that make firms more inclined to choose outsourcing as a strategy, and it's important to emphasize the significance of maintaining regular communication to prevent the loss of core competencies. There is a prevailing tendency to approach outsourcing in a pure business transactional manner, and often missing out on the intended benefits. Consequently, firms perceive suppliers solely as extension of their operations rather than equal of valuable partners. It's important to emphasize the significance of maintaining regular communication to prevent the loss of core competencies. In conclusion, a hybrid approach combining both outsourcing and collaboration proves to be the most effective strategy. Collaboration with partners provides insights into a firm's core competencies over time. This knowledge helps determine which competencies should be retained. Meanwhile, outsourcing can further enhance a business's competitive advantage through cost efficiency, particularly when core competencies are well-defined. Therefore, it's the combination of these two strategies that offers the optimal solution in the context of adopting digital process technologies.

Figure 1

Conceptual model hypothesis 1, 2 and 3



5. CONCLUSION

This chapter presents a summary of the results and the conclusion of this study. To answer the research question, a mixed method study was conducted. The following research question was formulated for this study: “How does outsourcing production activities affect the adaptation of digital process technologies, and to what extent is this influenced by collaboration production?”

Inconsistent with the theoretical arguments proposed in this study, no quantitative support was found for the hypothesis that outsourcing and collaboration within the production domain, lead to a statistically significant higher adoption rate of digital process technologies. No evident relationship between outsourcing, collaboration production and the adoption of digital process technologies could be found. In support of this, the qualitive findings indicate that outsourcing production alone does not have a significant effect on the adoption of digital process technologies. Outsourcing is only seen as a transactional relationship focused on addressing capacity for manufacturing firms.

The qualitive part finds support that the adoption rate of digital process technologies, depends in part upon the level of collaboration that firms engage in. These findings confirm the expectation that for adoption of digital process technologies, collaboration is generating more knowledge and expertise than for isolated production operations, serving as a trigger to strengthen their position and achieve competitive advantage. This, however, could not be stated with the same statistical confidence, as no real relationships were found to exist within the quantitative analysis. These results indicate that collaboration within the production domain appears to have a limited scope in the quantitative analysis.

With regard to the moderator effect, this study has found that a positive relationship exists. More collaboration in combination with outsourcing production tends to have larger adoption rate of digital process technologies. In this case, it has become clear that the contractual arrangements associated with outsourcing does not immediately increase the adoption rate of digital process technologies and does not provide opportunities for knowledge exchange and gaining access to new technologies. The moderator effect occurs, but clearly certain conditions and factors influence this relationship. With these findings, this study provides proof that outsourcing production activities alone doesn’t affect adoption, but collaboration (in combination with outsourcing) positively influence a higher adoption rate of digital process technologies among manufacturing firms.

6. DISCUSSION & IMPLICATIONS

The sixth chapter presents the discussion of the theoretical and practical implications. Derived from the findings of the conceptual model, several implications can be derived. Both outsourcing and collaboration were expected to have a positive impact on the adoption of digital process technologies. Although outsourcing was a prevalent and frequent business strategy among respondents, the desired benefits did not become visible in practice Recent research evidence showed that outsourcing could also be applicable to access new technologies and expertise (Sen & MacPherson, 2009), but in practice it's still limited to simple transactional relationships. If firms, that are at the start of their digitalization process, want to make a successful adoption of digital technologies, they should recognize the importance of constantly being dynamic and adaptable to their environment. The essential difference between outsourcing and collaboration is co-creation, where firms go into deeper partnerships beyond a formal contract (Ishizaka et al. (2020) and come together to share insights and create value.

Collaboration on its own also facilities the knowledge flows between business entities, but the combination of outsourcing and collaboration forms a powerful hybrid strategy that maximizes the strength of both approaches. It allows firms to assess their core competencies and optimize their resources by delegating non-core functions to external partners.

These implications serve as valuable starting points for further exploration and application of the analyzed concepts. Collaboration is in this study the key to success, but for future research it's interesting to examine the background why knowledge of competences can be lost because of outsourcing. Future research can also delve deeper into determining the minimum required level for firms to avoid hollowing out.

6.1. Theoretical implications

This study contributes to collaboration research among manufacturing firms, showing that the effects of collaboration with respect to adoption of digital process technologies differ with respect to relational aspects. Prior research often measures collaboration in terms of sharing activities, resources, and risks (Bowersox et al., 2003; Matapoulous et al., 2007; Michaealides et al., 2013) and arrives at different conclusions about which relational aspects have a good fit to capture the concept. The proposed proxy has a nice meaning, but it's not clear what this proxy measures of a collaborative relationship. Consequently, measuring the specific relational aspects that contribute to a collaborative relationship can be challenging. With the quantitative analysis the hypothesis was rejected, while the qualitive analysis found evidence that collaboration within the production domain positively influences the adoption of digital process technologies. The discrepancy is measuring collaborative relationship quantitatively versus quantitively raises important considerations in this thesis. It is evident that there are differences in how relationships were measured using quantitative analysis and qualitive analysis. A secondary database in the quantitative part has been used, where collaboration was already predefined as “voluntary inter-firm relationship beyond business relations”, and data has been collected for a different purpose. The database did not contain a wide range of relational questions in comparison with the interviews that were conducted. The core of the discrepancy between quantitative and qualitive lies in the construct validity (Hair et al., 2018), which means that there are concerns related to how well the question in EMS accurately represents the collaborative relationship. Out of the semi-structured interviews, several relational aspects were found that also can be valuable additions to the quantitative questionnaire on collaboration. Examples that were given were knowledge exchange, shared goals and vision, risk management, capacity, resources, communication, etc. These relational aspects could be included in a new ideal variable that can be created for further research that also fits within the quantitative analysis. So collaborative relationship is measured differently in qualitive analysis than quantitative analysis. Although the quantitative measurement is questionable, with the qualitative method there are also some concerns to address. Respondents sketch a collaborative relationship, but sometimes it’s still not clear what kind of relationship they refer to. The relationship could still be a simple transaction relationship, equivalent relationship, or mutually beneficial interplay relationship. For instance, firms can share customers and share machinery equipment, but don’t engage in joint technology development. In such cases, there is no consensus about what defines a collaborative relationship. Most desirable is that collaboration will be described based on the characteristics of a collaborative relationship, different forms, and intensity.

The effect of collaboration confirms the findings of studies that those collaborative relationships are positively linked with adoption of digital process technologies. However, in this study partners are considered in a broad sense, i.e. customers, suppliers, competitors, and research institutions. Including diverse types of partners examine the effects of collaboration from multiple perspectives. But looking at the production domain within the supply chain, it’s more interesting to focus solely on collaboration with suppliers. It highlights the role of a specific partner as a key driver of adoption of digital process technologies.

Finally, the index of digital process technologies shows a well-based construct validity. The twelve items that are used in both analyses cover a broad perspective and indicate a collection of different technologies. These twelve technologies are the most applicable and relevant technologies across the different sectors. Although there are more than 1000 different technologies, most of these technologies are not generic for all firms. The validity of this measurement index fits the concept of adoption in this study.

6.2. Practical implications

Firms face the critical need to prioritize digitalization to remain competitive. The findings imply that collaboration is an undeniable important factor for managers of manufacturing firms to embrace and integrate digital process technologies. Firms must move away from viewing outsourcing relationships as mere transactions and recognizing the importance of effective communication. This communication plays a role in the design and development of outsourced products. By frequent communication or deliberation, firms can continually exchange information about the progress and challenges within the outsourcing process. Furthermore, firms need to avoid the mindset and believe that they can handle everything independently. Instead, they should maintain continuous contact with their external environment to stay relevant and competitive.

7. LIMITATIONS & FUTURE RESEARCH SUGGESTIONS

Although the triangulation of quantitative and qualitative results is a strength of this study, it's necessary to acknowledge the potential limitations associated with this method. Beginning with the quantitative analysis, one limitation is the potential bias for content validity. Content validity refers to the extent to which individual items represent the construct being measured and cover the full range of the construct (Field, 2018). In this case, the constructs used in the quantitative analysis are not precisely aligned with the constructs measured in the EMS data survey. It means that the questions used in the EMS data survey may lack a clear and unambiguous meaning to capture the constructs in the right way. As a result, only a small percentage can be explained by the model, which indicates that a significant portion of the findings are influenced by factors not included in the quantitative analysis. The models fail to capture a big part of the variance of adoption of digital process technologies and should be expanded by adding more control variables. It would be interesting to start with the factors that influence the dependent variable outside the conceptual model. Despite the broad definitions of constructs, the effects explored in this study are limited due to the dichotomous measurements of outsourcing and collaboration. This limitation arises from categorizing organizations, without consider the full range of possibilities. Future research might want to utilize multi-item scales that capture different dimensions of these constructs that go beyond the predetermined list. The qualitative part in this study also presents certain limitations as it relied on a small sample size. The qualitive findings were valuable for understanding the constructs and their relationships to each other, but it's critical to interpret these findings within the context of certain limitations. The sample size of only five respondents restricts the diversity of different perspectives that can be obtained. Although efforts were made to conduct interviews with managers or directors in different industry sectors, it's important to recognize that the external validity of the study may be questionable, and the results could still be limited. Having respondents from different firm sizes and industry sectors provides a broader spectrum of experiences and practices. However, an overall conclusion can't be drawn. By aiming for a bigger population in future research, researchers can overcome the lack external validity with small sample sizes.

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APPENDIX

Appendix 1: Descriptive statistics

Table 1: Descriptive statistics

Descriptive Statistics

	Mean	Std. Deviation	N
Digi_Production index of digitalization process innovations used	2,8235	2,08098	153
lnSize number of employees 2017 (log)	3,7725	,93881	153
Food	,0784	,26973	153
Textile	,1373	,34525	153
Construction	,0196	,13910	153
Chemical	,1373	,34525	153
Machinery	,1699	,37681	153
Electronic	,2484	,43348	153
Outsourcing manufacturing/ production abroad	,1895	,39323	153
Coll_production Production co-operation, capacity compensation, joint utilization of machinery	,3137	,46553	153
OutColl interaction Outsourcing and Coll_production	,0850	,27975	153

Table Caption

Table 2: Item statistics adoption digital process technologies

Reliability Statistics

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

Table 3: Reliability statistics

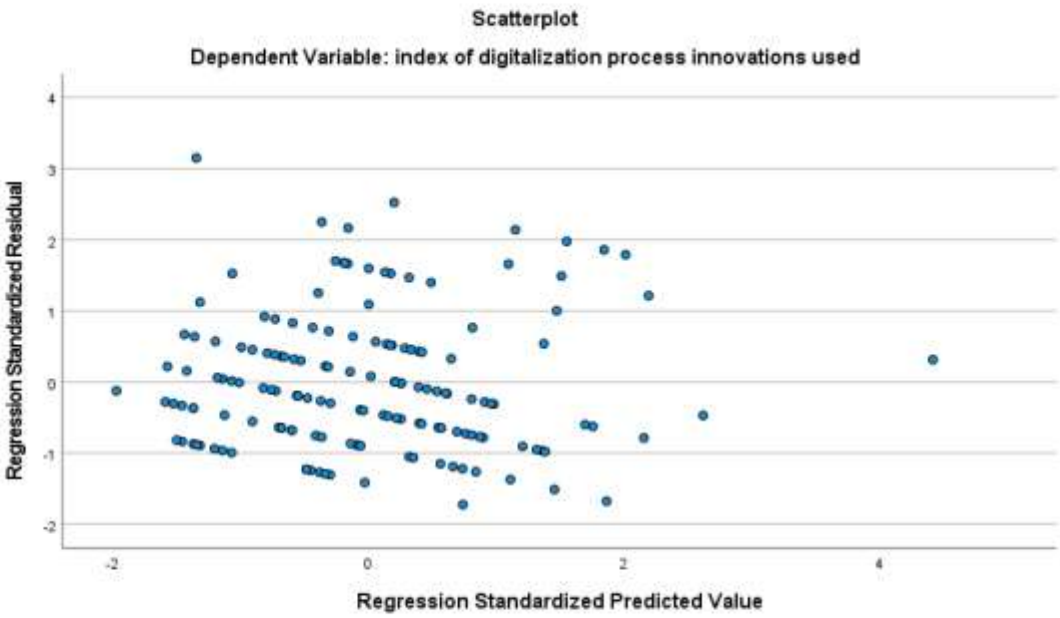
Reliability Statistics

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

Appendix 2: Check for assumptions

Assumption 1: Linearity

Figure 1: Scatterplot



The assumptions of linearity in multiple regression analysis refer to the relationship between the independent variables and the dependent variable (Hair et al., 2018). It assumes that the relationship is linear, which means that a change in the independent variable will lead to a change in the dependent variable. To check if the regression model is linear, the scatterplot figure is used to examine linearity. This scatterplot figure is based on the standard residuals and the standardized predicted values of the dependent variable based on the conceptual model provided in chapter 2. It's essential that the scatterplot doesn't show a clear pattern. The dots don't form some sort of clear pattern, thereby leading to indicate that there is linearity.

Assumption 2: Constant Variance of Error Terms

The next assumption is related to dependence relationships between variables. Homoscedasticity refers to the assumption that the variance of dependent variables remains consistent or equal across the entire range of predictor variables (Hair et al., 2018). Homoscedasticity can be checked by looking at the same scatterplot again to see if there is some pattern in the residuals. As shown earlier in the scatterplot, there is not a consistent pattern that shows heteroscedasticity. In other words, the variance is constant, so the data is homoscedastic.

Assumption 3: Independence of the Error Terms

Table 1: Residuals Statistics

Residuals Statistics[a]

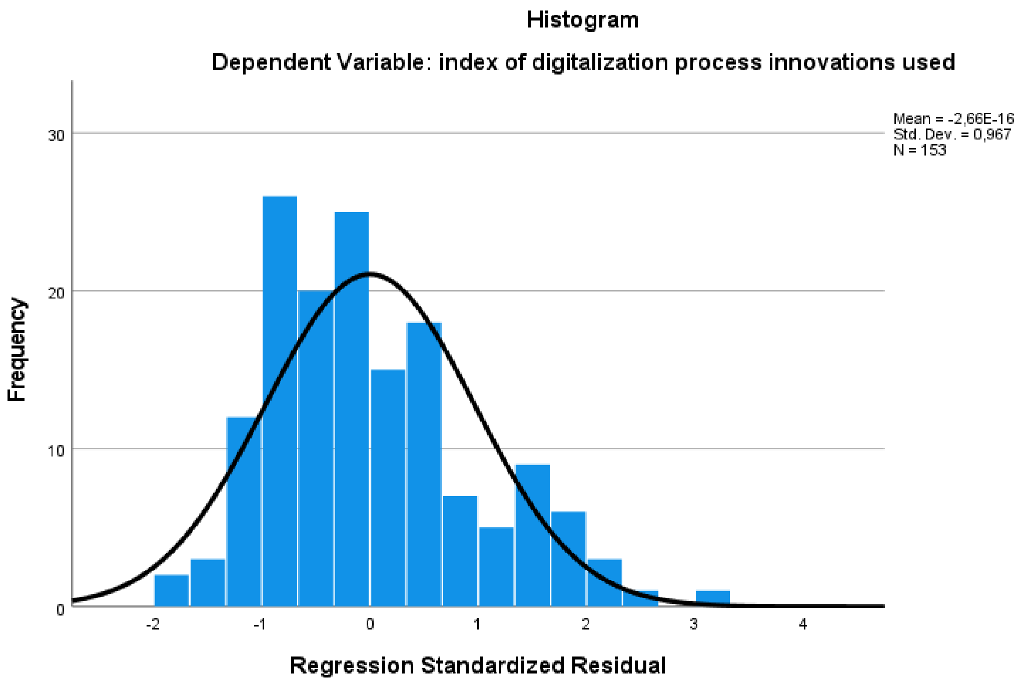
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1,2442	6,3766	2,8235	,80342	153
Residual	-3,42198	6,25382	,00000	1,91964	153
Std. Predicted Value	-1,966	4,422	,000	1,000	153
Std. Residual	-1,723	3,149	,000	,967	153

a. Dependent Variable: Digi_Production index of digitalization process innovations used

The third assumption of multiple regression analysis is the assumption of independence of error terms. This assumption implies that each predicted value is independent and isn't influenced by any other predictions (Hair et al., 2018). The error term represents the variance that remains unexplained by the independent variables in the multiple regression analysis. Examining the residual statistics output helps to explain whether there exists any correlation between the error and the independent variables. Within the residual statistics output the standardized predicted value is the column to watch. If the mean is 0.0 and the standard deviation is 1.0, there is no correlation between the errors and independent variables. Both are the case in the residual statistics, so the assumption of independence among error terms is met. The errors don't influence the regression model.

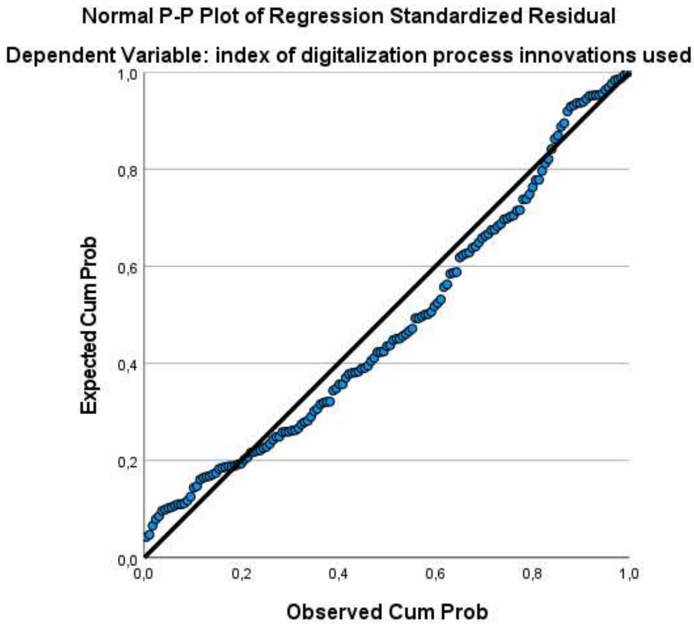
Assumption 4: Normality of error term distribution

Figure 2: Histogram



Normality refers to the distribution of data and is assessed though kurtosis and skewness. To determine if the data is normally disturbed, a histogram can be used to compare the observed data values with a normal distribution. By visually inspecting the normal curve of the standardized residuals of the variables, the histogram is quite normally distributed. Another way to assess the normality of errors is by examining the normal probability plot. If the errors follow a normal distribution, the dots on the plot should closely align with the diagonal line. In the provided normal p-plot in figure 4 the observed points seem to cluster around the diagonal line Except for some outliers in the histogram and normal p-plot, the assumption of normality of the multiple regression analysis is completed.

Figure 3: Normal P-P Plot of Regression Standardized Residual



Assumption 5: Multicollinearity

According to Hair et al. (2018), when conducting a multiple regression analysis, it is considered desirable to have a strong correlation between the independent variables and the dependent variable, while minimizing the correlation among the independent variables themselves. In other words, multicollinearity is the extent to which variables overlap with each other (Hair et al., 2018). The presence of multicollinearity among variables adds complexity to interpreting regression effects, because it will be harder to accurately determine the true impact of induvial factors. It's essential to avoid situations of perfect collinearity in regression analysis. With the collinearity statistics in table 1, multicollinearity can be checked by two indicators: variance inflation factor (VIF) and the tolerance value. Large VIF values indicate a high degree of multicollinearity among the independent variables (Hair et al., 2018). In the dataset the highest value of VIF is 2.301, which is quite low, because the maximum value can be 10.0. Looking at the tolerance value, the suggested preferred cut-off for the tolerance value is 0.10, and as the tolerance value approaches 1.0, the level of multicollinearity decreases. All tolerance values are relatively high, because all tolerance values are above 0.4, and some even above 0.7. Based on the results, there is no significant multicollinearity present among the predictor variables.

Table 2: Interpretation of Regression Results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-,065	,733		-,089	,929		
	lnSize number of employees 2017 (log)	,782	,175	,353	4,465	<,001	,954	1,049
	Food	-,625	,673	-,081	-,928	,355	,781	1,281
	Textile	-,312	,556	-,052	-,562	,575	,700	1,429
	Construction	-,014	1,195	-,001	-,012	,991	,931	1,074
	Chemical	,470	,557	,078	,844	,400	,698	1,433
	Machinery	,129	,528	,023	,245	,807	,652	1,534
	Electronic	-,217	,475	-,045	-,458	,648	,608	1,645
2	(Constant)	,106	,756		,141	,888		
	lnSize number of employees 2017 (log)	,722	,181	,326	4,001	<,001	,898	1,114
	Food	-,678	,677	-,088	-1,001	,319	,773	1,294
	Textile	-,347	,558	-,058	-,622	,535	,696	1,438
	Construction	,132	1,206	,009	,110	,913	,917	1,091
	Chemical	,405	,559	,067	,724	,470	,692	1,445
	Machinery	,143	,529	,026	,271	,787	,650	1,540
	Electronic	-,238	,476	-,049	-,500	,618	,607	1,649
	Outsourcing manufacturing/ production abroad	,579	,428	,109	1,352	,179	,910	1,099
	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	-,126	,356	-,028	-,355	,723	,937	1,067
3	(Constant)	,099	,759		,130	,897		
	lnSize number of employees 2017 (log)	,729	,183	,329	3,982	<,001	,878	1,139
	Food	-,666	,681	-,086	-,979	,329	,769	1,300
	Textile	-,345	,560	-,057	-,617	,538	,695	1,438
	Construction	,146	1,211	,010	,120	,904	,915	1,093
	Chemical	,393	,563	,065	,698	,486	,687	1,455
	Machinery	,144	,530	,026	,272	,786	,649	1,540
	Electronic	-,253	,481	-,053	-,527	,599	,597	1,676
	Outsourcing manufacturing/ production abroad	,483	,569	,091	,850	,397	,519	1,927
	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	-,176	,406	-,039	-,433	,666	,725	1,379
	OutColl interaction Outsourcing and Coll_production	,223	,873	,030	,255	,799	,435	2,301

a. Dependent Variable: Digi_Production index of digitalization process innovations used

Appendix 3: Correlation matrix

To explore the relationships between variables, a correlation matrix is employed prior to the hypotheses tested in this research. Table 2 presents the correlation matrix, displaying the Pearson's correlation coefficients. These coefficients measure the strength and direction of the relationships between the variables. The values range from -1 to +1, where a coefficient of +1 indicates a perfect positive correlation, -1 indicates a perfect negative correlation, and 0 indicates no correlation (Hair et al., 2018). The highest correlation exists between outsourcing manufacturing and the interaction effect outsourcing manufacturing and collaboration production with a value of 0.630. It's worth noting that the observed high correlation may be attributed to the overlap between these variables.

Table 1: Correlation matrix

Correlations

		Digi_Production index of digitalization process innovations used	lnSize number of employees 2017 (log)	Food	Textile	Construction	Chemical	Machinery	Electronic	Outsourcing manufacturing/ production abroad	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	OutColl interaction Outsourcing and Coll_production
Pearson Correlation	Digi_Production index of digitalization process innovations used	1,000	,343	-,046	-,067	,012	,061	,097	-,053	,178	-,004	,082
	lnSize number of employees 2017 (log)	,343	1,000	,096	-,052	,025	-,115	,159	-,027	,225	-,019	,007
	Food	-,046	,096	1,000	-,116	-,041	-,116	-,132	-,168	,045	-,092	-,089
	Textile	-,067	-,052	-,116	1,000	-,056	-,159	-,180	-,229	,001	-,065	-,053
	Construction	,012	,025	-,041	-,056	1,000	-,056	-,064	-,081	-,068	,108	-,043
	Chemical	,061	-,115	-,116	-,159	-,056	1,000	-,180	-,229	,049	-,024	,083
	Machinery	,097	,159	-,132	-,180	-,064	-,180	1,000	-,260	,003	,107	-,013
	Electronic	-,053	-,027	-,168	-,229	-,081	-,229	-,260	1,000	-,008	-,030	,096
	Outsourcing manufacturing/ production abroad	,178	,225	,045	,001	-,068	,049	,003	-,008	1,000	,140	,630
	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	-,004	-,019	-,092	-,065	,108	-,024	,107	-,030	,140	1,000	,451
	OutColl interaction Outsourcing and Coll_production	,082	,007	-,089	-,053	-,043	,083	-,013	,096	,630	,451	1,000
Sig. (1-tailed)	Digi_Production index of digitalization process innovations used	.	<,001	,288	,206	,441	,225	,116	,257	,014	,482	,156
	lnSize number of employees 2017 (log)	,000	.	,118	,263	,378	,079	,025	,371	,003	,409	,466
	Food	,288	,118	.	,076	,306	,076	,052	,019	,290	,129	,137
	Textile	,206	,263	,076	.	,244	,025	,013	,002	,495	,212	,256
	Construction	,441	,378	,306	,244	.	,244	,216	,159	,200	,093	,298
	Chemical	,225	,079	,076	,025	,244	.	,013	,002	,272	,384	,154
	Machinery	,116	,025	,052	,013	,216	,013	.	,001	,484	,095	,436
	Electronic	,257	,371	,019	,002	,159	,002	,001	.	,462	,356	,119
	Outsourcing manufacturing/ production abroad	,014	,003	,290	,495	,200	,272	,484	,462	.	,042	,000
	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	,482	,409	,129	,212	,093	,384	,095	,356	,042	.	,000
	OutColl interaction Outsourcing and Coll_production	,156	,466	,137	,256	,298	,154	,436	,119	,000	,000	.
N	Digi_Production index of digitalization process innovations used	153	153	153	153	153	153	153	153	153	153	153
	lnSize number of employees 2017 (log)	153	153	153	153	153	153	153	153	153	153	153
	Food	153	153	153	153	153	153	153	153	153	153	153
	Textile	153	153	153	153	153	153	153	153	153	153	153
	Construction	153	153	153	153	153	153	153	153	153	153	153
	Chemical	153	153	153	153	153	153	153	153	153	153	153
	Machinery	153	153	153	153	153	153	153	153	153	153	153
	Electronic	153	153	153	153	153	153	153	153	153	153	153
	Outsourcing manufacturing/ production abroad	153	153	153	153	153	153	153	153	153	153	153
	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	153	153	153	153	153	153	153	153	153	153	153
	OutColl interaction Outsourcing and Coll_production	153	153	153	153	153	153	153	153	153	153	153

Appendix 3: Correlation matrix

To explore the relationships between variables, a correlation matrix is employed prior to the hypotheses tested in this research. Table 2 presents the correlation matrix, displaying the Pearson's correlation coefficients. These coefficients measure the strength and direction of the relationships between the variables. The values range from -1 to +1, where a coefficient of +1 indicates a perfect positive correlation, -1 indicates a perfect negative correlation, and 0 indicates no correlation (Hair et al., 2018). The highest correlation exists between outsourcing manufacturing and the interaction effect outsourcing manufacturing and collaboration production with a value of 0.630. It's worth noting that the observed high correlation may be attributed to the overlap between these variables.

Table 1: Correlation matrix

Correlations

		Digi_Production index of digitalization process innovations used	lnSize number of employees 2017 (log)	Food	Textile	Construction	Chemical	Machinery	Electronic	Outsourcing manufacturing/ production abroad	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	OutColl interaction Outsourcing and Coll_production
Pearson Correlation	Digi_Production index of digitalization process innovations used	1,000	,343	-,046	-,067	,012	,061	,097	-,053	,179	-,004	,082
	lnSize number of employees 2017 (log)	,343	1,000	,096	-,053	,025	-,115	,159	-,027	,225	-,019	,007
	Food	-,046	,096	1,000	-,116	-,041	-,116	-,132	-,168	,045	-,092	-,089
	Textile	-,067	-,053	-,116	1,000	-,056	-,159	-,180	-,229	,001	-,065	-,053
	Construction	,012	,025	-,041	-,056	1,000	-,056	-,064	-,081	-,068	,108	-,043
	Chemical	,061	-,115	-,116	-,159	-,056	1,000	-,180	-,229	,049	-,024	,083
	Machinery	,097	,159	-,132	-,180	-,064	-,180	1,000	-,260	,003	,107	-,013
	Electronic	-,053	-,027	-,168	-,229	-,081	-,229	-,260	1,000	-,008	-,030	,096
	Outsourcing manufacturing/ production abroad	,179	,225	,045	,001	-,068	,049	,003	-,008	1,000	,140	,630
	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	-,004	-,019	-,092	-,065	,108	-,024	,107	-,030	,140	1,000	,451
	OutColl interaction Outsourcing and Coll_production	,082	,007	-,089	-,053	-,043	,083	-,013	,096	,630	,451	1,000
Sig. (1-tailed)	Digi_Production index of digitalization process innovations used	.	<,001	,288	,206	,441	,225	,116	,257	,014	,482	,156
	lnSize number of employees 2017 (log)	,000	.	,118	,263	,378	,079	,025	,371	,003	,409	,466
	Food	,288	,118	.	,078	,306	,076	,052	,019	,290	,128	,137
	Textile	,206	,263	,076	.	,244	,025	,013	,002	,495	,212	,256
	Construction	,441	,378	,306	,244	.	,244	,218	,159	,200	,093	,298
	Chemical	,225	,079	,076	,025	,244	.	,013	,002	,272	,384	,154
	Machinery	,116	,025	,052	,013	,216	,013	.	,001	,484	,095	,436
	Electronic	,257	,371	,019	,002	,159	,002	,001	.	,462	,356	,119
	Outsourcing manufacturing/ production abroad	,014	,003	,290	,495	,200	,272	,484	,462	.	,042	,000
	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	,492	,409	,128	,212	,093	,384	,095	,356	,042	.	,000
	OutColl interaction Outsourcing and Coll_production	,156	,466	,137	,256	,298	,154	,436	,119	,000	,000	.
N	Digi_Production index of digitalization process innovations used	153	153	153	153	153	153	153	153	153	153	153
	lnSize number of employees 2017 (log)	153	153	153	153	153	153	153	153	153	153	153
	Food	153	153	153	153	153	153	153	153	153	153	153
	Textile	153	153	153	153	153	153	153	153	153	153	153
	Construction	153	153	153	153	153	153	153	153	153	153	153
	Chemical	153	153	153	153	153	153	153	153	153	153	153
	Machinery	153	153	153	153	153	153	153	153	153	153	153
	Electronic	153	153	153	153	153	153	153	153	153	153	153
	Outsourcing manufacturing/ production abroad	153	153	153	153	153	153	153	153	153	153	153
	Coll_production Production co-operation, capacity compensation, joint utilization of machinery	153	153	153	153	153	153	153	153	153	153	153
	OutColl interaction Outsourcing and Coll_production	153	153	153	153	153	153	153	153	153	153	153

Appendix 4: Overall Model Fit

Table 1: Model Summary

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	,371[a]	,138	,096	1,97851	,138	3,308	7	145	,003	
2	,386[b]	,149	,095	1,97958	,011	,922	2	143	,400	
3	,386[c]	,149	,089	1,98608	,000	,065	1	142	,799	1,781

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

b. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Textile, Chemical, Machinery, Coll_production Production co-operation, capacity compensation, joint utilization of machinery, Outsourcing manufacturing/ production abroad

c. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Textile, Chemical, Machinery, Coll_production Production co-operation, capacity compensation, joint utilization of machinery, Outsourcing manufacturing/ production abroad, OutColl interaction Outsourcing and Coll_production

d. Dependent Variable: Digi_Production index of digitalization process innovations used

Table 2: ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	90,635	7	12,948	3,308	,003[b]
	Residual	567,601	145	3,914		
	Total	658,235	152			
2	Regression	97,857	9	10,873	2,775	,005[c]
	Residual	560,378	143	3,919		
	Total	658,235	152			
3	Regression	98,115	10	9,811	2,487	,009[d]
	Residual	560,121	142	3,945		
	Total	658,235	152			

a. Dependent Variable: Digi_Production index of digitalization process innovations used

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

c. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Textile, Chemical, Machinery, Coll_production Production co-operation, capacity compensation, joint utilization of machinery, Outsourcing manufacturing/ production abroad

d. Predictors: (Constant), Electronic, lnSize number of employees 2017 (log), Construction, Food, Textile, Chemical, Machinery, Coll_production Production co-operation, capacity compensation, joint utilization of machinery, Outsourcing manufacturing/ production abroad, OutColl interaction Outsourcing and Coll_production

Appendix 5: Interview Script

Thema	Hoofdvragen en doorvragen a.d.h.v. steekwoorden of subvragen
Intro; 5 minuten	Mijn naam is Sebastian van Kessel, 25 jaar en masterstudent Strategic Management aan de Radboud Universiteit in Nijmegen. Voor mijn Master Thesis doe ik onderzoek naar de invloed van uitbesteding van productie op de adoptie van digitale proces technologieën binnen de Nederlandse maakindustrie. Voordat we beginnen, wil ik u alvast bedanken dat ik hier mag komen en u de tijd heeft vrijgemaakt om mij te woord te willen staan. Mag ik u vriendelijk verzoeken om toestemming te krijgen om dit gesprek op te nemen, zodat ik uw antwoorden nadien accuraat kan uitwerken en transcriberen? De opname wordt uitsluitend voor de transcriptie gebruikt, is volledig anoniem en zal niet identificeerbaar zijn naar u of het bedrijf. Ik zal het transcript voorafgaand aan de analyse eveneens met u delen ter verificatie, als u dat wenst te ontvangen. Het interview zal circa 60 minuten duren. Indien u geen vragen meer heeft, stel ik voor dat we kunnen beginnen aan het interview.
Oriënterende vragen; 5 minuten	**a. Wie bent u en wat is uw rol binnen het bedrijf?** (Functie, ervaring algemeen, arbeidsduur) **b. Wat voor bedrijf is uw bedrijf** (Aantal medewerkers, hoofdproduct(en), aanvullende diensten) **c. Binnen welke markt(en)/industrie(ën) opereert uw bedrijf met name?** Welke werkzaamheden en activiteiten worden uitgevoerd?
Uitbesteding: 10 minuten	De eerste set vragen gaan over uitbesteding van productie. Uitbesteding is een strategie waarbij bedrijven taken of diensten overdragen aan externe partijen. Uitbesteding kan voorkomen in verschillende vormen zoals offshoring, strategic alliances, nearshoring, etc. **a. Welke delen van productie zijn overgeheveld naar andere bedrijven?** (digitaal ontwerp a.d.h.v. software, assemblage fysieke goederen) **b. Welke delen van productie zijn overgeheveld naar het buitenland?** Naar welk(e) land(en)? Binnen Europa of elders? Waarom? **c. Wat zijn de belangrijkste redenen voor uitbesteding of verplaatsing van (delen van) productie?** (kostenbesparing, efficiëntieverbetering, schaalbaarheid in productiecapaciteit, toegang tot gespecialiseerde kennis en technologie) **d. Wat zijn mogelijke risico's die verbonden zijn het aan het uitbesteden van taken of diensten aan andere bedrijven?** (aanhoudende afhankelijkheid, verlies en verminderde controle, kwaliteitsproblemen, verlies intellectueel eigendom)
Digitalisering: 10 minuten	Met het tweede concept, zou ik graag het nu met u willen hebben over de mate van digitalisering van het bedrijf. Digitalisering verwijst naar het daadwerkelijk in gebruik nemen van digitale proces technologieën. Voorbeelden zijn software voor productieplanning, robots, 3d printing, etc. **a. Op welke manier maakt het bedrijf gebruik van digitalisering van productie?** (Mobiele/draadloze apparaten,, digitale productieplanning, digitale prototypes, datamanagement, automatisering, industriële robots) **b. Wat voor invloeden hebben deze technologieën op het bedrijf gehad?** (Strategie, heroriëntatie, nieuwer markten/producten, meer kennis) **c. Wat was of waren de grootste uitdaging(en) bij het implementeren van deze technologieën?** (Kennis, financiële middelen, ervaring, human capital)
Samenwerking: 10 minuten	De volgende vragen hebben betrekking op het laatste onderwerp, namelijk eventuele partnerships of samenwerkingen die uw bedrijf heeft met andere bedrijven. Een samenwerking kan ontstaan indien het bedrijf vrijwillig een ander bedrijf kiest en de samenwerking verder gaat dan eenmalige formele transacties. Samenwerkingen hoeven niet alleen met andere soortgelijke bedrijven te zijn, maar kunnen ook bestaan met onderzoeksinstituten, klanten of leveranciers. **a. Op welke gebieden van productie werkt uw bedrijf samen met andere bedrijven?** (Ontwerp, design)

	b. Wat vormt de aanleiding voor samenwerkingen met andere partners? Is dit een additionele aanvulling op of meer een onmisbare toevoeging? **c. Op welke manier dragen deze samenwerkingen bij aan de adoptie en implementatie van digitale proces technologieën binnen het bedrijf?** (Toegang van expertise, gedeelde kosten en risico's, versnelling proces)
Effect uitbesteding op digitalisering: 10 minuten	Tenslotte zijn er nog wat vragen over de invloed die uitbesteding heeft op adoptie van digitale proces technologieën. Waarbij u kunt denken aan uitbesteding van bepaalde productieprocessen, wat leidt tot een verschuiving in de vraag van bepaalde technologieën. **a. Op welke manieren beïnvloedt uitbesteding van (delen van) productie de adoptie van digitale proces technologieën?** (Voorbeelden, risico's, ondersteuning, activiteiten) **b. Op welke manieren beïnvloeden externe samenwerkingen de adoptie van digitale proces technologieën?** (Voorbeelden, risico's, ondersteuning, activiteiten) **c. Hoe denkt u dat externe samenwerkingen de relatie tussen uitbesteding en de adoptie van digitale proces technologieën beïnvloeden?** (Voorbeelden, risico's, ondersteuning, activiteiten)
Outro	Dank u wel voor uw tijd en deelname aan dit interview. Zoals ik al eerder heb vermeld, zal ik het interview volledig anonimiseren en het transcript aan u voorleggen. De opname zal per direct worden verwijderd indien het transcript adequaat is uitgewerkt. Tot slot heb ik nog een laatste vraag voor u. Zou u geïnteresseerd zijn in het ontvangen van exemplaar van het onderzoeksrapport nadat het is afgerond?

Appendix 6: Quotes used in qualitative analysis

Quotes used in qualitative analysis		
Outsourcing production		**Open code**
EC2	"Ja, ik denk als je op gegeven moment aan je capaciteit grens zit, hè, dat je iets hebt van ja oké, dit is in-house en we zouden het kunnen, maar we hebben er gewoon de tijd en resources niet voor."	Capaciteit
HM2	"Kijk, ik zal het niet zomaar uitbesteden op het moment dat we het zelf kunnen bouwen. Als wij capaciteit hebben op de machine, dan is de eerste insteek zelf doen."	Capaciteit
FD2	"Maar het kan ook gewoon een ordinair zijn, dat we dan zelf niet de capaciteit hebben of de resources niet hebben of whatever."	Capaciteit
FD3	"Zeg maar, in sommige dingen is de markt natuurlijk ook efficiënter dan jij zelf."	Efficiency markt
EC3	"We hebben een aantal processen inderdaad overgegeven, nou bijvoorbeeld naar China. En de grootste reden daarvoor is sowieso loonkosten, de loonkosten liggen daar een stuk lager dan in Nederland, dus denk aan bekabeling en kabelbomen trekken voor een elektronica."	Loonkosten
HM3	"Risico's zijn natuurlijk dat buiten de tolerantie terug geleverd krijgt."	Kwaliteit issue
EC4	"Je bent afhankelijk, dus je bent ook afhankelijk van leveringen van andere partijen."	Afhankelijk
FD4	"Dat we zo afhankelijk worden van processen die door anderen gedaan worden en dat we daar zelf de kennis niet van hebben hè. Dus dat je dan gewoon ook ja, in ook onderhandelingen slechts staat, dat soort dingen. Maar ook dat je natuurlijk voor je traceability en dat soort thema 's, ja ook wel moet zorgen dat die die datastromen en die informatie goed gedeeld blijft worden."	Afhankelijkheid
EC5	"Want ja, de investering die je moet doen om bijvoorbeeld, ik noem maar iets PCBA's, te kunnen produceren die is gigantisch."	Investering
HM4	"We hebben relatief veel plaatwerk eigenlijk nodig, maar dat verantwoord niet de investering van een hele eigen plaatwerkerij."	Investering
HM5	"Inmiddels zijn leveranciers die we zelf zijn gaan opschalen groter geworden, hebben grotere machines gekocht en daarmee denk ik af en toe bijna concurrent om dingen te doen."	Opkomst concurrenten
FD5	"Maar ook dat je natuurlijk voor je traceability en dat soort thema 's, ja ook wel moet zorgen dat die die datastromen en die informatie goed gedeeld blijft worden."	Traceability
EC6	"Maar als ik naar het bedrijf kijk dan wordt er geoutsourcet. Ja, vooral de inkoop van componenten hè. Dus het productieproces daar omheen hebben we zelf in-house."	Inkoop
IP2	"Op het moment dat het bedrijf X intern is, is dat niet zo een issue."	Intern outsourcing
Quotes used in qualitative analysis		
Collaboration production		**Open code**
MC3	"Dan vraagt de klant van hé, kunnen jullie iets voor ons ontwikkelen? Ja, dan ontstaat dat meer vanuit de klantvraag. Ja dat is eigenlijk bij ons wel de voornaamste drijfveer voor echt een partnership."	Klantvraag
EC2	"Het specialisme van echt het onderhoud en het troubleshooten, dat zit gewoon altijd bij de leverancier en dat zal altijd denk ik zo blijven."	Specialisme
FD2	"Je kan dat heel ver trekken en zo kan je dus die waarde in de keten verhogen, want de speklappen die worden goedkoper als je met de rest ook iets kan, want anders moet je compenseren voor de rest waar je niks mee kan. Dus dat doen we heel veel en daar zijn we	Waarde keten

	ook actief mee bezig om dat soort ketens op te zetten van groepen boeren koppelen aan groepen klanten.”	
HM3	“Mijn beleving is dat op dit moment echt een onmisbare toevoeging is. We zijn met 250 man. We hebben sales force die redelijk groot is voor de omzet van het bedrijf, maar ja toch te klein en niet actief genoeg om wereldwijd in die markt rond te gaan. En zeker als je kijkt naar de diversiteit aan producten. Als je dan gebruik kunt maken van partners en daarmee business genereert, want dat is eigenlijk het doel.”	Business genereren
FD3	“Samenwerken heeft ons altijd beter gemaakt.”	Waardevol
IP3	“Ja kijk, uiteindelijk is het natuurlijk gewoon business, hè? Iedereen die zit er voor zijn eigen business.”	Waarde creëren
IP4	“Datzelfde bedrijf maakt ook magazijnstellingen, alle magazijnstellingen die wij bij bedrijf X kopen, die komen wel van die fabriek, dus wij proberen ook wel zeg maar in twee richtingen verkeer te creëren. Waarbij je zegt, wij proberen klant te zijn van onze klanten. Dat versterkt over het algemeen ook de relatie, zeg maar in alle vormen.”	Wisselwerking
Quotes used in qualitative analysis		
Adoption of digital process technologies		**Open code**
EC3	“En daar zullen we altijd ook wel heel actief naar kijken hoe het makkelijker kan en vooral hoe je gewoon FTEs kan besparen.”	FTE besparing
FD3	“Ja daarnaast bewerken met camera's, met sensors, met ja van allerlei soorten.”	Gadgets
HM3	“Dus data verzamelen, analyseren, kijk wat die data zegt, acties definiëren, zodat je bijstuurt en opvolgen of dat ook een effect heeft en indien niet kringetje weer opnieuw doorlopen.”	Dataverzameling
IP3	“En ja wij hebben nu eigenlijk een digitale bus, dus iedere bus die geleverd wordt, die hebben wij ook digitaal en volgen we van A tot Z, waardoor we heel veel feedback en data krijgen. Dus de data verzamelen is ook enorm belangrijk.”	Datagegevens
IP4	“Wij denken dat we zonder digitalisering in de toekomst zeg maar de boot gaan missen. Dus ja, je moet wel. Anderzijds helpt het ons enorm bij het feit dat je zegt, ja, we hebben mensen schaarste aan goed vakmanschap en personeel. Je kunt hiermee wat schakels eigenlijk uitschakelen.”	Efficiëntie
HM4	“Mensen mee krijgen. Ja, kijk dit hadden we al heel lang, dus dit weet ik niet. Maar die andere tools die ik net schets is vooral uitleggen wat die tool gaat doen, wat we daarmee kunnen, wat het gaat opleveren.”	Werknemers
FD4	“Maar dat moet je niet onderschatten, want dat vraagt andere taken, vaak andere organisatie opzet, misschien wel andere hiërarchie, andere mensen die je in moet gaan huren, noem maar op.”	Interne organisatie
FD5	“Bij een bedrijf met lage marges zal je nog beter die prioriteiten moeten stellen en kijken waar je die zak geld aan besteed.”	Winstmarge
HM5	“Kijk, als je veel geld verdient en je kunt veel geld investeren, dan kun je wat makkelijker besluiten om wat digitale systemen in te voeren.”	Investeren
MC3	“Maar ons las proces is dermate, door die Engineering to Order, dat een robot die iedere keer hetzelfde doet vaak wel uitkomt. Maar we hebben nooit hetzelfde, dus ons eigen proces is vaak toch nog echt met de handjes.”	Specifiek product
HM6	“Nee, zeker geen lopende band werk. Ja, we zijn geen massaproductie, dus enkel stuks en zeker het draaien en frezen. Het is vakwerk.”	Specifiek product

Appendix 7: Research integrity form

Name: Sebastian van Kessel	Student number: s1086934
RU e-mail address: sebastian.vankessel@ru.nl	Master specialisation: Strategic Management

Thesis title: Beyond boundaries with supply chain: Effect of outsourcing and collaboration on adoption technologies
Brief description of the study This thesis set to examine which factors influence the adoption of digital process technologies by Dutch manufacturing firms. It does so by drawing upon the make-or-buy decision in terms of outsourcing, and by including the external context, more specially the opportunity of collaboration within the production domain. The relationship between outsourcing production and adoption of digital process technologies in this study is proposed to hinge upon one contextual factor: collaboration in production. Five semi-structured interviews were conducted, and an analysis of 152 Dutch manufacturing firms from 2018 were under investigation to provide answers. The study finds that outsourcing production does not lead to a higher adoption rate of digital process technologies. Other results this study found are that collaboration in the production domain, trigger firms to engage in several collaborative partnerships to gain access to digital process technologies. However, the study found that when collaboration is narrowly defined, the relationship does not receive significant evidence. Finally, collaboration was found to play a moderating role in the relationship between outsourcing production and adoption of digital process technologies. Adding to this, outsourcing production only has a positive effect on this adoption of technologies when firms collaborate beyond mere transactions. In light of the results, this study contributes to theory on collaboration and adoption digital process technologies by concluding that collaboration, in the production domain, provides access to new knowledge, and stimulates firm’s competitive advantage.

It is my responsibility to follow the university's code of academic integrity and any relevant academic or professional guidelines in the conduct of my study. This includes:

- providing original work or proper use of references;
- providing appropriate information to all involved in my study;
- requesting informed consent from participants;
- transparency in the way data is processed and represented;
- ensuring confidentiality in the storage and use of data;

If there is any significant change in the question, design or conduct over the course of the research, I will complete another Research Integrity Form.

Breaches of the code of conduct with respect to academic integrity (as described / referred to in the thesis handbook) should and will be forwarded to the examination board. Acting contrary to the code of conduct can result in declaring the thesis invalid

Student's Signature:____________________________________**Date: 23-06-23**

To be signed by supervisor

I have instructed the student about ethical issues related to their specific study. I hereby declare that I will challenge him / her on ethical aspects through their investigation and to act on any violations that I may encounter.

Supervisor's Signature:____________________________________**Date:**