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# Industry 4.0: New Technologies and Potential for Increased Value Creation

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## Problem definition

Industry 4.0: new technologies and potential for increased value creation.

An explorative study of the potential opportunities presented by industry 4.0 and the factors affecting firms' ability to exploit these opportunities.

- How can some fundamental concepts like eg. innovation and competitiveness be understood in line with industry 4.0?
- Can these technological advances lay a foundation for an improved competitive position?



## Preface

This thesis marks the conclusion of my Master's program in Industrial Economics and Technology Management at the Norwegian University of Science and Technology (NTNU). The work was performed during the spring and summer of 2017, and is within the specialisation of strategy and international business development. More specifically, the field of study in this thesis concerns how the emerging concept of industry 4.0, can be understood through previously well-established concepts. My hope is that this work may contribute to a greater understanding of the challenges and opportunities firms face on the brink of the fourth industrial revolution.

I am grateful for all the help and support I have received during the work on this thesis. First and foremost, I would like to thank my academic supervisor professor Arild Aspelund for his invaluable guidance, constructive feedback and curious enthusiasm along the way.

Second, I am grateful for the help and support I received from Magne Løfaldli and Iren Sæterbø in SIV Industri-Inkubator AS. Their inspirational support and help with the case study was of great importance.

Third, I would especially like to thank all the interviewees in the case companies for their help, positive attitude and taking the time to meet me for interviews.

Last, but not least, I would like to thank all my family and friends for providing invaluable support combined with most welcome distractions. For this I am most grateful.

Oslo, 19.09.17

Erling Laugsand



## Abstract

How to increase value creation from industrial production? This is an enduring question for business leaders, researchers and policymakers alike. This explorative study examines the concept industry 4.0, which opportunities and challenges this concept presents to SMEs and which factors that affect their ability to take advantage of these new opportunities.

First, a theoretical overview of the concepts industry 4.0, innovation, technology, competitiveness and internationalisation is provided. Based on this, a framework for understanding the interlinkages of these concepts is developed. Through a case study of six firms, insight is gathered which are analysed in a discussion based on the framework and theoretical foundation. Finally, some implications for future research, managers and policymakers are presented.

Industry 4.0 presents firms with new opportunities to modernise industrial production and increase value creation. This provided they are capable of exploiting the associated uncertainty, have the capabilities necessary and don't remain too constricted or limited by their existing resource base. While customised products are perceived by the interviewees to hinder automation of production, theory suggests that customisation may in fact be a driving force behind industry 4.0. Furthermore, it may present new opportunities to succeed with combination strategies.

Core rigidities, especially along the values dimension may hamper the ability firms have to innovate and adapt to industry 4.0. It is suggested that the importance of dynamic capabilities, absorptive capacity and exploration is likely to increase in the shift to a new regime for industrial production.

For managers, this study directs attention to some challenges and opportunities that should be addressed facing the fourth industrial revolution. Several propositions are developed that could be basis for future research, and implications that will be important topics for policy development under industry 4.0 are suggested.





## Sammendrag

Hvordan øke verdiskaping fra industriell produksjon? Dette er et varig spørsmål for både bedriftsledere, forskere og politikere. Denne utforskende studien ser nærmere på konseptet industri 4.0, hvilke muligheter og utfordringer dette konseptet stiller små og mellomstore bedrifter overfor og hvilke faktorer som påvirker deres evne til å utnytte disse nye mulighetene.

Først presenteres en teoretisk oversikt over konseptene industri 4.0, innovasjon, teknologi, konkurransevne og internasjonalisering. Basert på denne oversikten blir det utviklet et rammeverk for å forstå hvordan disse konseptene er koblet sammen. Innsikt om disse problemstillingen er samlet gjennom en case studie av seks bedrifter, som deretter er analysert basert på rammeverket og de teoretiske konseptene. Til slutt presenteres noen implikasjoner for fremtidig forskning, bedriftsledere og politikere.

Industri 4.0 gir nye muligheter for bedrifter til å modernisere industriell produksjon og dermed øke verdiskaping. Dette forutsetter at de er i stand til å utnytte den usikkerheten som følger med denne utviklingen, at de innehar de nødvendige ferdighetene og at de ikke blir for begrenset av sin eksisterende ressursbase. Intervjuobjektene anser skreddersøm som et hinder for automatisering, mens teorien tilsier at skreddersøm heller kan være en faktor som driver frem industri 4.0. Det kan også være slik at det gir nye muligheter for å lykkes med kombinasjonsstrategier.

Eksisterende ressurser kan gi opphav til en gjennomgripende rigiditet, som kan være spesielt til hinder for innovasjon og overgang til industri 4.0 langs verdi-dimensjonen. Det blir foreslått at viktigheten av dynamiske kapabiliteter, absorptiv kapasitet og evne til utforskning kan bli viktigere i overgangen til et nytt regime for industriell produksjon.

For bedriftsledere peker denne studien på noen utfordringer og muligheter som de vil møte i den fjerde industrielle revolusjon. Det presenteres flere proposisjoner som kan gi grunnlag for videre forskning, og det pekes på implikasjoner som kan bli viktige tema i utforming av politikk under industri 4.0.



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## 1. Introduction

How to increase value creation from modernised industrial production? This is a key question of interest both for business leaders, workers and politicians at all levels of government. This thesis was initiated in collaboration with a local initiative to increase industrial value creation in a regional business network located in Nordmøre, Norway. At the heart of this local initiative lies the question: With an overarching goal of regional development, how can efforts be made to increase the number of jobs and value creation from modernised industrial production (Løfaldli, 2017a, 2017b)? This question provides the fundamental backdrop for this study.

Globalisation, economic liberalisation and increased world trade has presented producers of goods in high-cost countries with increasingly fierce competition (Cavusgil, Knight, Riesenberger, Rammal, & Freeman, 2012; van Liemt, 1992). Production in many high cost countries has been challenged by products from low cost countries all over the world (Bang & Markeset, 2012; Krugman, Cooper, & Srinivasan, 1995). After a period of time where the trend has been towards offshoring and outsourcing of production, technological developments in automation and robotisation might present new opportunities for industrial production also in high cost countries like Norway. Recent coverage in both technical publications and news media suggest that this is a field of great current interest (Bakken, 2017; Seglsten, 2017).

Automation of industrial processes is not a new phenomenon. Today, substantial attention is devoted to what many are speaking of as the fourth industrial revolution, industry 4.0. Industry 4.0 is characterised by advances in automation technology, use of robots, IT and censoring technology, to name but a few (Kang et al., 2016; Wang, Wan, Li, & Zhang, 2016).

Technological developments change Norwegian industry as we know it. Several initiatives have been put forward to address the challenges and opportunities this presents to Norwegian businesses, including the first white paper to the parliament on industrial production since 1981. "New materials are being utilized, processes are adapted, automated and digitalised. Partially it is about more efficient, more precise and more automated production, partially about new products, new value chains and new business models." (*Meld.*

*St. 27 (2016 – 2017) Industrien – grønnere, smartere og mer nyskapende, 2017)*. Thus, understanding technology and developing technological capabilities are important, and increasingly so, with regard to firm performance and competitiveness (Afuah, 2002; Kogut & Zander, 1993).

Innovation has been found to be key for economic growth, both for countries and firms (Lucas, 1988; Sood & Tellis, 2005). Considering the many emerging technologies related to industry 4.0 and the increasing competitive pressure by globalisation, there is reason to believe that innovative capabilities will only become more important in the time to come.

The research objective of this thesis will be to understand more about how firms, and more specifically the firms in this study, can take advantage of these new technologies. Which opportunities does this present for firms? Could these technological advancements lay a foundation for an improved competitive position? Furthermore, which factors and characteristics affect how the firms can utilise these new technologies? To guide the research going forward, the following research questions are presented:

*RQ1) How does the firms in question currently work with product and process innovation?*

*RQ2) How can small and medium-sized firms increase competitiveness by adapting to the anticipated changes and associated opportunities presented by industry 4.0?*

*RQ3) What are the factors that facilitates and mitigates the firms' ability to take advantage of these new opportunities?*

This thesis will start by presenting theory on industry 4.0, along with established theory on competitiveness, innovation, technology and internationalisation. Different connections between these concepts will be explored to develop a framework to analyse how firms can assess their current situation and plan for future growth. In a case study, data from the industry is gathered, which are then analysed in accordance with the theory and the research questions. Finally, the thesis presents implications and paths for future research, before the conclusion and limitations are presented at the end.

## 2. Theoretical background

In order to address the research questions and gain a deeper understanding from the case study, it is necessary to establish a theoretical background for the research. Many different subjects are relevant to the research questions. In the theoretical background these subjects will be introduced and explained. They will serve as building blocks for the subsequent analysis of the case study findings. Building on this insight a framework will be established to understand more about the linkages between these subjects, how they are intertwined and how they come into play with regard to the case companies.

On a more aggregated level, the theoretical foundation of this thesis will build on five main concepts; industry 4.0, competitiveness, innovation, technology, and internationalisation. Industry 4.0 will serve as the starting point, and the other four concepts originate from this starting point. This emerging concept is considered a fundamental trend that captures and represents a range of the opportunities and challenges that firms will face in the years to come. Industry 4.0 is presented as a new regime of industrial production. In order to transition from an old to a new regime, a high level of product and process innovation will be necessary. While industry 4.0 has innovation as a driving force and requirement for firm survival, firms may also find that it facilitates their innovation processes.

Fundamentally this fourth industrial revolution is made possible by a number of new and emerging technologies. Therefore, it was deemed natural to expand upon the theoretical background of technology. As the emergence of industry 4.0 poses a range of strategic questions, core concepts related to competitiveness will be presented. The idea was that for business activities and job creation to be sustainable, they would need to be based on competitive production and product offering. In order to grow, the firms need to expand their markets somehow. One possibility for this is by expanding internationally, and thus, internationalisation serves as the last concept to be studied. While several other concepts could be of interest to study based on the starting point of industry 4.0, the research was confined to these five main concepts to reduce the scope of the study in line with the available time and resources. The link between each topic and industry 4.0 is summarised at the end of the presentation of theory for each topic.

## 2.1. Industry 4.0

The term industry 4.0 was originally introduced as a strategic initiative in Germany in 2011, to cover and advance the many developments happening within manufacturing industries based on new information and communication technologies (ICT). It seeks to integrate emerging technologies like e.g. smart sensors, additive manufacturing (3D-printing), artificial intelligence and big data analytics to name but a few. More generally it concerns the integration of cyber-physical systems (CPS) into industrial processes (Drath & Horch, 2014; Kang et al., 2016). This paper will not delve further into the facilitating technologies, but refer to Kang et al. (2016) for a more detailed presentation of these technologies.

Industry 4.0 as a concept bears resemblance to American initiatives regarding Industrial Internet and Smart Manufacturing, where industry 4.0 can be understood as the full realization of smart manufacturing (Drath & Horch, 2014; Kang et al., 2016). The National Institute of Standards and Technology, part of the US Department of Commerce, defines Smart Manufacturing as “fully-integrated and collaborative manufacturing systems that respond in real time to meet the changing demands and conditions in the factory, supply network, and customer needs” (Kang et al., 2016, p. 1).

Wang et al. (2016, p. 2) state that the core idea of industry 4.0 is to “use the emerging information technologies to implement IoT and services so that business process and engineering process are deeply integrated making production operate in a flexible, efficient and green way with constantly high quality and low cost.” Further, they stress that there are three key features that should be considered when implementing industry 4.0.

- First, one should aim for horizontal integration between different firms participating in the same value networks.
- Second, vertical integration within the factory is a key element, linking together the different machines and units of the production process.
- Third, one should consider end-to-end engineering integration, thus linking the different stages in the value creation process, from product design through production and to service.



This shows that full implementation of industry 4.0 principles will need to be an all-encompassing strategy for the firm. Furthermore, these definitions imply that one needs to employ a holistic view of the value network, extending beyond the individual firms. The main emphasis in this paper will however be placed on the individual firms, in order to limit the scope of the thesis.

From these two definitions, it is apparent that smart manufacturing and industry 4.0 are facilitated by new technologies, integration is a key part of the concept, and it provides new opportunities for flexible and efficient production. Still, it is also evident that different definitions may encompass differing elements. For instance, some researchers consider industry 4.0 as integrated with different theories on green and sustainable production, while others don't include this as an integral part of the concept. In this paper, the implications for sustainability will not be emphasised. Differing views also emerge considering to which extent emphasis is put on the physical manifestation of automated production processes, or the virtual world with big data and cloud computing (Drath & Horch, 2014; Monostori, 2014; Schmidt et al., 2015).

Automation of industrial processes is a key part of the industry 4.0 concept. According to Strandhagen, Alfnes, Strandhagen, and Swahn (2016, p. 242), manufacturing equipment under the industry 4.0 paradigm, will be characterized "by the application of highly automated machine tools and robots".

Schmidt et al. (2015) did a quantitative study of firms in Germany, Switzerland and Austria. They found that even though the level of automation has a positive effect on the potential use of industry 4.0, this effect is not significant. They did however find support for claims in literature that mass customisation is a strong driver for industry 4.0. This is in line with the findings of Monostori (2014, p. 9) that "industrial production of the future will be characterized by the strong individualisation of products under the conditions of highly flexible (large series) production,...".

The denotation Industry 4.0 reflects that manufacturing industries are on the brink of a fourth industrial revolution. It will bring change to supply chains, product design, manufacturing processes, and business models. Thus, industry 4.0 may be considered as the emergence of a new paradigm. Schmidt et al. (2015, p. 17) emphasise that this presents business organisations with a dilemma; “Neither to wait too long with their industry 4.0 implementation nor to start too early and commit fatal errors”. According to Pfeffer (1982) as cited in Leonard-Barton (1992), evolutionary change or adaption is made nearly impossible by the internal consistency which constitutes a paradigm.

Hence, it is apparent that the emergence of industry 4.0 poses firms with a range of questions regarding innovation, technology and strategy. These concepts will therefore be elaborated upon in the following sections.

## 2.2. Competitive advantage and strategy

One of the key elements of strategy is the subject of how firms gain and sustain competitive advantage. Internationalisation of markets and economic activities increases the competition (Álvarez, Marin, & Fonfría, 2009). Furthermore, global competition along with technological advances and changing needs of consumers, drives firms to compete along different dimensions simultaneously, e.g. product design, manufacturing and marketing (Singh, Garg, & Deshmukh, 2008). This makes the issue of competitive advantage increasingly important. Two of the most influential theories concerning competitive advantage are the resource-based view (RBV) and the industry structure view (De Wit & Meyer, 2010).

### 2.2.1. Industry structure view

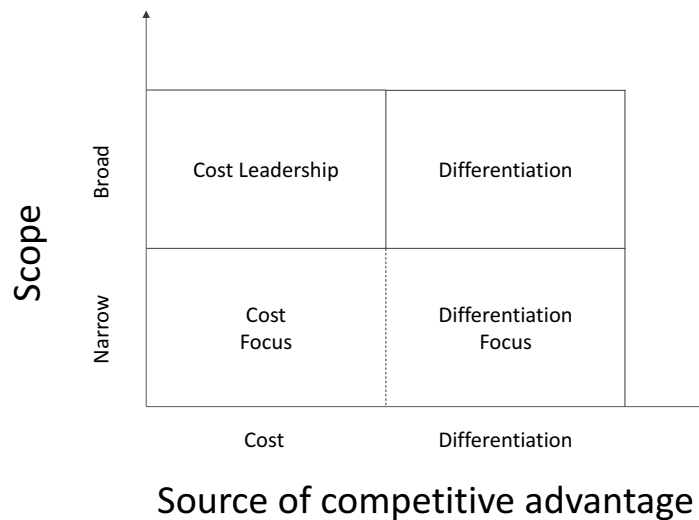
In the industry structure view of competitive advantage, the two fundamental questions are the attractiveness of the industry and the relative competitive position of a firm within the industry (Porter, 1985). Profitability is determined by how much of the value created that can be captured by the firm. Under the industry structure view, the determinants of performance are found to be external to the firm, in the industry structure. Thus, the industry structure view advocates an outside-in perspective on business strategy.

According to Porter (1985), firms can possess one of two basic types of competitive advantage 1) low cost, or 2) differentiation. These in turn leads to three possible generic strategies, depending on whether they make a strategic decision to compete in broad markets or focus on specific market segments (Dess & Davis, 1984; Porter, 1985). Thus, the three possible generic strategies are: 1) cost leadership strategy, 2) differentiation strategy or 3) focus strategy. He claims that firms will only be successful if they choose and commit to one of these strategies, while a combination of these strategies will prove unsuccessful.

In contrast with Porter's view stands the school of thought that believes firms can achieve success through a combination of these strategies, namely a combination of low-cost and differentiation strategies (Wright, Kroll, Kedia, & Pringle, 1990). High-quality products lead to high demand for the products produced under the differentiation strategy. This in turn leads to a high production volume, which allows for economies of scale and scope, and thereby to lower costs. Thus, the result is a combination of the two generic strategies (Yamin, Gunasekaran, & Mavondo, 1999).

Several studies including Miller and Friesen (1986), Wright et al. (1990), and Miller (1992), all find that firms who pursue such combination strategies, outperforms those who follow Porter's advice and pursue a "pure" generic strategy. In a study of firm performance in small- and medium-sized enterprises (SMEs) in Austria, Leitner and Guldenberg (2010, p. 169) found that "a combination strategy is a viable strategic choice for SMEs in the long run".

Generally, a firm's competitive position can therefore be determined according to two dimensions where the choice between cost leadership versus differentiation constitutes one axis, while the choice between a focused or broad scope regarding market segments constitutes the other, as illustrated in Figure 1.



*Figure 1 Source of competitive advantage – competitive positioning*

### 2.2.2. The resource-based view

In the resource-based view (RBV), firms are considered as collections of resources and capabilities. The source of a firm’s sustained competitive advantage can be found in its resource base (Amit & Schoemaker, 1993; J. B. Barney, 1986; Dierickx & Cool, 1989; Wernerfelt, 1984). Thus, the RBV takes an inside-out perspective on the determinants of competitiveness. J. Barney (1991, p. 102) defines that a firm has a competitive advantage when “it is implementing a value creating strategy not simultaneously being implemented by any current or potential competitors”. Furthermore, he presents four key attributes that he deems necessary for a resource to be able to provide a sustained competitive advantage. The resources must be valuable, rare, imperfectly imitable and nonsubstitutable (VRIN). In addition, an organisation must be in place to absorb, organise and apply these resources.

Resources may be classified as either tangible or intangible (Collis, 1994; Galbreath, 2005; Grant, 1991). According to Itami and Roehl (1987), intangible resources are most likely to fulfil the four requirements posed by Barney. They are therefore of key importance to firms when it comes to competitive advantage (Galbreath, 2005). Technology, or rather technological knowledge, is by some considered as a knowledge-intensive intangible resource, which sometimes manifests in a tangible product or production process (Kogut & Zander, 1993;

López Rodríguez & García Rodríguez, 2005). Depending on the degree of tacitness of this technological knowledge, it will to a varying degree fulfil the requirements posed by Barney. Thus, under the resource-based view, technology may be a well-suited source of competitive advantage.

Over the years, a range of critiques has been launched at the resource-based view. One critique is that it only applies to firms in stable environments. Another critique argues that the RBV provides little insight to firms that are satisfied with their competitive position, because it only applies to firms that are striving to achieve sustainable competitive advantage. Therefore, “its relevance follows directly from managers’ aspirations and intentions” (Kraaijenbrink, Spender, & Groen, 2009, p. 353). Furthermore, Kraaijenbrink et al. (2009) argues that the most substantial of these critiques relate to the indeterminate nature of the concepts value and resource, along with an insufficient conceptualisation of competitive advantage.

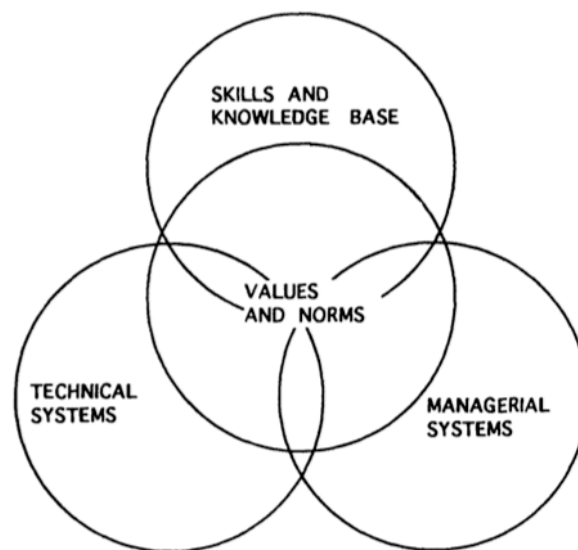
With regard to the conceptualisation of competitive advantage, one element of the critique is that the RBV overemphasises the individual resources, and fails to adequately recognise the importance of the synergistic combination of resources. Another element is that “the RBV does not fully recognise the role of the individual judgments or mental models of entrepreneurs and managers” (Kraaijenbrink et al., 2009, p. 356). While the RBV sought to critique the emphasis on external forces which predominates in the industry structure view, it may fail to explain firm performance precisely due to a lack of consideration of the context in which firms operate.

The assumptions underlying the concept of value, may prove another challenge to the RBV. While the value of an individual resource may appear at the moment of selection, the full impact this resource will have on value creation will be determined by the firm’s capacity to develop and synergistically utilise the resource in question, that is, a firm’s capabilities. Thus, the value which can be ascribed to capabilities will only appear after resource deployment (Kraaijenbrink et al., 2009). Furthermore, in dynamic or unpredictable environments, the assumption that a resource is valuable may not hold. Rather, in such environments the source

of value creation may lay “within the imaginative and creative capabilities of the people involved in it” (Kraaijenbrink et al., 2009, p. 364).

The RBV has been criticised for applying an overly simplistic definition of resources, not sufficiently distinguishing between resources and capabilities (Kraaijenbrink et al., 2009). In an attempt to address this critique, several extensions of the theory have been advanced which emphasises the distinction between resources and capabilities. Thus, this critique also seeks to address the notion that the RBV only applies to stable environments. It is suggested that resources must be converted to capabilities in order to provide a competitive advantage (Day, 1994; Teece, Pisano, & Shuen, 1997). Resources may be defined as “stocks of available factors that are owned or controlled by the organization”, while “capabilities are an organisation’s capacity to deploy resources” (Amit & Schoemaker, 1993, p. 35).

Core capabilities have been defined as “a set of differentiated skills, complementary assets, and routines that provide the basis for a firm’s competitive capacities and sustainable advantage in a particular business” (Teece, Pisano, & Shuen, 1990, p. 28). Applying a knowledge-based view, Leonard-Barton (1992) presents four dimensions to the knowledge set that constitutes core capabilities, illustrated in Figure 2.



*Figure 2 The four dimensions of a core capability. From Leonard-Barton (1992), s. 114*

Leonard-Barton (1992) argues that given the institutionalised character of core capabilities, they may present product and process development projects with a paradox. While fundamental for development, they may at the same time inhibit development. That is, they may become core rigidities; “inappropriate sets of knowledge” (Leonard-Barton, 1992, p. 118). Itami and Roehl (1987, p. 54) argues that new core resources should be developed “when the current core is working well.”

The dynamic capabilities perspective emphasises the evolving nature of capabilities in response to rapidly changing environments, so called dynamic markets (Eisenhardt & Martin, 2000; Helfat & Peteraf, 2003). Dynamic capabilities may be defined as “the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments” (Teece et al., 1997, p. 516).

#### 2.2.3. Competitiveness and industry 4.0

Preliminary theory suggests that industry 4.0 is a way to combine low production cost with a relatively high degree of product differentiation, by the employment of highly automated production processes. This contradicts Porter’s industry structure view, but is in accordance with other theorists that find that a combination strategy may be a viable alternative, also for SMEs.

The resource-based view emphasises resources, and several extensions of the theory further stress the importance of core and dynamic capabilities, as well as difficulties related to core rigidities. These concepts may contribute to explain both why firms experience difficulties in adapting to this revolution of industrial production, as well as the capabilities needed for such successful adaptation to take place. Innovation capabilities are closely connected to knowledge and technology, and are found to be important competitive factors.

### 2.3. Innovation

Innovation can be described as “the first commercial application of a new product or process” (Clark & Guy, 1998, p. 366). Hence, from this definition it is clear that innovation must be considered both with regard to the product itself and the production process, and these can

be innovated upon independently of each other. Innovation is found to be a driver of economic growth, both for firms and nations (Lucas, 1988; Sood & Tellis, 2005). Hitt, Ireland, Camp, and Sexton (2001, p. 480) defines entrepreneurship as “the identification and exploitation of previously unexploited opportunities”. Many scholars, like Drucker (1985) and Lumpkin and Dess (1996) as cited in Hitt et al. (2001), find that innovation is among the most important components of entrepreneurship. Therefore, while the emphasis in this paper will be on innovation, it will also draw on insight from the field of entrepreneurship.

Basile (2001) found that innovation capabilities are very important competitive factors. Support was found for the claim that higher process innovations were positively related to reduced production cost. Thus, process innovations contributed to improving the firm’s competitiveness abroad. “The export intensity of non-innovating firms is smaller than that of innovating firms” (Basile, 2001, p. 1199).

Hitt et al. (2001) argues that uncertainty may present opportunities if an entrepreneurial mindset is employed. Uncertainty about the value of an innovation may cause it to diffuse slowly. Because it makes the innovations diffuse so slowly, this uncertainty makes it possible for early adopters to gain competitive advantage even from innovations that are available for purchase (Greve, 2009). Carayannis and Samanta Roy (2000) found that firms are sensitive to the dynamics of technological innovation, and that small firms are more sensitive to market and technology influences than large firms.

Innovations are often categorised on a spectrum ranging from incremental to radical. Focusing on product development, Henderson and Clark (1990) developed a conceptual framework extending the custom of categorising innovations as incremental or radical. They introduce the terms modular and architectural innovations as intermediate stages between the two extremes, architectural innovations being more radical than the modular innovations. Sinha and Noble (2008) find that the likelihood of firm survival is positively affected if the firm innovate by early adoption of radical manufacturing technology and bundles of adopted radical manufacturing technology.



Some theorists, including Henderson and Clark (1990), find that incumbent firms are more likely to advance incremental innovations, while new firms are more likely to advance radical innovations. This can be understood in line with the findings that learning traps or core rigidities may inhibit the capability of incumbents to develop breakthrough inventions (Hitt et al., 2001; Leonard-Barton, 1992). However, Christensen and Rosenbloom (1995) find that incumbents will take all kinds of innovations, from incremental to radical to the marketplace, as long as they remain within the same value network. In other words, if these are so called sustaining innovations rather than disruptive innovations.

Schmidt et al. (2015) find that not only are new technologies a driver of industry 4.0, but the industry 4.0 technologies are also the basis of new business models. In this context, they argue that industry 4.0 is a disruptive innovation. “That means Industry 4.0 and its disruptive technologies have an above average growth rate and are able to replace conventional technologies shortly” (Schmidt et al., 2015, p. 23). Thus, there seems to be a question about whether or not incumbent firms will be able to adopt industry 4.0, depending on whether it represents sustaining or disruptive innovations.

As illustrated in Figure 2, the value dimension permeates the other core capabilities, and Leonard-Barton (1992) found that core rigidities along the value dimension were especially hampering for innovation. Foss, Klein, Kor, and Mahoney (2008), drawing on Penrose (1959) and subjectivism, emphasise the importance of entrepreneurial intuition and imagination. “Due, at least in part, to uncertainty and to the heterogeneity of these mental models, strategic factor markets may fail to price new resources accurately and may fail to anticipate the innovative ways firms accumulate and leverage their resources” (Foss et al., 2008, p. 80). Thus, innovation may be hampered by homogeneity of mental models.

According to Narula (2004), size and resource constraints limit the number of areas in which SMEs can keep high internal competence. This leads them to use R&D collaboration to a greater extent than larger firms. Furthermore, if firms are to outsource applied research and product development, they prefer to outsource it to public research institutes and universities. This due to fear of giving away knowledge to competitors.

Experimental knowledge is important in developing a firm's capabilities (Foss et al., 2008). Innovative development projects may serve as a source of such experimental knowledge by "highlighting core rigidities and introducing new capabilities" (Leonard-Barton, 1992, p. 122). Bigger changes may then eventually build on these smaller departures from tradition. The need for experimental knowledge accentuates the challenge of time as a scarce resource because it takes time to experiment and gradually build such knowledge (Foss et al., 2008).

#### 2.3.1. Innovation and industry 4.0

Given that industry 4.0 is a "revolution" and a new regime, it will require firms to perform a substantial degree of innovation, both with regard to products and processes. As already mentioned, innovation is closely connected to competitiveness and technology. Innovation has also been found to influence positively on a firm's export performance.

Theorists have reached different findings when it comes to how incumbents vs new entrants are able to advance incremental or radical innovations. Industry 4.0 has by some been categorised as a disruptive innovation, which might present additional challenges for incumbent firms. Innovation may also influence the extent to which adopted technology associated with industry 4.0, fulfils the requirements under the RBV. Mental models may inhibit the ability for innovation which is needed in the transformation to a new regime.

#### 2.4. Technology

Technology can be defined in a number of different ways. This paper will employ the definition by Rosenberg (1972) that technology are "those tools, devices, and knowledge that mediate between inputs and outputs (process technology) and/or that create new products or services (product technology)". Another definition is that technology can be defined as "a systematic body of knowledge about how natural and artificial things function and interact" (Itami & Numagami, 1992, p. 119). From these definitions it is clear that knowledge is a fundamental part of technology.

Leonard-Barton (1992, p. 118) finds that companies typically "displays a cultural bias towards the technical base in which the corporation has its historical roots". Furthermore, the tangible

elements of the technical systems dimension of core competences may embody a core rigidity, because these elements can easily become outdated. However, she argues that “the technical systems dimension is relatively easy to alter for many reasons, among them the probability that such systems are local to particular departments” (Leonard-Barton, 1992, p. 121).

Technology is found by several researchers to have a positive impact on competitive advantage and firm performance (Afuah, 2002; Davies & Ko, 2006). According to Afuah (2002), technological capabilities are drivers for differentiation or cost advantage. Kogut and Zander (1993), finds that technology is an important source of competitive advantage also for SMEs. Kirzner (1966) as cited by Foss et al. (2008), argues that the significance of capital assets like technology, are not determined by objective characteristics, but rather subjectively by entrepreneurs.

However, it should be noted that while technology is found to have a positive impact on performance, emerging research finds that “improvements in technology are far from being a sufficient condition for productivity growth”, Rosenberg (1995) as cited in Clark and Guy (1998, p. 379). Hamel and Prahalad (1994) argue that coordination of diverse production skills and integration of multiple streams of technologies are so important that it must be regarded among an organisation’s core competencies.

One way to categorise technology is to make a distinction between high- and low-technology industries. High-technology can be understood as use of state-of-the-art technology in manufacturing and/or the product itself (Wong, 1990). Boter and Holmquist (1996, p. 471) defines low-technology as “an established technology that can be purchased through well-known market channels”. As time goes by, high-technology which starts out as state-of-the-art, progresses over to the low-tech category.

Disruptive technologies embody the potential to upset an industry’s value chain, and therefore, existing competencies can be enhanced or destroyed by such technological discontinuities (Albrinck, Hornery, Kletter, & Neilson, 2001; Tushman & Anderson, 1986). Thus, firms are forced to quickly learn “either how to create more of the value using traditional

practices or more likely how to create value in ways different from historically practices” (Hitt et al., 2001, p. 481). Such learning may be hampered by learning traps or core rigidities imposed by the existing technological systems. Ahuja and Lampert (2001) find that one way to overcome these learning traps is to experiment with novel and emerging technologies. However, they suggest that such technological experimentation requires slack resources.

#### 2.4.1. Absorptive capacity

Technology may be developed internally or acquired from external sources. The concepts of absorptive capacity (ACAP) and technological capabilities concern how a firm might acquire and use technological knowledge. Cohen and Levinthal (1990, p. 128) state that absorptive capacity is critical for firms’ innovative capabilities, and defines absorptive capacity as “the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends”. They argue that the absorptive capacity of a firm is largely a function of its prior knowledge. Differential absorptive capacity may be a source of firm heterogeneity because managers’ mental models “gives rise to a subjective productive opportunity set for the firm” (Foss et al., 2008, p. 80).

Zahra and George (2002) reconceptualise absorptive capacity and argues that it should be viewed as two distinct components, potential ACAP and realized ACAP. Potential ACAP reflects a firm’s capacity to assess, acquire and assimilate knowledge. It does not however capture the capability a firm has to transform and exploit this new knowledge for profit generation, which is part of realized ACAP. “Realized ACAP reflects the firm’s capacity to leverage the knowledge that has been absorbed” Zahra and George (2002, p. 190). Thus, high potential ACAP is necessary, but not sufficient to leverage new knowledge into a sustainable competitive advantage.

##### 2.4.1.1. *Exploration and exploitation*

One may characterise a firm’s use of new technological knowledge in two ways, as either exploitation or exploration. This is the second step of the concept of absorptive capacity (Zahra & George, 2002). While several definitions of exploration and exploitation exist, this paper will employ the definition by March (1991, p. 85) that exploitation is “the refinement and extension of existing competencies, technologies, and paradigms exhibiting returns that

are positive, proximate, and predictable”. Exploration on the other hand can be defined as experimentation with new alternatives having returns that are “uncertain, distant, and often negative”.

Yalcinkaya, Calantone, and Griffith (2007) find that exploration has a positive effect on product innovation and market performance, while exploitation has a negative effect on product innovation and market performance. These findings are in line with findings of Lisboa, Skarmas, and Lages (2011), that only exploration has a positive effect on product differentiation and market effectiveness. Furthermore, García-Muiña and Navas-López (2007) find that in dynamic environments, a high level of exploration capabilities positively affects product differentiation and market effectiveness.

#### 2.4.2. Technology and industry 4.0

Technological developments may well be considered the most fundamental driving force behind industry 4.0. One could argue that technology is so inherent in industry 4.0 that it should not be considered as a separate concept. However, this study chose to consider industry 4.0 as a concept on a more aggregated level, and will therefore present technology only as one of the contributing underlying concepts. There are a number of new technologies emerging which presents firms with new opportunities for modernised industrial production.

Absorptive capacity, both potential and realised, is important to understand more about how firms assess and acquire new technology. The concepts of exploitation and exploration are related to how firms use new technology, and these concepts are further connected to innovation and market performance. While technological capabilities are crucial for adoption of industry 4.0, core rigidities may also originate from the tangible elements of the technical systems.

#### 2.5. Internationalisation

Internationalisation and globalisation of markets and economic activities has been a strong trend for the last decades, and it has important implications for strategies and operations of most firms (Bang & Markeset, 2012; Cavusgil et al., 2012). The process of globalisation may

be understood as an ongoing and even accelerating integration of the global economy, which is characterised by increased interdependency and integration (Bang & Markeset, 2012).

One contributing condition has been the increasing specialisation which leads to more firms producing niche products. These must often be aimed at the international market given too small of a domestic demand. Another factor has been global sourcing which facilitates rapid diffusion of innovative products (Knight & Cavusgil, 2005; Madsen & Servais, 1997).

Bang and Markeset (2012) argue that the trend of globalisation may be divided into five drivers and three effects. The drivers are reduced trade barriers, lower costs of transportation, lower cost of communication, development of information and communication technology (ICT), and spread of technology.

The associated effects are size effects, pressure effects and location effects. Size effects concern the size of the market potential. Markets are in many cases linked together, which makes them significantly larger, and thus they have become global rather than local (Bang & Markeset, 2012). The integration of markets leads to intensified competitive pressure caused by a higher number of competitors (van Liemt, 1992). Among other factors, this leads to higher pressure on cost and price, pressure towards specialisation and a more rapidly changing competitive environment (Bang & Markeset, 2012; Burda & Dluhosch, 2002). Last, location effects stem from the fragmentation of the production process. This partition of the value chain means that the different stages of the production process may be located in different places, including across country borders. Thus, location effects are related to international sourcing and increased trade across borders (Krugman et al., 1995; Mudambi & Venzin, 2010).

According to Flor and Oltra (2005), who studied supplier dominated industries, export performance is positively influenced by a firm's technological innovation capabilities. Specifically, internal non-R&D innovation activities like industrial design and production engineering contributes to better international performance, together with marketing of new or improved products. Investment in non-distinctive resources on the other hand, like "machinery acquisition, however, does not contribute to guaranteeing better export performance" (Flor & Oltra, 2005, p. 344).

Firms that innovate are more active in international markets, and high technological capacity was found by López Rodríguez and García Rodríguez (2005) to positively influence both the decision to export and export intensity. Lu and Beamish (2001) as cited in Hitt et al. (2001) find that the way in which firms internationalise is important. While direct investments in new international markets has a positive effect, export was found to have a negative moderating effect on return.

#### 2.5.1. Internationalisation and industry 4.0

Internationalisation of markets and economic activities is one of the fundamental trends during the last decades. It is suggested that internationalisation leads to size effects, pressure effects and location effects. Competitiveness is a prerequisite for internationalisation. Adaption to industry 4.0 may turn out to be necessary to remain competitive going forward, especially due to the pressure effects caused by internationalisation. Technological innovation capabilities and high technological capacity have a positive effect on internationalisation, while no such positive effect is found from non-distinctive resources like machinery acquisition. This implies that the capabilities needed for adapting to industry 4.0, may simultaneously lead to increased internationalisation.

## 2.6. Theoretical framework

Industry 4.0 is presented as the fourth industrial revolution, thus resulting in the establishment of a new regime for industrial production. If one accepts this as a premise going forward, firms will need to take this into account in their future strategies. Firms that wish to survive and prosper under an industry 4.0 regime, will need to assess their current state of affairs, and implement new and integrated strategies which support successful operation under industry 4.0.

In the theoretical background, established theory on innovation, technology, competitiveness and internationalisation was presented. By building on these well-established concepts, a new framework for understanding industrial production under industry 4.0 will be presented. This may facilitate a deeper understanding of both the driving and inhibiting forces, and the resulting outcomes of this fourth industrial revolution.

### 2.6.1. Theoretical model for understanding industry 4.0

The fundamental idea which will guide the research is to study the interdisciplinary links of well-known concepts under industry 4.0. If industry 4.0 represents a fourth revolution of industrial production, it must be considered on a higher level than just adoption of new technologies. Hence, for the purpose of analysis, the framework is put forward that industry 4.0 can be illustrated as the linking of these five key elements; industry 4.0, innovation, technology, competitiveness and internationalisation. It should be noted that this is not an attempt to provide an exhaustive explanation of industry 4.0, merely a framework to facilitate the analysis in this thesis. The interaction and interlinkages of these different factors are presented in Figure 3.



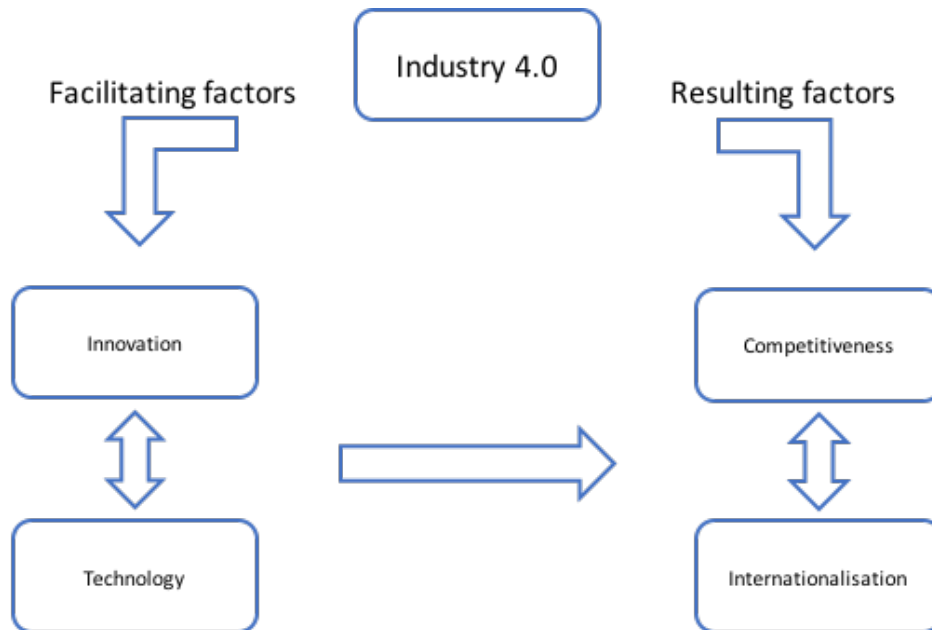


Figure 3 Theoretical framework for industry 4.0

- In this framework, innovation and technology will be denoted as facilitating factors under the industry 4.0 regime. This is because they are considered as necessary conditions or contributing factors for successful adaption to industry 4.0.
- In this framework, competitiveness and internationalisation will be denoted as resulting factors under the industry 4.0 regime. This is because they are considered as outcomes that arises from successful adaption of industry 4.0.

### 3. Methodology

In order to properly address the research questions of this thesis, careful consideration must be put into the choice and design of research method. This chapter will provide a thorough description of the methodology used to answer the research questions of this study, thereby ensuring replicability and reliability. First, the rationale for choice of research method will be presented, followed by a description of the design and plan for retrieving the data, and finally a description of the data gathering.

#### 3.1. Rationale for research method

Due to the explorative nature of the research questions of this thesis, a qualitative research method stands out as the most appropriate one. Generally, quantitative research methods entails a deductive approach to the link between theory and research, while qualitative research methods are better suited for an inductive approach where theories may be generated based on the data (Bryman & Bell, 2007).

More specifically, the case study method seems to be the one best suited to address the issues at hand. The case study method is especially well suited under a certain set of conditions. These conditions are; when dealing with contemporary phenomena, when the events studied cannot be controlled by the researcher, and when the questions posed are of an exploratory or descriptive nature (Yin, 2014). As can be seen, these conditions are all fulfilled in this study.

#### 3.2. Research design

According to Yin (2014), the research design consists of five distinct elements. The first two of these, *questions* and *propositions*, have already been addressed in the chapter theoretical background. Mark that this study is of a more exploratory nature and therefore will be based on research questions rather than propositions. In this section, the reasoning behind the choice of unit of analysis, as well as the choice of the specific cases will be made clear. Furthermore, this section will point towards how the data will be linked to the research questions.

### 3.2.1. Choice of unit of analysis

In approaching the study of the business network on Nordmøre, several different units of analysis could be of interest. First, it should be noted that locally the businesses are organised in several different networks based on business sector. This thesis will treat these businesses as one broader network due to their cooperation with the incubator SIV Industri-Inkubator AS. This incubator acts as the first point of contact and facilitates both the networks and the businesses in the networks. SIV Industri-Inkubator could in itself be an interesting unit of analysis. Although interesting, this lies outside the scope of this thesis. Second, the different networks could all be interesting units of analysis. The reasoning behind why these were not chosen as unit of analysis, is an impression that these networks are not close enough to be representative of distinctive characteristics for the firms within the networks. Third, the individual businesses within the networks constitute a possible unit of analysis, and in accordance with the research questions in the introduction, this is the one that will be employed in this study.

Several contextual actors are expected to be of relevance to the focal actors with regard to the research questions. Among others, these include educational institutions, research institutions, municipal functions and governmental bodies. Although they are not considered unit of analyses, they will be commented upon where relevant to answer the research questions. With several different business organisations as unit of analysis, this can further be considered as what Yin (2014) denotes as a holistic multiple-case design. Bryman and Bell (2007) also uses the term comparative design to denote multiple-case studies, because they are often associated with comparison and contrasting of the different cases to advance understanding of the phenomena being studied. It should be noted that critique has been presented against the multiple-case method, arguing that it presents a risk for overemphasising contrasts between the cases, while not paying enough attention to the context-specific factors (Bryman & Bell, 2007).

The choice of using the different business organisations as units of analysis allows for a multiple-case design. This is in line with advice from Yin (2014) who suggests that multiple-case designs should be preferred over single-case designs when possible. Bryman and Bell (2007) argues that use of a multiple-case design improves theory building.

Further, this allows for the possibility of following a replication design. Replication design is based on the logic that the different cases should predict either similar results and thus a literal replication, or predict contrasting results and thereby a theoretical replication (Yin, 2014, p. 57).

In this study there are no obvious reasons to expect directly contrasting results, and therefore a theoretical replication is not predicted. On the contrary, given that all the cases have in common that they are small- and medium-sized manufacturing firms located in the same region, a degree of literal replication will be expected.

### 3.2.2. Choice of case firms

From the outset, this thesis has been positioned by the cooperation with SIV Industri-Inkubator. Thereby, the firms relevant for studying has been limited to the firms within the networks which cooperate with the incubator. In dialogue with the staff at the incubator and the academic supervisor for this thesis, it was decided to go further with a total of six cases across the study, with two interviewees from each firm.

From each firm, two employees with knowledge of the production and product development process were interviewed. Deciding on which firms to interview was done in cooperation with two of the employees working in SIV Industri-Inkubator, who have extensive knowledge of the firms in the network. The individual informants were selected in cooperation with top level management in each firm. Main criteria for inclusion in the study was the firms' interest in participating in the study, and their willingness and ability to find employees who could be interviewed in the prospective time frame of the study. Since this selection depends on the willingness of firms to participate and self-selection within the firms, it should be noted this method lends itself to some self-selection bias.

This one-phase approach to screening of candidate cases resulted in the case study objects presented in Figure 4.

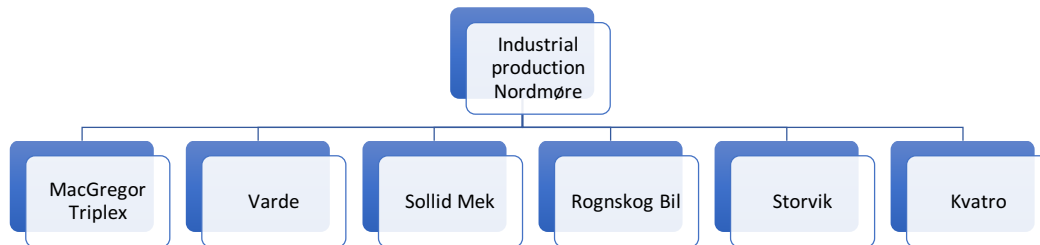


Figure 4 Units of analysis - case firms

### 3.3. Qualifications and preparations

The data collection phase of a case study is characterised by the fact that “data collection procedures are *not* routinized” (Yin, 2014, p. 72). This makes the case study data collection demanding to the researcher. According to Yin (2014), there are five attributes that characterise a good case study researcher. These are the ability to ask good questions, to be a good listener, stay adaptive, have a good grasp of the issues being studied and avoiding biases. These attributes served as guidelines during the interview process.

Although rather inexperienced, the researcher has performed one previous case study. That study was part of a research project at NTNU, studying step-change innovations in industrial manufacturing. It included interviews of management and production workers at a manufacturing plant in the same region as this project.

In preparation for the interviews, an interview guide was developed under guidance of the academic supervisor. This contributed a structure to the interviews and was an effort to ensure that the questioning revolved around the given subject. The interviews still allowed for follow-up questions and elaborations where this was deemed suitable. Thus, it is most correct to consider the interviews as semi-structured (Bryman & Bell, 2007).

### 3.4. Reliability, replicability and validity

When conducting research, criteria for evaluating the quality of the research should be addressed. Three important criteria are reliability, replicability and validity. Some researchers argue that these concepts are mainly rooted in quantitative research and have suggested other, but connected measures deemed more adequate for qualitative research (Bryman & Bell, 2007). However, given the established position and widespread use of these concepts, they will briefly be addressed in this thesis.

#### 3.4.1. Reliability

Reliability may be defined as “consistency of a measure of a concept” (Bryman & Bell, 2007, p. 163), or measures undertaken with a goal “to minimize the errors and biases in a study” (Yin, 2014, p. 49). Given that the interviews and case study was performed by only one researcher, inter-observer consistency should not be an issue. One source of error and inconsistency in the case study might be the differing meanings which the interviewees attribute to the concepts discussed, like automation and innovation. This has been addressed in the case study for some of the measures.

Translation of the interviews may present another source of error in the study. Although the quotes have been translated to the best of the researcher’s effort to convey the intended meaning of the interviewees, there might be nuances lost in the translation.

#### 3.4.2. Replicability

Yin (2014) addresses replicability as a part of reliability. Replicability concerns whether another researcher would arrive at the same results if the case study was conducted again. To meet the objective of replicability, the procedures followed were documented in a case study protocol.

#### 3.4.3. Validity

In an attempt to address validity, an effort has been made to find operational measures appropriate to study the concepts in question by drawing on former research and in

cooperation with the case study firms. Furthermore, validity is addressed by having multiple sources of evidence, in this case two informants in each firm.

External validity or generalisability is addressed by building on established theory in the field of process and product innovation as well as technology adoption. It should however be noted that this study does not claim that the findings are overall generalizable.

### 3.5. Collection of case study evidence

Here follows a brief overview of the collection of case study evidence. Initial contact was established with management at the firms through the contact in SIV Industri-Inkubator. First, introductory telephone meetings were held with management, explaining the background for the project, discussing and agreeing upon participation in the study. Second, an e-mail was distributed which contained a brief introduction of the researcher, the project and the topics for the interviews. Most of the initial contacts forwarded this e-mail to the interviewees.

All the interviews lasted 45-60 minutes and were conducted at the site of the case firms. Before the interviews, a more thorough explanation of the background and project was provided to the interviewees, with opportunity for clarifying questions before the recorded interviews started. In agreement with the interviewees, all interviews were recorded. These recordings along with transcribed versions of the interviews are retained in the case study database. All the interviews were conducted in Norwegian, and translated to English according to the researcher's best effort. The guiding principle regarding the translation was to preserve the intension and content of the quotes as precisely as possible, rather than a word-by-word translation.

## 4. Case study

While the method for data collection was described in chapter 3, this chapter contains the case study. First, information about the business region and the companies being studied will be presented. This establishes the context in which the data are retrieved. Second, the empirical data from the interviews will be presented and commented upon. Some of the more general information has been retrieved from company websites and other web-based resources, while most of the information was obtained in the interviews conducted with key personnel at the firms.

The fundamental backdrop of this research is to study the potential for increased value creation from industrial production. In line with the research questions, and structured by the theoretical framework, the empirical data will be presented in the following thematic structure. To begin with, the findings related to RQ1 will be presented, focusing on how the firms work with product and process innovation today. Thereafter, the opportunities and challenges presented by new technology, with a special emphasis on automation under industry 4.0 are addressed, in line with RQ2. These two topics both address the facilitating factors in the theoretical framework. Subsequently, findings on the factors that impacts competitiveness, both nationally and internationally will be presented, thus addressing the resulting factors in the theoretical framework. Throughout the case study, cross-disciplinary links will be drawn between the different thematic fields.

### 4.1. Introduction to the business region

This case study examines six firms all located in the region of Nordmøre, Norway. Nordmøre is a region consisting of eleven municipalities with a total population of approximately 62 000 inhabitants. It is located in the north-eastern part of the county Møre og Romsdal.

Business life in the region is characterised by many small- and medium-sized companies, with relatively few large firms. Historically, agriculture and fishing with related mechanical and food processing industries have been important business sectors, respectively in the inland and coastal parts of the region. Many of today's firms have a history as part of or as suppliers to these sectors.



Today the region is heavily influenced by firms in the oil and gas sector. Vestbase, located in the region center of Kristiansund, is an important supply base for the offshore activities in the Northeastern Atlantic and Norwegian Sea. Although the offshore activities are most dominant in the coastal parts, it plays a significant role for firms in the entire region. Aquaculture is an industry which has become increasingly important during the last decades, and it has experienced especially strong growth in the last couple of years.

In the inland parts of the region, forestry with related industrial production has played and still play a significant role. Mechanical workshops and engineering industry is a large employer in many parts of the region. There is also industry based on production of materials like plastic and aluminium, with aluminium plant Hydro Sunndal as the region's biggest private employer.

Generally, the education level in the region is relatively low. Establishment of an adequate college campus is a work in progress, while the access to skilled workers is fairly good.

#### 4.2. Case companies

**Rognskog Bil** is a mechanical repair shop located in Rindal, that specialises in designing and constructing custom-made changes and additions to heavy weight trucks. Quality and flexibility in delivering what customers want, are emphasised as the primary competitive advantages. They cater to customers all over Norway, but their main market is from Møre og Romsdal and all the way north of the country. Most of the parts that go into the production are produced locally, either by the company themselves or by a collaboration partner nearby. The trucks are made according to the customers' wishes, which leads to a high degree of customisation. Rognskog Bil has experienced significant growth in workload and turnover during the last couple of years. They believe one explanation for this is increased visibility in the market place due to a relatively new presence on Facebook, combined with a strong reputational record in the industry. For this study, manager and owner Harald Rognskog was interviewed, along with mechanic Per Egil Hendset.

**MacGregor Triplex**, located in Averøy, was established back in 1933. Today they are a modern supplier of equipment to the fishing, offshore and research fleets. Their most important

products are deck cranes, net hauling and anchor handling equipment. In their main segments within the fishing fleet in Norway they have a dominant market share. During the last years, they have also become an important supplier to the research fleet globally. Their products are sold worldwide to customers in more than 40 countries. Ownership of Triplex has shifted through the years, alternating between local ownership and ownership by larger corporations. In 2013 they became part of the MacGregor group. Through development of expertise and quality products MacGregor Triplex have gained a strong reputation and a competitive edge in the market. For this study, business development manager Per Olav Blikås and head of the engineering department Harald Kåre Staurnes were interviewed.

**Storvik** is a mechanical and engineering firm located in Sunndalsøra. They mainly offer products and services to the international aluminium and ferrosilicon industries, but are also aimed at the oil, gas and hydropower sector. Through close cooperation with the industry they have substantial experience with maintenance, modification and engineering, and delivers cast products and solutions. Storvik have customers worldwide, and cooperates among others with a supplier in the Czech republic. In addition to organic growth, they have acquired the companies Vefsn Sveis and Heggset Engineering during the last couple of years. Currently they are in a process of remodelling their organisational structure to incorporate all parts of the operation into a uniform structure. The interviewees were COO Inge Haugen and project engineer Gunnar Gravem, who is also among the owners and until recently were also chairman of the board.

**Kvatro** is a supplier to the building industry, producing modular walls, cladding panels, roof truss' and roof elements for buildings from their factory in Surnadal. They originate in a company that was started in 1972, although the product offering has changed in the years since. Kvatro is wholly owned by Coop Orkla Møre. In close collaboration with carpenters and vendors of prefabricated houses, they deliver modules for both houses, cabins, farmhouses, shops and industrial buildings. They collaborate with several such vendors, who in a way carries out parts of the market related activities for them. Their main market is locally in Møre og Romsdal, with no products being sold internationally. Production of roof elements were started up last year after buying the concept from a defunct company close by. For this study,

operation supervisor Roar Bævre was interviewed, along with the supervisor at the roof element department, Jan Tore Andersen.

**Sollid Mek Verksted** is an all-round mechanical workshop located in Surnadal. Sollid Mek was established in 1974, but the founders sold the company to the current owners in 2011. They deliver services and products to the agricultural sector, entrepreneurs, private customers, oil and gas, and the processing industry. In addition to carrying out a varied range of mechanical assignments and building custom-made products, their product range today mainly consists of a band saw and a moving target for shooting ranges. In addition to keep serving the traditional markets, the plan is to move further into industrially related surface treatment and specially machined products for the offshore industry. The main market for Sollid Mek is locally and regionally. For this case study, founder and machine operator Svein Sollid was interviewed, along with industrial mechanic Simon Landsem Kattem.

**Varde** is a firm with a main goal of helping people outside the workforce to get work, and to help people who are at risk of falling out of the workforce to keep their jobs. To manage this they offer training courses and individual work training. They have a catering department, a department producing equipment for playgrounds, and a mechanical department. The mechanical department is specialised in the production of ship equipment and custom made mechanical products. Although Varde has a varied range of activities, emphasis in this study will be on the mechanical department. Varde cooperates closely with all the biggest shipbuilders in Norway. Their goal is to have a market share of more than 80 % among the Norwegian shipyards' A-list. By following their customers from the Norwegian market abroad, they have gained a substantial international presence. Among others, they today collaborate with sub-suppliers in China and Bosnia. Interviewed for this study was CEO Erik Husby Pettersen and COO of the mechanical department, Anders Gulbrandsen.

Company	Storvik	MacGregor Triplex	Rognskog Bil	Varde	Kvatro	Sollid Mek Verksted
Industry	Production of metal constructions and parts	Production of cranes/handling equipment for ships	Maintenance and repair of motor vehicles	Production of parts for ships over 100 gross tons	Production of builders' supplies	Mechanical production of parts and machines
Products	Services, products and projects to the aluminium industry	Deck cranes, net hauling and anchor handling equipment	Customised modifications to heavy weight trucks	Anchor handling equipment, hatchways and doors	Prefabricated houses Roof truss' Modular roofs	Machined products, surface treatment, band saw
Customers	Aluminium and ferrosilicon plants	Shipowners Shipyards	Truck owners	Shipyards	Suppliers of houses/buildings	Oil- and process industry, entrepreneurs, agriculture and forestry
Turnover	190	300	10	68	35	8
Employees	80	85	6	70	20	9
Manager	Dag Sverre Sæsbøe	Per Olav Blikås	Harald Rognskog	Erik H. Pettersen	Bjørn A. Moen	Steinar Skrvøseth
Interviewees	Inge Haugen Gunnar Gravem	Per O. Blikås Harald K. Staurnes	Harald Rognskog Per E. Hendset	Erik H. Pettersen Anders Gulbrandsen	Jan T. Andersen Roar Bævre	Svein Sollid Simon L. Kattem
Location	Sunnal	Averøy	Rindal	Kristiansund	Surnadal	Surnadal

Figure 5 Key data for case firms

### 4.3. Innovation

In line with the first facilitating factor in the framework and RQ1), a closer examination into how the firms currently work with process and product innovation is carried out.

#### 4.3.1. Process innovation lacks attention compared to product innovation

All the firms report that they have made changes in their process by investing in new equipment during the last couple of years. Several of the firms have invested in new CNC-operated equipment for machining. Kvatro have bought a new and more advanced saw, Sollid Mek has recently bought a new cutter, and Triplex have bought both a new cutter and lathe. Still, several describe their machine park as being quite old in line with this statement from Husby Pettersen: *“We have renewed quite a lot during the last couple of years, both with regard to how the equipment is placed within the production process, and we have renewed some of our equipment, but we still have a long way to go. Generally speaking we have a lot of old machines”*.

Investments in new machines and equipment are not the only way in which the firms have worked to renew or innovate their process. Like mentioned by Husby Pettersen, changes in placement of machinery and thus in workflow can also be considered a process innovation. *“What we have done is buy some new equipment, e.g. a cutter, so we can carry out some more advanced machining. We have also done some changes in the workflow of repairs we’re offering”* (Gravem). In some instances, these are related such that new equipment has facilitated a new and more practical workflow. In the modular roof production at Kvatro, investments in a new elevating platform, work top and wagons helped smoothen the production process, resulting in less handling, and offering opportunities for more efficient work stations. Across the firms, this new equipment is mostly readily available and bought from vendors.

Blikås believes that changes in logistics and workflow offer the greatest potential for Triplex. *“Primarily for us, I believe the logistics are most important. Achieving a good logistical flow, removing bottle necks, implementing a planning system; what that could mean for utilisation of resources”*.

One way of changing the workflow which has been applied by several of the firms is outsourcing parts of the production. They cooperate with engineering firms abroad, buy machined parts from more specialised producers either locally or abroad, and in some instances, buy more complete products from other firms. This mainly as a way to lower costs. *“We purchase many of the components, and to a large extent they are readily machined today. It’s a question of business philosophy what to purchase externally and what to produce internally”* (Staurnes). Several of the interviewees stated that their collaboration partners have specialised in more automated production of work-intensive products.

New equipment and changes in workflow are not the only means of process innovation in the firms. Haugen describes how they have simplified their process and helped increase sales by adopting a new pricing model. *“On the larger recurring jobs, we have tried to increase our efficiency by adopting fixed prices for most assignments. (...) This has helped us make a lot of money, because it is much easier for the customer when he doesn’t have to ask for the price*

*every time*". None of the other firms mention changes in price policy as part of their process innovations.

It should be noted that the interviews were structured in a way that started off with questions about process innovations, while questions related to product innovations came later in the interview. However, many of the interviewees first replied to the process related questions with answers about product innovation. Thus, it seemed like the interviewees were more focused on and found it easier to answer about product innovation and development, than innovations in the process.

Generally, the interviewees described their process of learning and gathering inspiration about new production processes as rather incidental and/or insufficient. None of the firms stated that they employed a systematic approach for learning about production processes, but rather relied heavily on acquaintances, occasional visits to other firms and visits from equipment sales personnel. It was argued that this was partly due to a lack of time and resources, and it was also suggested that process innovation suffered a lack of attention. Reluctance to change among the employees was also stated as an issue on projects related to automation and lean.

#### 4.3.2. Product innovation – customers are most important source of new ideas

Although all the firms work with product innovation in one way or another, the characteristics of the product development process naturally differs somewhat between the firms in the study. One commonality across all the firms is that they all work closely with their customers to identify their needs and to develop new products accordingly.

*"The idea always stems from something we have seen, after a customer visit or something like that which generates an idea. We identify a need which then generates an idea. (...) The customer is our most important source for ideas"* (Gravem).

According to Sollid, many people stop by the workshop and some of them provide good ideas. *"(Our product development) is mostly based on people who come here asking. We're not*

*exposed to the challenges and needs on a daily basis. But people experience problems in their everyday working life” (Sollid).*

Based on previous work, Rognskog Bil develops new and tailor-made solutions. *“It is all about finding what solutions we can offer the particular customer according to his needs. We document our work a lot with pictures and sketches, which we keep and show to new customers. This is something we made for another customer, and you can have the same thing, with room for changes according to specific needs” (Hendset).*

Business reputation and former collaborations give rise to new products. Since many customers have worked with these firms in solving problems over several years, they find it natural to consult them again when new needs occur. *“The communication between the end user and us as supplier has been the driving force for the development so far. (...) If you just consider the segment “fisherman with a need”, he often comes to us because we started the adventure (with mechanisation aboard fishing vessels) to begin with” (Blikås).*

For some of the firms, the product development process is in a way taking place outside of the firms control. Some produce mainly according to established predefined standards, which leaves less room for product innovation. *“We produce according to the Norwegian standard, so it’s something anyone can produce. It’s described down to the smallest detail, ...” (Gulbrandsen).*

This also goes for Kvatro, whose products for the construction industry must adhere to strictly defined standards. Furthermore, they mainly receive ready orders from their collaboration partners at the construction firms and prefabricated house vendors. *“We have to deliver what the house vendors want, so they do most of the development. Likewise, it has to comply with the standards prescribed by Byggforsk” (Bævre).* Varde also mentions ISO-standards and input from classification firm DNV-GL as sources of inspiration in product development. Risk and stakeholder analyses as part of the ISO-certification process, was also mentioned as a useful source of input by Haugen in Storvik.

While some of the firms have a philosophy of constantly developing new products, others rely to a larger extent on products developed some time ago. There is a wide range in product life both within and among the firms. The oldest products were developed in the 1960's while the newest ones are still only prototypes or on the idea stage.

Sollid Mek mainly have two products for sale which they produce on a regular basis, the rest are made directly based on customer orders. The two products were both developed in the period before 1995, with only relatively minor changes and adjustments since then.

Varde has many products described in the Norwegian Standard. Some of these were described in the standard even long before Varde started producing them, going as far back in time as the mid 1960s. *"They were developed a long time ago. I think we started mechanical production of ship equipment in the 1980s, and we have produced some of those products since the very beginning"* (Husby Pettersen).

Triplex offer products developed in the period ranging from 1967 until today. *"Well, we still make net winches like in the beginning. They're modified, but they stem from a patent made in 1964. I think we actually still have production sketches dated in the 70s"* (Staurnes). Blikås explains that he had an idea when he started working there that they should develop two new products every year. *"When we take stock at the years end, we can see that we've made it. We've managed to develop both two and three innovations a year. Either a part of the triplex family with cranes we have developed further, or brand new concepts. And we have several patents"* (Blikås).

On a slightly aggregated level, it seems one can categorise the firms according to some shared characteristics when it comes to product development. Triplex and Storvik both have many products developed internally and work continuously with innovation to establish new products in the market place.

For Kvatro, the product development is in comparison a less central part of the business. Given that they mainly produce modular houses on orders from their collaboration partners, this means that they exert a relatively low degree of control over the product development



process. However, it should be noted that the recently started production of larger roof elements was a new product for Kvatro. Many of the products in Varde's mechanical department are based on long-standing technological standards. Thus, they like Kvatro have some products which provides them with little control over the product development process. It should be mentioned that Varde also develops products themselves, which makes their position a bit more similar to the one of Triplex and Storvik.

Sollid Mek and Rognskog Bil does not essentially have a product catalogue like the other firms, with a few exceptions. These two firms produce directly on order from customers, rather than having a predefined range of products.

In general, the firms' product development seems to be focused more on incremental, rather than radical innovations. Many of the products are developments of products that have been offered over a period of time. Triplex and Storvik stands out as the firms who work most actively with more radical product innovations, straying further away from their core products, venturing into new product domains and patenting new inventions. There is generally a relatively limited collaboration with public research institutions and universities, although some of the firms mention collaborations with research institute SINTEF.

#### 4.4. Technology

Technology is one of the main elements of industry 4.0 and is investigated as the second facilitating factor in the framework. In addition, it serves to unveil the opportunities and challenges this presents for the firms, in line with RQ2. Special emphasis has been put on automation and digitalisation, as this was considered to capture central parts of the technological possibilities and advancements brought forward by industry 4.0.

##### 4.4.1. Technology and production process

It was of interest to learn more about the technology employed in the production process. To understand more about the current state of the production process in the case firms, they were asked to what degree they consider their process to be technologically advanced or high-

tech. For benchmarking purposes the interviewees were asked to compare their process to that of other firms in the area or in the same industry.

Most of these firms, five out of the six firms studied, are mechanical workshops in some form. They typically have NC- and some CNC-operated equipment for machining. However, there is potential to renew their machinery with even more CNC-operated machines. Several of the interviewees state that this is something they wish for going forward. However, they face limitations such as a need for high capital expenditure, lack of physical space in the production facilities and questions regarding the profitability of such investments. The possibility of achieving a reasonable return on investment is, among other factors, determined by the scale of the firms' operations. It may be more difficult for the smaller firms to justify substantial investments due to smaller scale of production and thus, lower utilisation of new technology and machinery.

For a couple of the firms, the process is considered as more of a craft. This is particularly characteristic of the work in Rognskog Bil and Sollid Mek. *"Of course, we do have machines, but it's not high-tech, it's really a craft"* (Rognskog). The dependence on good workmanship as part of the production process is emphasised by several of the interviewees.

It appears to be a commonality that none of the firms in this case study characterise their process as being particularly advanced. Several of the interviewees describe their process as quite simple and not technologically advanced. They generally consider their process to be on approximately the same technological level as comparable firms in the area and firms operating in the same industry. It should however be noted that there are substantial differences in technological advancement among the firms if compared to one another.

Several interviewees mention that it is demanding to be among the early adopters. They make a point of finding the right timing, neither too early nor too late, when it comes to adopting new technology. One point worth mentioning is that some of the firms tell stories of how they were early adopters at previous technology shifts. For instance, Storvik was among the first in the area to go from 2D to 3D-design programs. Likewise, when first established, Sollid Mek had modern machining equipment relative to comparable firms in the region.

Several of the firms have worked with upgrading the skills and knowledge of their employees. By certifying the employees for work like welding, they ensure that production can be carried out in a speedy manner according to standards and regulations.

#### 4.4.2. Technology and products

After having studied technology in the production process in the preceding chapter, it is now time to go more into detail on the product-related findings. Here, an investigation will be made into how new technology can facilitate new products. This will also be further elaborated upon in the section on automation.

In line with RQ2) it was of interest to find out whether new production technology, and especially more automated processes, would facilitate increased value creation. Potential for product innovation was explored to capture the product-side element of value creation. The results from the interviews turned out to be quite mixed. While some firms consider it to be a lot of potential for new products if new technology is implemented, others find that this kind of process innovations doesn't really matter that much for development of new products. It is hard to say if this is mainly a function of the current state of the firms' equipment, the nature of the potential new products, or simply differing ideas and philosophies regarding production and product development.

Some emphasised how new technology could facilitate new products, lower the price and increase the efficiency of production. *"It is clear that new production processes would make us able to create new products, that it increases our capabilities. It would make it possible for us to make products where our production methods and equipment hinders us today. Hinders us in such a way that we cannot offer the products at a reasonable price. (...) There are both technical issues and a potential to save resources"* (Rognskog).

By more automated and efficient production methods, the price to customer could be lowered, and thus, it would become interesting for the firm to offer the product.

*“Today it simply takes too much time. When you can do it in a couple of minutes with a machine, and would use two hours to get the same result manually, it simply doesn’t pay” (Hendset).*

While some emphasised the elements concerning cost and efficiency, others were more interested in how new technology could provide possibilities from a technical point of view. *“For instance, 3D-printing is a typical example where you can make a design that was impossible before. How things are produced are definitely important when we develop new products. (...) Both how you produce it, how you transport it and how you install it are important parameters in a product development process” (Gravem).*

With one of their current development projects in mind, Haugen emphasised that sometimes the production technology itself was the real innovation. *“The product here is not patented. It is the method to make the product which is patented. (...) Thus, it can generate many different products” (Haugen).*

Even though some considered it likely that new technology would facilitate new products, others were not so sure. In their opinion, they already had the technology needed and were not hindered by it in their development of new products. Gulbrandsen in Varde did not think new production technology would open possibilities for new products which they were hindered from by today’s technology. *“No, not for us. (...) No, we’re not dependent on the production technology progressing very much, but of course we are dependent on it becoming more available and cheaper” (Gulbrandsen).*

Staurnes at Triplex was of the same point of view. *“There might be (new possibilities), but I don’t think it hinders us too much really. We’re not too constricted by what we’re able to produce in that way” (Staurnes).*

One challenge mentioned by Gulbrandsen, was that because the products they offer are technologically relatively simple, it is hard to justify big investments in the process. He argued that they would have to deliver more complex products if such investments were to pay off.

#### 4.4.3. Automation

In line with RQ2), one of the main goals of this thesis is to understand more about the opportunities presented by industry 4.0. Special emphasis was put on the potential for automation in the case firms, because this was considered to capture an important part of the development in the new technological regime. To study this further, we need a closer look at the current level of automation in the firms. The interviewees have also been asked about how they evaluate the potential for modernising production processes through increased adoption of automation going forward.

##### *4.4.3.1. Current degree of automation is relatively low*

One challenge when discussing and questioning about automation is that it means a lot of different things to different people, sometimes even within the same firm. For some it is about taking more advantage of software and IT for construction and communication. Others mainly think about CNC-operated machining equipment. Either more advanced machines than what are operated today, or to replace tasks that are currently done manually or by NC-operated tools. For others still, they think more in line of batch production, robots and 3D-printers.

Overall, the firms describe their current production process as being relatively manual. Few of the tasks are currently automated. Most of them have only to a very limited extent automated tasks or implemented robots in their production as of today. As described in the preceding chapter on technological advancement of production process, the firms consider their own processes to be comparable in technological advancement to those of competitors. It should be noted that Varde has some additional considerations to make regarding automation of their production. Given their goal of helping people back into the workforce, they are in need of some relatively simple and manual tasks for training purposes. These tasks would perhaps otherwise be the easiest ones to automate.

Some of the firms deliver solutions that help their customers automate. For instance, Storvik and Triplex delivers solutions which helps automate some of the processes of their customers, but this is to a little extent incorporated into their own production. *“Locally, here in Sunndal, we have a long way to go when it comes to improving our efficiency and automate our production”* (Haugen). Even though some of the firms deliver somewhat technologically

advanced products, they don't consider this particularly characteristic for their production process.

#### *4.4.3.2. Obstacles to automation - customisation is considered an obstacle by all firms*

One finding that stands out as a commonality across all the firms, is that they consider their products and process to be too customised to lend itself readily to more automated production. This was a challenge mentioned by all the firms, without exception, when asked about the potential for automation. Many described this non-automated and customised production as a fundamental characteristic of their firm and how they operate. Several of the interviewees mention that their production cannot be compared to batch production or an assembly line. Setting up more automated production with the current technology or current available technology is considered to be too labour-intensive. It will require too much manual input in the machines to achieve the required level of customisation for the products. This means that the reduction in time spent on machining and actual manufacturing, is offset by increased time in preparations, setting the machines correctly and so forth.

Here are some representative statements on this matter:

*"Robots are very well suited when producing product series. It is more difficult for us because we produce too few units of each product. We seldom produce two identical products. (...) Our production is not enough of a batch production, and obviously, this hinders more automation"* (Gravem).

*"I believe some segments of our production could be automated, but since we have more of a one-piece delivery, there's little homogeneity in the products"* (Blikås).

*"If we are to automate, especially the production of wall modules, we need to be a bit bigger. We need to increase our production quite a bit and to standardise more. (...) Automation might not be an option before we standardise more"* (Bævre).

Not only is this customisation descriptive of their production process today. For some, it is even considered one of the main competitive advantages. It is precisely the flexibility and

customisation of products they consider as their strength in competition with larger and cheaper vendors outside Norway.

*“(Some competitors) have more of a streamlined production where they make thousands of the same product, that’s natural. Maybe that’s not where our market should be anyway, because if something is that straightforward to manufacture, it will be produced in Eastern Europe anyway. We must work with customisation, but try to implement some elements that are the same from product to product” (Rognskog).*

#### 4.4.3.2.1. Substantial resources and cost of investment required

Two other fundamental obstacles that hinders automation are the substantial costs and work required for investments in new and automated machinery. It is especially hard to find the time in a busy work schedule to dedicate time and effort to the research and planning that is needed to carry out technological leaps in the production. Many interviewees describe how they’re so busy producing and delivering the current products, that they don’t have enough time for working with R&D. Especially not on the more superior level.

Blikås describes how he feels they need external help to make bigger advancements. Both with regard to resources and competence. *“I believe we need external help to get us going, that was the thought behind the production logistics projects we applied for. If we could get some input from external resources who are theoretically competent, then we can carry out the practicalities” (Blikås).*

The required investment costs are also an issue. Given a relatively low production-volume, it is a question whether the investments can be justified economically. *“We’re not big enough, we don’t have the volume to do it. We’ve had a look at the robots, and prices on automation have decreased radically during the last 20 years. It is not unthinkable for us at some point in the future, but today it’s not part of our plans” (Gulbrandsen).*

#### 4.4.3.3. Possibilities – still some promising potential

The challenges presented due to customisation and single-piece production, does not however mean that they don’t see potential for automation or digitalisation.

Haugen believes that automation is one of the measures that should be considered to create growth in the production locally. Staurnes also sees potential for bringing back production that are done externally today. He says automation then would be needed to reduce the hours worked on these products. In the future, Blikås believes that it will become necessary to either automate or streamline the production more.

#### 4.4.3.3.1. Digitalisation may ease communication and remove bottlenecks

Digitalisation of communication and documentation is emphasised by several interviewees as an area with potential. *“All communication could be digitalised really. There’s a lot of bottle necks in communication. (...) Henceforward, having shared data available online is something we need to work quite a lot with to obtain a better system”* (Gravem). *“I think we need to learn how to use more digital tools for design and calculations. Then we can hire others to produce the physical products based on those digital documents”* (Rognskog). More than just adopting technologies for automated production, they talk about technology facilitating an overall more automated or streamlined process.

For construction most already use 3D-programs, and at least for the larger firms in the study, these 3D-models can be transferred directly to some of the machines in the production. However, in some cases they still choose to program the jobs directly on the machines.

*“When it comes to machining, we take 3D-models directly into machining programs. It goes directly from the construction programs down to the machines, on some jobs where that is practical. But the programming languages on the machines are so easy to use that it’s not always the most practical way to do it. You can do it just as quickly directly on the machine”* (Staurnes).

According to Gravem, there is potential in reducing the distance from the drawing board to the machines. He believes digitalisation could help communicate faster and more precisely from the constructor to the machine operator. *“There is potential for shortening the distance from a product is designed on the computer and until it goes straight into a numerically*



*operated machine. And there is still quite some development needed before it can go directly into a 3D-printer” (Gravem).*

#### 4.4.3.3.2. Product design – nature of products

The design and nature of the products are crucial elements when it comes to how suitable a certain production is for an automated production process. As customisation is considered as perhaps the biggest challenge for automation, some products better lend themselves to a more automated process than others. *“I believe there is potential for automation in some segments (...). We have some long objects on the cranes, so we are thinking about whether it could be possible with a more automated surface treatment” (Blikås).*

Andersen believes there is potential for automation in their production even without a need to modify the products, and says this is something they’re already considering. *“We are discussing having a robot to do the screws. About 90 % of all our modules are identical. (...) It would be tremendously simple to have a rail on the wall and a robot inserting the screws” (Andersen).*

Naturally, the design of products is not fixed, but can be modified in a such a way as to facilitate different production processes. *“You will need to keep it in mind when you’re designing. That it’s designed in such a way that it can be carried out by a welding robot. But their so flexible, maybe even more flexible than a person. (...) But everything we design today is done in 3D, so I believe it would be possible to have a system where you just take the 3D-model into the programming-module for a robot and take it from there” (Staurnes).*

#### 4.4.3.3.3. Production technology – nature of process

Another crucial element is the equipment and technology being employed in the production. While many describe their technology today as being too manual and too simplistic to facilitate automation, there might however be possibilities arising from increasingly smarter technologies. Some describe a need for the machines to read out of digital models themselves, and points at this as a factor that would facilitate further automation. *“You will need to have a robot that can basically read out of a digital model, and then by itself find out how to weld together an object. That’s not impossible, everything works by rules and predefined principles.*

*So if you provide the rules, the model, then it should be possible, but then the robot would have to find out for itself how to carry out the job. We're not quite there yet"* (Gravem).

#### 4.5. Competitiveness and business situation

It should be noted that the case firms constitute quite a heterogeneous group as they operate across a range of different industries, both locally and internationally, and with different scale of operations. In order to address the resulting factors of the framework, an investigation into the firms' current business situation and thereby competitive position was carried out. While uncovering what the firms consider to be their biggest challenges and opportunities and the factors affecting these, it will also provide insight related to RQ2 and RQ3.

##### 4.5.1. Current activity is on a high level

Generally speaking, the overall impression is that nearly all the case firms report of current high activity levels and a positive business outlook. Several of the interviewees state that things have improved during the last couple of years. Most of the firms report that they are very busy and that one of the main challenges lately has been to deliver products with the required quality on time. This suggests that they currently have a decent competitive position. It should be noted that the interviews were conducted during a so-called oil price crisis. While a closer study of the effects of this crisis lies outside the scope of this study, it should be acknowledged as an important contextual backdrop for the study and the firms in question.

Staurnes at Triplex has been surprised by how activity levels have stayed at a remarkably high level. *"We have sort of believed that we've been on the top of a boom for the last five years, but it has just kept on growing. I believe it will level off going forward, but my department has really had too much to do"* (Staurnes).

For Rognskog Bil the last years have showed a steady increase in business, presenting them with new challenges regarding capacity and delivery times. *"We had a record revenue last year. That means we constantly have challenges with delivering within reasonable lead times. And we also experience challenges in maintaining high quality"* (Rognskog).

These statements are supported by the interviewees from both departments at Kvatro. *“Kvatro is a firm that is growing and the outlook seems very good going forward”* (Bævre). *“For roof modules there is an intense demand actually. It will be more challenging to deliver, than finding new customers”* (Andersen).

Several of the firms report that they have conducted little marketing of their products during the last years, because they don't have sufficient capacity to produce more without compromising on quality and/or delivery time. They state that they don't want to grow too fast, and that too high activity levels leaves little time for development projects.

#### 4.5.2. Challenges

While there to a large extent are commonalities in how the firms describe their current business situation, it is a more varied picture when it comes to which challenges they consider moving forward. The answers also suggest that there might be diverging views on this question within the companies.

Market conditions and external factors outside of the firms control are considered by some as the most pressing factors in the foreseeable future. Gulbrandsen at Varde stress the international market conditions as the most crucial challenge. *“For us the greatest challenge is the market conditions, it's an international market. Most of our products go out of the country, and thus we struggle with an international market, foreign currency, customs authority and regulations from the EU”*. In addition, as they have a subcontractor in China, he mentions political conditions and how they influence the relationship and opportunities for cooperation between Norway and China.

According to Haugen, the general markets conditions will be the biggest challenge for Storvik, like they have been during the preceding decade with low aluminium prices. *“Obviously the risk, our greatest challenge is the dollar exchange rate, the aluminium price and how it affects the profitability of the smelting plants”* (Haugen). Gravem on the other hand emphasises the scale of operations, a need to deliver more complete solutions into the overall system: *“Our biggest challenge is size. What is requested are more and more overall solutions”*.

Both Kvatro and Sollid Mek emphasise the need for qualified people as one of the main challenges. Especially with location in a rural area, it can be challenging to find educated people who are interested in moving outside the bigger cities to work. According to Triplex, access to adequate personnel-resources has been a continuous challenge.

Price, quality and delivery time are elements of the general competitive offering that are considered important challenges. Keeping the delivery time down while producing high quality products at a reasonable price is a challenge mentioned by all the firms. *“Our challenge is to be able to deliver, on time and with the right quality. Maybe increase efficiency in a way that leads to both higher quality and higher reliability in delivery”* (Rognskog). The cost, time and price elements are also stressed by Staurnes: *“The challenge is to be able to produce this at a reasonable price also, rapidly and at low cost”*.

As can be seen from these statements, the interviewees offer a wide range of different challenges they are facing and deem as the most crucial ones for their firm. However, most of these seem to be of such a general nature that they could probably be endorsed as important by all of these firms. This is also implied by the fact that representatives from the same firm stress different challenges as the most important ones. The factors highlighted by the interviewees; cost, price, quality, workforce and market conditions are central elements in determining the competitiveness of the firm. That these are the factors most frequently highlighted as challenges by the interviewees, suggests that the question of finding the right competitive position remains the most challenging for the firms studied.

#### 4.5.3. Opportunities

Some of the firms emphasise their ability to produce efficiently with regard to price and quality as one of their key opportunities. *“We have started to consider more and more actually to bring production back closer to home from eastern Europe. When you look at plumbing, components and more complex products, there aren’t really a big price difference. It also gives us better control over the product”* (Haugen).

Sollid Mek has recently invested in a new CNC-controlled cutter which they hope will help them compete on price. *“I see opportunities now, when we get the new cutter going. It will open opportunities to compete on price with others that have the same equipment”* (Kattem).

For the roof module production at Kvatro, the physical premises in which they operate are well suited to improve efficiency without large investments. *“You can at least double the efficiency if we doubled the staff. Our premises are ideal really”* (Andersen).

Others highlight product developments and market opportunities in the main segments as one of the key opportunities. *“Our opportunities are that we have many products and ideas, and a market with room for expansion, I think there’s potential”* (Rognskog). The same goes for Triplex where they have worked with product development over the last decades and still see further potential. *“The typical triplex-product is a handling product. ..., but there can also be other things within fisheries we can partake in”* (Staurnes). At the same time, they are careful not to stray too far away from their key segments or enter into low cost products. *“We never speculate due to lack of orders to enter into price wars. Then we will have lost already”* (Blikås).

Existing products provide a solid fundament which in turn allows for resources being spent on development of new products. *“We also work with developing new products, but of course we have some standard products that will still be our core business. Our customers challenge us, which leads to increased production both here and in China. It is crucial that we innovate and renew our products”* (Husby Pettersen).

Several of the interviewees mention that they act according to strategic considerations when evaluating new opportunities and challenges. Some refer to strategy plans with time frames from two to six years. When scouting for new opportunities, they generally look within industry and product segments that are given by the current strategy. Likewise, they believe that revision of strategy is instrumental if more substantial changes to the production process are to be carried out. According to several interviewees, they stick with what they know until further notice. Gulbrandsen stress the importance of these plans being open to changes, but that their situation is not so precarious that they need to heedlessly jump onto new things.

	Challenges	Opportunities
Products	Lower cost competitors Copying Technology adaption Scale of operations	High quality products Ideas for new products Flexibility in offering Good value for money
Market	Market demand Currency Customs Authority	Strong reputation Growing market Accessible related markets
Workforce	Access to qualified workers	Competent current workforce
Other	Political conditions Delivery time	New technology gives new opportunities

Figure 6 Most frequently mentioned challenges and opportunities

#### 4.5.4. Potential for reshoring of production

One question which was central to the local initiative on increasing industrial value creation, was whether new technology could improve competitiveness in a way that would make it possible to bring back production to Nordmøre. Both production that has previously been outsourced, and that has always been sourced externally are of interest.

Most of the firms in the study, as previously mentioned, have outsourced some parts of their production, either to operators elsewhere in Norway or abroad. Among the firms there are examples of both engineering competence and physical products being sourced externally. Labour-intensive components are typically produced externally at firms who have a more specialised production for the components in question. Thus, the unit cost is reduced compared to producing the parts internally.

To be able to bring back production is a question of time and resources according to Haugen. In Storvik they have started talking about and considering the possibilities to bring back some parts that are sourced externally today. He says it's not necessarily about bringing back the entire production, but doing more of the assembly internally. *"Partly because it gives us more control. And we also see that there is an economic benefit because we can compete on price*

*by doing it here*" (Haugen). Another benefit is that production or assembly of more standardised components offers an opportunity to reduce so called "internal time". Thus, it is possible to lower the price, because it will still be beneficial compared to having "internal time".

While it could be possible from a technical point of view, some parts of the production are still difficult to bring back according to Gravem: *"Those who produce for us today have specialised in that kind of production, and have specially designed systems to do that"*. He states that Storvik has specialised in service and maintenance, thereby making a strategic choice not to produce all parts internally.

Blikås says that there partly are strategic reasons behind what they choose to produce in-house. They have chosen to excel in medium and large machining, merging of modularised components, assembly and quality control. *"Based on our organisational structure, it is hard for us to make money on anything with a sales-price lower than 600 000 NOK"* (Blikås). Thus, production of the smaller components are considered outside the strategic scope of the firm.

It is also a question of capacity and resources. Sub-suppliers are used when necessary due to capacity constraints. Besides the strategic considerations, there are two important issues when considering bringing back production; capacity and costs. *"For us to bring it back in-house it needs to be cost-efficient, and we need to have enough capacity. Today we lack capacity on welding and machining"* (Staurnes). Capacity comes down to both machinery and personnel, but the latter being most important. While the machines can work 24/7, the capacity restraints are mainly due to lack of personnel.

This is in line with Hendset at Rognskog Bil. He says there are several things they buy elsewhere which could be produced internally, but that it's down to a question of time and price. If the number of units produced is too low, then the unit cost will be too high to make a profit. *"Many of those parts are produced in line production by machines. If there's only a few parts, then it won't be possible to make a profit"* (Hendset).

Rognskog, CEO at Rognskog Bil says that even though there are many things they would like to produce internally, it's not necessarily the most appropriate way to do it. Fundamentally, it's a question of costs. The products he imagine they could produce themselves demand new machines, extending the production facilities and educating machine operators. In fact, for Rognskog Bil he rather thinks it would be beneficial if they could produce even more parts externally. If they implemented a bit more advanced digital design programs, it could facilitate more external production.

Investments undertaken in a new machine allowed Kvatro to take back a relatively small task in the roof element production, that was previously bought elsewhere. Both interviewees at Kvatro consider the potential for bringing back more production as very limited.

Investments in new machinery seems to be the decisive condition in several of the firms. Regardless of investments in machinery and automation, Husby Pettersen states that some products simply can't be produced internally at a competitive price. *"We see now that we can buy completed products to a lower price than what we would have to pay for the steel before even starting to handle it. We can try to bring back production and to automate, but it will be impossible given that the raw materials are so much more expensive here than (in China)"* (Husby Pettersen).

#### 4.6. Internationalisation

There is a clear division of the firms when it comes to export of products. For Triplex, Storvik, and Varde, the international market is very important. Most of their products are marketed for sale also in the international market. In contrast, Rognskog, Kvatro and Sollid operate exclusively in the Norwegian market, although Sollid has had two international sales quite some years ago.

Export is a matter of necessity to be able to justify investments in product development according to Gravem. It would be too costly to undertake product development just for the Norwegian market. *"If we are to carry out product development, we need to consider a bigger market. For us, it's standard procedure to operate internationally"*. In addition, most of their



clients operate on an international scale. They state that one of the challenges when operating internationally is that it takes a long time to build relations with new customers.

Triplex find that its technology may be applied in all the relevant markets, but have faced organisational constraints in international marketing. *“It was one of the reasons why we were sold, we understood that we needed a more extensive marketing department and financing to reduce risk of investments and future operations”* (Blikås).

In Varde they haven't really made a marketing effort internationally, but followed clients from Norway in their international operations. They also find that some of their products are part of the “makers list” in shipbuilding. This means that their products are requested when design packages for new ships are sold from Norwegian constructors to international customers.

Sollid Mek does not operate internationally today, but recounts two instances in the past where they sold products abroad. However, they never received any additional orders, and suspect that this is because these products were copied. Fear of copying is a consideration stated also by Varde, which states that this has kept them from entering the market in certain countries.

Kattem states that he thinks the high cost level makes it difficult to start more regular production of products in Norway. *“Since Norwegians are so well-paid, everything that comes from Norway is too expensive for most people. So, export is difficult really”*.

## 5. Discussion

This thesis started by a review of established theoretical concepts which was found relevant due to the research questions. Based on this insight, a framework was developed, depicting industry 4.0 as interlinkages between the four concepts innovation, technology, competitiveness and internationalisation. In the case study, data was gathered and the corresponding research questions addressed accordingly. This chapter will provide an analysis of how the findings from the case study can be understood in line with the framework and existing theory. Where seen fit, some propositions will be presented based on the discussion. The analysis will be structured in two parts. First, focus will be on the opportunities and challenges created by industry 4.0 in line with RQ2. Second, the discussion will centre on the factors that hampers and facilitates the firms' ability to take advantage of these new opportunities in line with RQ3. While RQ1 about innovation was addressed thoroughly in the case study, it will also be addressed throughout the discussion, particularly in the 5.1.1 and 5.2.1 on innovation.

### 5.1. Industry 4.0 – Opportunities and challenges

#### 5.1.1. Innovation – uncertainty may offer opportunities for early adopters

The framework depicts innovation as one of the facilitating factors in the new regime under industry 4.0. Theory states that higher process innovations positively contribute to reduced production cost (Basile, 2001). Most of the firms mentioned production cost as one of their most crucial challenges. Furthermore, the theory suggests that firm survival is positively affected by early adoption of radical manufacturing technology. Such radical manufacturing technologies are at the core of the industrial revolution resulting in industry 4.0 (Kang et al., 2016; Schmidt et al., 2015). By implementing radical manufacturing technology, firms may undertake process innovations which provides opportunities for reduced production cost, and thereby an improved competitive position.

It seemed as a shared characteristic of the firms studied that they carried out a greater number of innovative development projects related to their products than their production process. The firms may have an opportunity to leverage their innovative capabilities from product innovation projects, to facilitate innovations in the production process. Given the

importance ascribed to production cost by the interviewees, this suggests that it may be justified to focus more on process innovations going forward.

The firms studied may be challenged by competitors who adopt more radical production technologies, with the implications this has for both their own and their competitors' competitive offering. Furthermore, Schmidt et al. (2015, p. 23) state that the disruptive technologies under industry 4.0 have substantial potential to "replace conventional technologies shortly". Since all the firms studied rely nearly entirely on conventional technologies, this poses a significant threat that will need to be addressed.

Christensen and Rosenbloom (1995) argue that it is the question of value network which will determine whether incumbents will be able to bring radical innovations to the market. If the firms can move towards industry 4.0 while continuing to operate within the same value network, they could also be able to exploit the opportunities entailed in industry 4.0 to bring radical innovations to the market.

The newly developed and emerging technologies associated with industry 4.0 represents a high degree of uncertainty. Uncertainty over how the technology works, which advantages and disadvantages that are associated, and how it will develop in the time to come. For firms, uncertainty can be a source of opportunities if an entrepreneurial mindset is employed (Hitt et al., 2001). By finding innovative ways to utilise the new technologies in their production process and product offering, it may be possible to exploit the opportunities that arise from this uncertainty. Whether the firms will be able to employ such an entrepreneurial mindset will be discussed in greater detail in part two of the discussion.

Greve (2009) finds that uncertainty leads innovations to diffuse slowly, and that this offers firms an opportunity to gain a competitive advantage also from technologies that are available for acquisition. Thus, the uncertainty of industry 4.0 presents the firms with possibilities to gain competitive advantage by acquiring available technology like the firms do today. This does however require that they are among the early adopters, which is not particularly characteristic of the firms at the present time.

The changes from disruptive innovations under industry 4.0 may present the firms with more substantial challenges not to be left behind depending on the speed with which these changes are implemented by competitors. Schmidt et al. (2015) state that the timing of industry 4.0 implementation will be one of the crucial dilemmas facing businesses in the years to come, while Carayannis and Samanta Roy (2000) find that small firms are more sensitive to market and technology influences than large firms. If this holds, and given that all the firms studied are defined as SMEs by most standards, they may be able to react more readily to these influences than larger competitors. It should however be noted that some of the companies in the case study in fact are relatively large compared to most other firms in the business region.

End-to-end engineering is argued to be one of the key features considered when implementing industry 4.0 (Wang et al., 2016). This may be seen in relation to the finding that some of the current product design complicate more automated production. Product innovation with an emphasis on end-to-end engineering could contribute to ease the difficulties which are experienced today, by offering products more suitable for automated processes.

Analysis of the findings in relation to literature has shown that innovation is closely related to the other elements of the model, namely technology, competitiveness and internationalisation. This thesis will argue that considering innovation as a facilitating factor under an industry 4.0 regime, provides insight which may be helpful for assessment of the opportunities and challenges firms face in dealing with this fourth industrial revolution.

#### 5.1.2. Technology – customisation can be a driver, not an obstacle for industry 4.0

Technology is denoted as a facilitating factor for industry 4.0. It is perhaps the most central one of all the elements in the model. Based on the theory on industry 4.0, it is apparent that disruptive technologies are a key part of the new regime (Kang et al., 2016). Such technological discontinuities have the potential to alter the impact of existing capabilities by upsetting an industry's value chain (Albrinck et al., 2001; Tushman & Anderson, 1986). Thus, it seems clear that firms may expect technologies associated with industry 4.0 to bring substantial alterations to their business environment.

While no closer study was performed of the specific facilitating technologies, theorists like Kang et al. (2016) and Drath and Horch (2014), emphasise industry 4.0 as integration of cyber-physical systems into industrial processes. This may be seen as related to Wang et al. (2016)'s point of vertical integration as a feature of industry 4.0. New opportunities may arise for the firms due to this integration, both with regard to products and processes.

One example of integration in the production process today, is how 3D-programs can send models directly to the machines. While some of the firms had the possibility of doing this already, it was not always found to be the most adequate solution. Some of the interviewees believed that digitalisation of information with the intent of simplified sharing, along with a shortening of the distance from drawing board to production, offered perhaps the biggest opportunities to simplify and automate processes. These steps would be in line with the theory that suggests vertical integration within the factory. It was argued that more digitalised information and communication could also facilitate horizontal integration in the value chain, as it would simplify outsourcing the production of certain parts. By providing new technology for vertical and horizontal integration, industry 4.0 may offer opportunities to smoothen and simplify the production process. This may further translate to reductions in production cost and delivery time.

Access to enough skilled workers is a challenge for several of the firms. In a high-cost country like Norway, wages are among the most important elements in determining production cost and thus, profitability. Likewise, capacity constraints partly caused by the restricted workforce are mentioned as a challenge. By automating more of the production, the number of workers needed may be reduced. This will ease the challenges faced both regarding access to personnel, capacity and the high cost of salaries. However, it will present new challenges concerning the competence and skillset of the remaining workers.

If a move towards industry 4.0 facilitated a reduction of staff, this would counteract the very objective of the regional initiative which has as its goal to increase job creation through industrial production. One must therefore pay attention to whether reduction of jobs in some

parts of the production can be offset by job creation through increased production levels or in other parts of the firms' operations.

The first main hindrance for automation, one which was mentioned by all the firms, was difficulties in applying automated production systems for products with a high degree of customisation. However, the theory suggests that mass customisation is a strong driver of industry 4.0 (Kang et al., 2016; Schmidt et al., 2015). Thus, it would seem like the technological advancements facilitating industry 4.0 may eventually bridge the gap between the need for customisation and automation of production processes. While many describe their technology today as being too manual and simplistic to facilitate automation, new possibilities might arise from increasingly smarter technologies.

Rather than customisation being the biggest challenge of adopting more automated production and thus, industry 4.0, as stated by the firms, industry 4.0 may offer an opportunity to remedy one of the most fundamental challenges to more automated production. It is still an open question, and outside the scope of this study, whether the different technologies at the present time have come far enough in their development to offer such a solution with regard to the firms, products and processes in question. It would require a more extensive study, both of the facilitating technologies and the production process of each firm, to be able to evaluate the appropriateness of a move towards industry 4.0 at the present time.

The second main hindrance for automation was investment cost. Newly developed technologies typically become cheaper, more advanced, and more available over time. Thus, new production technologies like welding robots and 3D-printers may not be attractive for the firms in the case study at the present price point, but this does not however mean that it will always be the case. The firms will have to stay up to date and alert as to how these technologies develop going forward. It was characteristic of the firms that they described their production process as rather low-tech. However, high-technology typically progresses over to the low-tech category. This suggests that even without implementing major changes in strategy or innovative capabilities, the technologies facilitating industry 4.0 may eventually be considered as attractive and appropriate by the firms.

Some argued that it was difficult to justify investments in automation and robotisation due to the simple technological character of current products. While some interviewees stated that their production process did not hinder development of new products, others believed that new technologies could facilitate new products. If emerging technologies under industry 4.0 also facilitates production of more technologically advanced products, this will provide the firms with new opportunities to justify investments which upgrades their production process.

Technological capabilities are found to be a driver for differentiation or cost advantage (Afuah, 2002). While some of the firms specifically mentioned that they stayed away from competing on low price, all the firms emphasised the need to produce high quality products at a competitive price. Industry 4.0 seeks to address exactly the need for flexible production at low cost, while maintaining high quality (Wang et al., 2016). For firms like Varde which offers products defined in publicly available standards, and Kvatro which deliver according to design determined by collaboration partners, production cost may be an even more important competitive factor than for the others.

#### 5.1.3. Competitiveness – industry 4.0 facilitates combination strategies

In the framework it is proposed that competitiveness is a resulting factor under industry 4.0. The preceding discussion has cited theory on how different elements of innovation and technology contribute to competitiveness. This will be elaborated upon in this section.

The origin of the denotation industry 4.0 is that the emerging changes represents a revolution of industrial production. Not only products and production processes will be affected, but nearly all factors that determine and are determined by competitive position. Thus, it is crucial to understand the implications of industry 4.0 on the competitiveness of firms.

Porter's industry structure view (Porter, 1985) state that firms need to choose between cost leadership, differentiation or focused strategy, and that combination strategies will prove unsuccessful. It is stated that one of the core elements of industry 4.0 is to make "production operate in a flexible, efficient and green way with constantly high quality and low cost" (Wang et al., 2016, p. 2). Thus, industry 4.0 may in itself facilitate combination strategies, in contrast with Porter's theory. Even if one were to base strategy development on Porter's theory,

industry 4.0 may facilitate those firms following one of the proposed strategies; cost leadership, differentiation or focus respectively.

In addition comes the findings and theories contrasting Porter, that combination strategy may be a successful and viable strategy also for SMEs (Leitner & Guldenberg, 2010; Wright et al., 1990). If this is the case and combination strategies in fact are a viable alternative, industry 4.0 offers a particularly interesting development. This would also be in line with the theory that increased competition due to globalisation requires firms to compete on different dimensions simultaneously (Singh et al., 2008). Based on these reflections, the following proposition is put forward:

***P1 Industry 4.0 will facilitate combination strategies***

Under the resource-based view (RBV) it is argued that there are four key attributes which are deemed necessary for a resource to provide sustainable competitive advantage. They should be valuable, rare, imperfectly imitable and nonsubstitutable. Whether a resource is valuable may be determined by how it contributes to improving efficiency or effectiveness. The possibility of efficient and effective industrial production lie at the heart of the concept industry 4.0 (Wang et al., 2016). It appears that the value attribute may be the one most readily fulfilled by the industry 4.0 technologies. Fulfilling the other three attributes may prove more difficult.

There is a possibility that the firms may develop or configure the industry 4.0 technologies in such a way that also these requirements can be met. It is also possible that the products may contribute to provide a combination of product and process which fulfils all four attributes. Whether these attributes can be fulfilled will to a greater extent depend on the capabilities of the firms. This will be elaborated upon in part two of the discussion.

One question which was central to the local initiative of increased value creation was whether new technology offered opportunities to bring back outsourced production. Although the interviewees stated that this could be the case in some instances, it is not given that this would provide the most beneficial opportunities for growth going forward. This might be a way to



increase job creation, but is not necessarily the most profitable way in which this can be done. Even under an industry 4.0 regime the most interesting opportunities may not be homesourcing of production, but rather increased production of new and innovative products which better fulfils the attributes necessary for sustained competitive advantage.

#### 5.1.4. Internationalisation – industry 4.0 offers new opportunities for competitiveness

Internationalisation is depicted as a resulting factor in the framework. Increasing specialisation and global sourcing are conditions which have facilitated globalisation of trade and production (Knight & Cavusgil, 2005; Madsen & Servais, 1997). Furthermore, development of ICT and spread of technology are important drivers for internationalisation (Bang & Markeset, 2012). One could say that the emergence of industry 4.0 is the next step in these technological developments, or rather an aggregation and integration of the developed technologies. In this way, it may seem appropriate to consider internationalisation as a resulting factor of industry 4.0.

Several of the firms work closely with subcontractors outside Norway. This is in line with the location effects which have facilitated outsourcing and offshoring. When Wang et al. (2016) emphasise horizontal integration as a key feature of implementation of industry 4.0, this might present a distinct set of opportunities and challenges if the value chain is global rather than regional or local. Furthermore, progress to a more integrated value chain may lead the firms to internationalise further, or at least become more integrated with their international suppliers.

Firms in many high-cost countries have struggled to compete internationally due to high costs of production which again leads to expensive products. Industry 4.0 offers opportunities to produce flexibly and efficiently, “with constantly high quality and low cost” (Wang et al., 2016, p. 2). This may provide Norwegian firms with new opportunities to produce efficiently enough to compete in the international market, and further supports the idea that internationalisation may be a resulting factor of industry 4.0.

Bang and Markeset (2012) summarise the effects of globalisation as size effects, pressure effects and localisation effects. It was stated by Storvik that they needed to operate in the

international market to be able to defend investments in R&D. The Norwegian market was not considered big enough to provide a reasonable return on investment. Thus, this falls well in line with the proposed size effects and pressure effects of globalisation. Due to size effects, the market potential of products is larger than what would otherwise have been the case. Thus, internationalisation with its associated size effects may offer a potential to justify the investments needed in new equipment and technology in adoption of industry 4.0, due to access to a bigger market. Although the emphasis in this thesis has been on internationalisation, these effects could perhaps be covered more broadly under the terms market development or market expanding activities.

Pressure effects caused by internationalisation lead to intensified competitive pressure which stress the importance of cost and price. Pressure effects may present the firms which only operate regionally and nationally with intensified competitive pressure on their current market in the future, for instance by entrance of foreign firms.

These effects may perhaps more accurately be explained as driving forces or facilitating factors of industry 4.0, rather than resulting factors. Thus, it seems like it may be too limited to depict internationalisation only as a resulting factor of industry 4.0.

## 5.2. Ability to exploit and address opportunities and challenges

This part of the discussion entails an analysis that delves deeper into the firms' ability to exploit and address the opportunities and threats which are presented by industry 4.0.

### 5.2.1. Innovation – homogeneity of mental models hampers innovation

Generally, the interviewees described acquisition of new and more modern machinery as an important part of their work with process innovation. It was also found that the work with both process and product innovation was dominated by incremental innovations. This is in line with research that shows how incumbent firms are more likely to implement incremental rather than radical innovations (Henderson & Clark, 1990). However, if industry 4.0 actually represents such a disruptive innovation as suggested by Schmidt et al. (2015), it implies that

the current work with mostly incremental innovations will be insufficient under the new regime.

Ability to undertake incremental and radical innovations may be understood in light of the concepts of core capabilities and core rigidities (Leonard-Barton, 1992). Breakthrough innovation, especially in incumbent firms, may be inhibited by learning traps and core rigidities (Hitt et al., 2001; Leonard-Barton, 1992). Furthermore, Leonard-Barton (1992) found that core rigidities were especially hampering for innovation along the value dimension of core capabilities. Homogeneity of mental models hampers innovation (Foss et al., 2008), and the internal consistency which constitutes an existing regime mitigates evolutionary change (Pfeffer, 1982). While this has implications for innovation, it will be discussed in greater detail in the following section on competitiveness.

All the firms appeared to be more focused on product than on process innovation. This was exemplified by how the interviewees first tried to reply with answers about product innovation, even to questions specifically about process innovation. Some even stated that the strategic focus had not been on the internal process. By not focusing on process innovation, they might miss out on experimental knowledge that could build the capabilities needed for more substantial process innovations. Furthermore, this accentuates the issue of timing process innovations appropriately, as it takes time to build capabilities through experimentation (Foss et al., 2008; Leonard-Barton, 1992). There might also be additional challenges related to process innovation due to technology which will be elaborated upon in the following section.

Findings from the case study show that there are substantial differences between how the firms work with innovation. Some firms may be characterised as more innovative than the others. Triplex, Storvik and Varde stands out as the most innovative of the firms studied. They are also the largest firms studied and the only firms with international operations. This is in line with theory stating that innovative capabilities are important competitive factors (Basile, 2001). It may also be that the greater size of these firms allows for a broader set of competencies, including those related to innovation. While this is considered likely, this study

has not aimed at or been comprehensive enough to say anything certain about the causality of these effects.

#### 5.2.2. Technology – increased importance of dynamic capabilities and ACAP

The concept of absorptive capacity (ACAP) provides insight into how firms assess and acquire new technology (Cohen & Levinthal, 1990). Zahra and George (2002) distinguish between potential and realised ACAP. Especially with regard to the production process, most of the interviewees described their process of assessing new technologies and collecting knowledge and inspiration from external sources as rather incidental. It seems like most of the firms could increase their potential ACAP by applying a more structured search for new technologies.

Most interviewees described their current state of technological advancement as being relatively low-tech or on par with comparable firms. When the firms have not chosen to be particularly early adopters so far, one may assume that this is partly due to long-running experience with the difficulties entailed in early adoption. While this experimental knowledge about technology adoption may contribute to the firms' core competencies, it may at the same time be source of a core rigidity.

It is argued in the theory that firms need to employ dynamic capabilities to realise the value-creating capacity of resources and turn them into a source of competitive advantage (Teece et al., 1997). This may be considered in line with the concept of realised ACAP. For the firms studied, this implies that they need to leverage the technologies they acquire to realise their full potential. Furthermore, it is suggested that exploration is more beneficial than exploitation when it comes to product innovation and market performance (Zahra & George, 2002).

The way in which most of the firms studied operate today seems to favour exploitation over exploration. Thus, there is a discrepancy between what the theory suggests and how the firms operate. Ultimately, all aspects of a firm's operation and situation must be considered to determine the appropriate level of this balance, and this would go beyond the scope of this thesis. Nevertheless, based on the preceding discussion, the following proposition is presented:

***P2 Industry 4.0 will accentuate the importance of dynamic capabilities, absorptive capacity and exploration.***

Several researchers, like Rosenberg (1972) and Itami and Numagami (1992), underscore the knowledge component of technology. The intangible nature of knowledge and thereby technology, may provide firms with a competitive advantage under the resource-based view. It has been stated in the interviews that the firms in the case study generally buy their production technology readily available in the market. This positions the technology employed by the firms further toward the tangible part of the spectrum. Technology may then not provide the firms with a resource that is rare or inimitable enough to fulfil the requirements of attributes posed by J. Barney (1991). However, it should be noted that several of the firms have undertaken measures to upgrade the skills and competences of their workforce. In this way, they work to increase the degree of intangible knowledge in the firms, which in turn can have a positive effect on competitiveness.

Across all the firms, it was argued that their products and processes were too customised to be adapted to a more automated production. However, this objection may not hold, as addressed in part one of the analysis. Furthermore, many described this customisation as a fundamental characteristic of their firm, in contrast to batch production or assembly lines. This indicates that the interviewees have a clear conception of which technologies and processes that are appropriate for their firms. The mental models underlying this conception may become a core rigidity in assessing the suitability of new and emerging technologies. It may be an example of what Leonard-Barton (1992, p. 118) describes as a “cultural bias towards the technical base in which the corporation has its historical roots”. For most of the firms studied, the roots and current characteristic are as mechanical workshops. As indicated by the interviews, automated processes are considered to lie outside their domain, and more within the domain of industrial mass-production. It should also be noted that several interviewees stated that their collaboration partners had specialised in more automated production of labour-intensive products. The discussion on mental models as a core rigidity in the transformation to industry 4.0 leads to the following proposition:

***P3a Industry 4.0 will be hindered by core rigidities in the form of mental models.***

Another core rigidity may arise from the tangible elements of the technical systems dimension of core competencies. Leonard-Barton (1992) argues that core rigidities concerning these tangible elements may be more easily overcome, because they are often local to particular departments. However, for the firms studied, the production process appears to be of a more pervasive nature. Due to their size, they only to a limited extent have different production processes confined to different departments. This means that more substantial technological upgrades of the production process may quickly become more all-encompassing than the firms are comfortable with. While experimentation with emerging technologies may be a way to overcome learning traps (Ahuja & Lampert, 2001), this experimentation may be limited due to firm size and the pervasive nature of current production process. It may also be one of the reasons why product innovations are preferred over process innovations.

Furthermore, such technological experimentation requires slack resources (Ahuja & Lampert, 2001). Substantial work and costs are associated with production process investments like new and automated machinery. Nearly all the interviewees stated resource constraints as one of the major hindrances for research and development. They described a situation of narrow economic margins and difficulties in dedicating the time of required personnel, because they were so busy delivering current products. One could argue that how R&D is balanced against current production is also a question of differing mental models, because it depends on the value ascribed to such development efforts.

Several of the interviewees stated that they were waiting for the prices on new technologies to drop, as to provide a more beneficial cost-value relationship. This indicates a view which ascribes an objective value to the different new technologies. However, Foss et al. (2008, p. 80) argue that the value of such new resources is subjective and may be faultily priced in the market, because it fails to “anticipate the innovative ways firms accumulate and leverage their resources”.

Scale of operations may also be a determining factor when it comes to deciding whether investments in new technologies can be justified economically. Smaller scale of production

may cause new production technologies to be underutilised, and this presents another impediment for investment in new technology. It does however seem somewhat paradoxical that several of the firms have hold back on their marketing efforts, thus not capturing their full market potential, due to lack of production capacity. While not delivering a clear-cut answer on how firms should strike the right balance of marketing, capacity and technological investments in practice, this paradox does indicate how intertwined these concepts are.

### 5.2.3. Competitiveness – overemphasis on resources may lead to lost opportunities

Several of the firms cited strategic considerations for what they produce internally and what they source from external suppliers, and it was referred to strategies with a horizon from two to six years. Although these strategies may be sound at the present time, they will need to be under continuous assessment given how new technology presents a steadily developing competitive landscape.

The resource-based view has been criticized for only applying to firms in predictive environments (Kraaijenbrink et al., 2009). In dynamic or unpredictable environments, the assumption that a resource is valuable may not hold. By relying too much on their current resource-base, firms may fail to properly address the changes in their external environment, like the emergence of industry 4.0 and its disruptive technologies.

Another critique of the RBV is that it fails to recognise the importance of the mental models of entrepreneurs (Kraaijenbrink et al., 2009). This has been touched upon in the preceding sections on innovation and technology. It may be assumed that in the transformation to a new regime, industry 4.0, most firms are characterised by mental models that are homogeneous in the way they ascribe to the internal consistency of the existing regime. Thus, even heterogeneous mental models within an existing regime, may be considered homogeneous in relation to the new regime. This challenge may be accentuated in SMEs, if one assumes that there is a correlation between the number of employees and the heterogeneity of mental models. While this has implications both for innovation and technology, it may also be a challenge on a more aggregated strategical level.

If one combines these points with the discussion on hindrances for experimentation with process innovations, the following proposition may be presented:

***P3b It will be particularly difficult for SMEs to overcome the core rigidities caused by mental models.***

This suggests that insight from the industry structure view of competitive advantage may render firms more open to exploit and address the opportunities and threats that arises from industry 4.0. Thus, in updating their strategy plans, it will be important to strike the right balance between how much they rely on their resource-base and how aware they are of external changes.

It is considered likely that if progressing to an industry 4.0 regime, the firms in question will mostly base this on acquired technologies. Thus, they will not directly fulfil the rare, inimitable and nonsubstitutable attributes, which are fundamental under the resource-based view. This suggests that the firms' dynamic capabilities may turn out to be of increased importance if industry 4.0 in fact results in an even faster evolving competitive environment (Teece et al., 1997).

While Hamel and Prahalad (1994) argue that integration of multiple streams of technologies should be regarded among an organisation's core competencies, this may be further corroborated by the emphasis on vertical integration under industry 4.0 (Wang et al., 2016).

All the firms hold substantial resources and capabilities based on their historical experience and current operations. They have solid reputations, a competent workforce, and have managed to innovate on their products and processes in a way that positions them at the current high activity levels. It is suggested by theory that whether the firms will be able to remain successful under an industry 4.0 regime will depend on their ability to build on their core competencies and dynamic capabilities, to overcome their core rigidities.

The fact that most of them are currently experiencing success with their product offering, may turn out to be a blessing in disguise if this leads them to become complacent about their



situation. The RBV has been criticised for providing little insight for firms that are satisfied with their competitive position. Itami and Roehl (1987) states that it is when the current core is working well that new core resources should be developed, and this may be the case for the firms in question.

#### 5.2.4. Internationalisation – industry 4.0; both a resulting and facilitating factor

The size of the firms may prove an obstacle to internationalisation. Blikås in Triplex mentioned that the acknowledgment of a need for a more extensive marketing department with regard to international sales, was one of the reasons they were sold to a bigger corporation. Furthermore, in addition to being a question of resources, international marketing requires distinct competences that may not be found today in the firms that have only operated in Norway until now.

Mental models of international competitiveness may prove another challenge for international expansion, and thus constitute a core rigidity. When one of the interviewees in Sollid Mek states that export is difficult due to the high cost level in Norway, it is a reflection that is understandable in a historical context. However, it may also be an example of how one may be restricted when considering the potential market for new products produced in the innovative ways that may be possible through utilisation of industry 4.0.

Export performance is found to be positively influenced by firms' technological innovation capabilities (Flor & Oltra, 2005). Both the decision to export and export intensity are positively related to high technological capacity. It seems that this study corroborates these findings, as also the firms in the case study show a positive relation between innovation, technological capabilities and export.

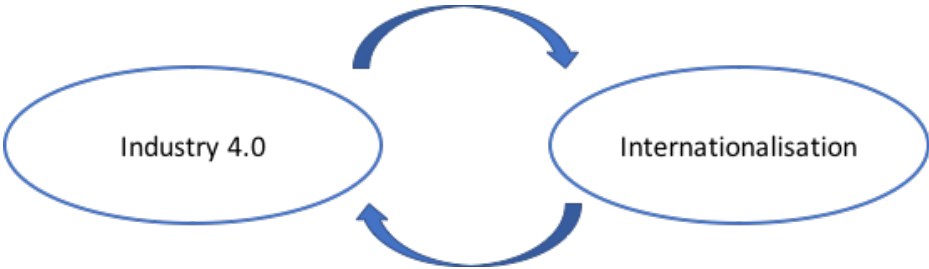
While internal non-R&D innovation activities like product design and production engineering were found to specifically improve international performance, non-distinctive resources like machinery acquisition was not found to contribute to guaranteeing better export performance (Flor & Oltra, 2005). This suggest that, as previously discussed under the sections innovation and technology, the current work with process innovation which to large extent is based on precisely machinery acquisition, might not be sufficient to succeed with

internationalisation in the future. If technological capabilities are increased in an effort to adopt industry 4.0, this may in turn facilitate international expansion.

Given that nearly all the firms describe their customers as their most important source of ideas for new products, it may be assumed that increased international presence may also lead to an increase in their access to new product ideas. Furthermore, all firms describe their work with assessing new technologies for production and collecting inspiration from external sources as rather incidental and often based on acquaintances. It is not unreasonable to assume that internationalisation may lead to an increase in the access to and number of sources for such inspiration, perhaps even more so given differences in knowledge and capabilities between different countries. This suggests that internationalisation is not only a resulting factor of industry 4.0, but may also be a facilitating factor. If this is combined with the discussion on internationalisation in 5.1.4, the relationship between industry 4.0 and internationalisation may be more accurately depicted as mutually enhancing, as illustrated in Figure 7.

This leads to the last proposition:

**P4    *There is a reciprocal relationship between industry 4.0 and internationalisation***



*Figure 7 New understanding of relationship between internationalisation and industry 4.0*

### 5.3. Implications

In this thesis, it is suggested that industry 4.0 can be depicted as interlinkages of the concepts innovation, technology, competitiveness and internationalisation. The findings from the case study and discussion presents implications for research, managers and policymakers.

#### 5.3.1. Implications for future research

Theories on competitiveness and competitive advantage has produced a range of different hypotheses and findings with regard to strategy formation. While Porter (1985) argues that only one out of three distinct strategies can be successfully followed by a firm, this has been contradicted by researchers like Leitner and Guldenberg (2010) and Wright et al. (1990). It is suggested in proposition 1 in this thesis, that the emergence of industry 4.0 may further facilitate and corroborate the findings that combination strategies can be a viable alternative. More research is needed to increase the understanding of combination strategies, and especially how these strategies may be affected by industry 4.0.

Innovation and technological capabilities are found to be of crucial importance for competitiveness, especially under an industry 4.0 regime. Given the importance of radical innovation, early adoption and exploration as suggested by literature (Basile, 2001; Sinha & Noble, 2008), a more detailed study of how the firms work with these issues would be in its place, as suggested in proposition 2. More generally, how SMEs can work to upgrade innovation and technological capabilities may need to be studied further in relation to industry 4.0.

It is suggested in the discussion that the firms' view of "who and what they are" may be a core rigidity along the values dimension, caused by the existing mental models within the firms. These preconceived notions may hamper innovation both with regard to product and process, in adoption of new technologies and in openness to internationalisation. The effect of mental models and how to overcome them is a topic that is worthy of further examination, as proposed in proposition 3a, and with regard to SMEs in particular as suggested in proposition 3b.

Strategy formation and internationalisation as a process has not been studied in this thesis. It would be interesting to study in more detail how SMEs in Norway work with strategy development and internationalisation, and whether this is mainly emergent or intentional. This would be even more interesting in relation to proposition 4, that there is a reciprocal relationship between industry 4.0 and internationalisation.

### 5.3.2. Implications for managers

It is claimed that industry 4.0 will have all-encompassing effects on industrial production. This suggests that managers will need to evaluate all parts of their firm's operation and how to compete under a new industry 4.0 regime.

Innovation and technological capabilities stand out as the two most important factors facilitating implementation of industry 4.0. This implies that managers should devote substantial resources in upgrading the employees' competences within these two fields.

Many of the facilitating technologies in industry 4.0 are under development. Timing in adoption of these new technologies will continue to be a crucial dilemma in the years to come, as will the balance of exploration vs exploitation. This implies that managers will need to work more extensively with upgrading of absorptive capacity in the firms, such that emerging technologies may be assessed and implemented accordingly.

### 5.3.3. Implications for policymakers

Industry 4.0 presents new opportunities for industrial production also in high cost countries. It is in the interest of policy makers to implement initiatives which may facilitate the efforts needed by firms to realise the potential benefits in the new industrial regime. One important condition will be the access to knowledge and research. Thus, policy makers may help by funding research and development of the technologies important for industry 4.0. Given that the Norwegian business sector consists of a large number of SMEs, this might be particularly important because many of these firms lack the resources to develop these technologies themselves.

Furthermore, firms will need access to workers with the relevant competence. This implies that educational institutions on all levels must educate workers which hold the skills needed for implementation of industry 4.0.

Modern industrial production may present opportunities both for creating jobs, and producing goods with a lower environmental footprint. This should further incentivise policy makers to facilitate the implementation of industry 4.0. However, as discussed, new technologies may also render some workers obsolete in the production processes. Policy makers may have to devote substantial attention to how jobs can be created in a time of increased automated production. It is likely that this will also affect labour market regulations in the time to come.

The issue of trade and national industrial production in a globalised era has received extensive attention during the last couple of years, e.g. in political contexts such as Brexit and the American presidential election of 2016. In the Norwegian context, it should be noted that the first export deficit in nearly 20 years was just reported. It is suggested that modern industrialised production and industry 4.0 may be a key factor for export performance. Thus, policy makers should pay close attention to the contribution modern industrial production and industry 4.0 can make to the export balance sheet.

## 6. Conclusion

How to increase value creation from modernised industrial production? This was the fundamental backdrop of this thesis. In particular, a closer examination was done into the concept of industry 4.0 and the opportunities and challenges this presents to firms, as well as the factors affecting ability to take advantage of these new opportunities.

The emergence of industry 4.0 and the associated technological developments produces uncertainty for firms, especially with regard to the value of these technological developments, their applicability and timing of adoption. This uncertainty may offer opportunities for early adopters. However, the firms studied are generally not early adopters of new technology, and this may prove a challenge in exploiting these opportunities.

Most of the firms considered their customised products as an obstacle to more automated production. Theory and preliminary studies suggests that customisation may in fact be a driver, not an obstacle for industry 4.0 due to the opportunities for flexible automated production. Furthermore, while it has been claimed that firms need to decide on only one out of several available strategies e.g. cost leadership or differentiation, it is suggested that industry 4.0 may facilitate and enhance the employment of combination strategies.

Product and process innovation will be crucial in the transformation to an industry 4.0 regime. However, core rigidities may hamper the firms' ability to carry out this transformation. It is suggested both from theory and the case study that core rigidities along the values dimension, caused in part by homogeneity of mental models, may be especially hampering for innovation and technology adoption. It is proposed that it may be particularly difficult for SMEs to overcome these core rigidities.

Dynamic capabilities, absorptive capacity and exploration will likely become more important on the road to an industry 4.0 regime. This suggests that the firms should work to upgrade these capabilities going forward. While a strong resource-base is important for future success, an overemphasis on the existing resource-base may lead firms to lose out on new

opportunities by being too internally focused. Thus, the potential for value creation may not be fully exploited.

Through offering opportunities for efficient production, new opportunities for international competitiveness may also arise from the employment of more modernised production. Furthermore, it is suggested that there exists a reciprocal relationship between industry 4.0 and internationalisation, so that industry 4.0 may lead to further internationalisation and vice versa.

### 6.1. Limitations

The reader should be aware of certain limitations of this study. One consideration is the generalisability of the findings. While the firms studied can all be characterised as SMEs, the results may not be applicable to SMEs in all sectors. All but one of the firms can be characterised as mechanical workshops, and thus the results may be more relevant to other firms within the same industry. Furthermore, the firms studied are all localised in the same region, Nordmøre, which should be considered in evaluating the applicability of this research to firms in other regions. In essence, although this thesis may provide some insight across regions and industries, the specific situation and context of each firm should be taken into account.

When selecting the firms for the case study, this was based on discussions with a local initiative for industrial growth, as well as with the firms in question. The firms decided internally who were to be interviewed. This may be source of some self-selection bias, and is therefore noted as another limitation. Although an effort was made to construct an interview guide that would capture the most essential insight from the firms, there might have been relevant information that was not obtained because of the selection or phrasing of the interview questions.

While the interviews provided valuable insight into the firms, time and resource constraints limited a more extensive study of the production process, work with product development and the specific new technologies of industry 4.0.

## 7. Bibliography

- Afuah, A. (2002). Mapping Technological Capabilities into Product Markets and Competitive Advantage: The Case of Cholesterol Drugs. *Strategic Management Journal*, 23(2), 171-179.
- Ahuja, G., & Lampert, C. M. (2001). Entrepreneurship in the Large Corporation: A Longitudinal Study of How Established Firms Create Breakthrough Inventions. *Strategic Management Journal*, 22(6/7), 521-543.
- Albrinck, J., Hornery, J., Kletter, D., & Neilson, G. (2001). Adventures in corporate venturing. *Strategy and business*, 118-129.
- Álvarez, I., Marin, R., & Fonfría, A. (2009). The role of networking in the competitiveness of firms. *Technological Forecasting and Social Change*, 76(3), 410-421.
- Amit, R., & Schoemaker, P. J. H. (1993). Strategic Assets and Organizational Rent. *Strategic Management Journal*, 14(1), 33-46.
- Bakken, J. B. (2017). Nordiske bedriftsledere: Måten vi jobber på er gammeldags innen fem år. *Dagens Næringsliv*. Retrieved from dn.no website: <https://www.dn.no/nyheter/2017/06/26/0716/Teknologi/nordiske-bedriftsledere-maten-vi-jobber-pa-er-gammeldags-innen-fem-ar>. Retrieved: 17. september 17.
- Bang, K. E., & Markeset, T. (2012). Identifying the Drivers of Economic Globalization and the Effects on Companies' Competitive Situation. In J. Frick & B. T. Laugen (Eds.), *Advances in Production Management Systems. Value Networks: Innovation, Technologies, and Management: IFIP WG 5.7 International Conference, APMS 2011, Stavanger, Norway, September 26-28, 2011, Revised Selected Papers* (pp. 233-241). Berlin, Heidelberg: Springer Berlin Heidelberg.
- Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, 17(1), 99-120.
- Barney, J. B. (1986). Strategic Factor Markets: Expectations, Luck, and Business Strategy. *Management Science*, 32(10), 1231-1241.
- Basile, R. (2001). Export behaviour of Italian manufacturing firms over the nineties: The role of innovation. *Research Policy*, 30(8), 1185-1201.
- Boter, H., & Holmquist, C. (1996). Industry characteristics and internationalization processes in small firms. *Journal of Business Venturing*, 11(6), 471-487.
- Bryman, A., & Bell, E. (2007). *Business research methods*. New York: Oxford University.



- Burda, M. C., & Dluhosch, B. (2002). Cost Competition, Fragmentation, and Globalization. *Review of International Economics*, 10(3), 424-441.
- Carayannis, E. G., & Samanta Roy, R. I. (2000). Davids vs Goliaths in the small satellite industry: The role of technological innovation dynamics in firm competitiveness. *Technovation*, 20(6), 287-297.
- Cavusgil, S. T., Knight, G. A., Riesenberger, J. R., Rammal, H. G., & Freeman, S. (2012). *International Business: Strategy, Management, and the New Realities*. Upper Saddle River, NJ: Pearson Prentice Hall.
- Christensen, C. M., & Rosenbloom, R. S. (1995). Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. *Research Policy*, 24(2), 233-257.
- Clark, J., & Guy, K. (1998). Innovation and competitiveness: a review. *Technology Analysis & Strategic Management*, 10(3), 363-395.
- Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35(1), 128-152.
- Collis, D. J. (1994). Research Note: How Valuable are Organizational Capabilities? *Strategic Management Journal*, 15(S1), 143-152.
- Davies, H., & Ko, D. (2006). Up-grading and performance: The role of design, technology and business strategy in Hong Kong's electronics industry. *Asia Pacific Journal of Management*, 23(3), 255-282.
- Day, G. S. (1994). The Capabilities of Market-Driven Organizations. *Journal of Marketing*, 58(4), 37-52.
- De Wit, B., & Meyer, R. (2010). *Strategy: Process, content, context*: Cengage Learning EMEA.
- Dess, G. G., & Davis, P. S. (1984). Porter's (1980) Generic Strategies as Determinants of Strategic Group Membership and Organizational Performance. *The Academy of Management Journal*, 27(3), 467-488.
- Dierickx, I., & Cool, K. (1989). Asset Stock Accumulation and Sustainability of Competitive Advantage. *Management Science*, 35(12), 1504-1511.
- Drath, R., & Horch, A. (2014). Industrie 4.0: Hit or Hype? [Industry Forum]. *IEEE industrial electronics magazine*, 8(2), 56-58.

- Drucker, P. (1985). *Entrepreneurship and innovation: Practice and principles*. NY: Harper Business.
- Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic Capabilities: What Are They? *Strategic Management Journal*, 21(10/11), 1105-1121.
- Flor, M., & Oltra, M. J. (2005). The influence of firms' technological capabilities on export performance in supplier-dominated industries: The case of ceramic tiles firms. *R and D Management*, 35(3), 333-347.
- Foss, N. J., Klein, P. G., Kor, Y. Y., & Mahoney, J. T. (2008). Entrepreneurship, subjectivism, and the resource-based view: toward a new synthesis. *Strategic Entrepreneurship Journal*, 2(1), 73-94.
- Galbreath, J. (2005). Which resources matter the most to firm success? An exploratory study of resource-based theory. *Technovation*, 25(9), 979-987.
- García-Muiña, F. E., & Navas-López, J. E. (2007). Explaining and measuring success in new business: The effect of technological capabilities on firm results. *Technovation*, 27(1-2), 30-46.
- Grant, R. M. (1991). The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation. *California Management Review*, 33(3), 114-135.
- Greve, H. R. (2009). Bigger and safer: The diffusion of competitive advantage. *Strategic Management Journal*, 30(1), 1-23.
- Hamel, G., & Prahalad, C. (1994). *Competing for the Future* Boston, MA: Harvard Business Press.
- Helfat, C. E., & Peteraf, M. A. (2003). The dynamic resource-based view: capability lifecycles. *Strategic Management Journal*, 24(10), 997-1010.
- Henderson, R. M., & Clark, K. B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly*, 35(1), 9-30.
- Hitt, M. A., Ireland, R. D., Camp, S. M., & Sexton, D. L. (2001). Guest Editors' Introduction to the Special Issue Strategic Entrepreneurship: Entrepreneurial Strategies for Wealth Creation. *Strategic Management Journal*, 22(6/7), 479-491.
- Itami, H., & Numagami, T. (1992). Dynamic Interaction between Strategy and Technology. *Strategic Management Journal*, 13, 119-135.

- Itami, H., & Roehl, T. W. (1987). *Mobilizing invisible assets*. Boston, MA: Harvard University Press.
- Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., Son, J. Y., . . . Noh, S. D. (2016). Smart manufacturing: Past research, present findings, and future directions. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 3(1), 111-128.
- Kirzner, I. M. (1966). *An essay on capital*: Augustus m Kelley Pubs.
- Knight, G. A., & Cavusgil, S. T. (2005). A Taxonomy of Born-global Firms. *MIR: Management International Review*, 45(3), 15-35.
- Kogut, B., & Zander, U. (1993). Knowledge of the Firm and the Evolutionary Theory of the Multinational Corporation. *Journal of International Business Studies*, 24(4), 625-645.
- Kraaijenbrink, J., Spender, J. C., & Groen, A. J. (2009). The Resource-Based View: A Review and Assessment of Its Critiques. *Journal of Management*, 36(1), 349-372.
- Krugman, P., Cooper, R. N., & Srinivasan, T. N. (1995). Growing World Trade: Causes and Consequences. *Brookings Papers on Economic Activity*, 1995(1), 327-377.
- Leitner, K.-H., & Güldenber, S. (2010). Generic strategies and firm performance in SMEs: a longitudinal study of Austrian SMEs. *Small Business Economics*, 35(2), 169-189.
- Leonard-Barton, D. (1992). Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development. *Strategic Management Journal*, 13, 111-125.
- Lisboa, A., Skarmeas, D., & Lages, C. (2011). Entrepreneurial orientation, exploitative and explorative capabilities, and performance outcomes in export markets: A resource-based approach. *Industrial Marketing Management*, 40(8), 1274-1284.
- Løfaldli, M. (2017a). SIV II feb. Surnadal: SIV Industri-Inkubator AS.
- Løfaldli, M. (2017b). *Strategi og virksomhetsområder 2017-2020*. Retrieved from Surnadal:
- López Rodríguez, J., & García Rodríguez, R. M. (2005). Technology and export behaviour: A resource-based view approach. *International Business Review*, 14(5), 539-557.
- Lu, J. W., & Beamish, P. W. (2001). The Internationalization and Performance of SMEs. *Strategic Management Journal*, 22(6/7), 565-586.
- Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1), 3-42.

- Lumpkin, G. T., & Dess, G. G. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. *Academy of management Review*, 21(1), 135-172.
- Madsen, T. K., & Servais, P. (1997). The internationalization of Born Globals: An evolutionary process? *International Business Review*, 6(6), 561-583.
- March, J. G. (1991). Exploration and Exploitation in Organizational Learning. *Organization Science*, 2(1), 71-87.
- Meld. St. 27 (2016 – 2017) Industrien – grønnere, smartere og mer nyskapende.* (2017). Oslo.
- Miller, D. (1992). The Generic Strategy Trap. *Journal of Business Strategy*, 13(1), 37-41.
- Miller, D., & Friesen, P. H. (1986). Porter's (1980) Generic Strategies and Performance: An Empirical Examination with American Data. *Organization Studies*, 7(1), 37-55.
- Monostori, L. (2014). Cyber-physical Production Systems: Roots, Expectations and R&D Challenges. *Procedia CIRP*, 17, 9-13.
- Mudambi, R., & Venzin, M. (2010). The Strategic Nexus of Offshoring and Outsourcing Decisions. *Journal of Management Studies*, 47(8), 1510-1533.
- Narula, R. (2004). R&D collaboration by SMEs: New opportunities and limitations in the face of globalisation. *Technovation*, 24(2), 153-161.
- Penrose, E. (1959). *The Theory of the Growth of the Firm.* London: Basil Blackwell.
- Pfeffer, J. (1982). *Organizations and organization theory:* Pitman Boston, MA.
- Porter, M. E. (1985). *Competitive Advantage: creating and sustaining competitive advantage:* New York: Free Press.
- Rosenberg, N. (1972). *Technology and American economic growth:* Harper & Row.
- Rosenberg, N. (1995). Perspectives: A view from the USA. *Europe's Next Step.*
- Schmidt, R., Möhring, M., Härting, R.-C., Reichstein, C., Neumaier, P., & Jozinović, P. (2015). Industry 4.0 - Potentials for Creating Smart Products: Empirical Research Results. In W. Abramowicz (Ed.), *Business Information Systems: 18th International Conference, BIS 2015, Poznań, Poland, June 24-26, 2015, Proceedings* (pp. 16-27). Cham: Springer International Publishing.
- Seglsten, P. H. (2017). Vil hente hjem industriproduksjon: 22 bedrifter planlegger felles robotfabrikk. *Teknisk Ukeblad*. Retrieved from <https://www.tu.no/artikler/vil-hente->

[hjem-industriproduksjon-23-bedrifter-planlegger-felles-robotfabrikk/382778?key=7mH4Xrcs](https://www.researchgate.net/publication/382778?key=7mH4Xrcs). Retrieved: 17. september 17.

- Singh, R. K., Garg, S. K., & Deshmukh, S. G. (2008). Strategy development by SMEs for competitiveness: a review. *Benchmarking: An International Journal*, 15(5), 525-547.
- Sinha, R. K., & Noble, C. H. (2008). The adoption of radical manufacturing technologies and firm survival. *Strategic Management Journal*, 29(9), 943-962.
- Sood, A., & Tellis, G. J. (2005). Technological Evolution and Radical Innovation. *Journal of Marketing*, 69(3), 152-168.
- Strandhagen, J. W., Alfnes, E., Strandhagen, J. O., & Swahn, N. (2016). Importance of production environments when applying Industry 4.0 to production logistics—a multiple case study (pp. 241-247). *Advances in Economics Business and Management Research: Atlantis Press*.
- Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic Capabilities and Strategic Management. *Strategic Management Journal*, 18(7), 509-533.
- Teece, D. J., Pisano, G. P., & Shuen, A. (1990). *Firm capabilities, resources, and the concept of strategy: four paradigms of strategic management*: University of California at Berkeley, Center for Research in Management, Consortium on Competitiveness & Cooperation.
- Tushman, M. L., & Anderson, P. (1986). Technological Discontinuities and Organizational Environments. *Administrative Science Quarterly*, 31(3), 439-465.
- van Liemt, G. (1992). Economic globalization: labour options and business strategies in high labour cost countries. *Int'l Lab. Rev.*, 131, 453.
- Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing Smart Factory of Industrie 4.0: An Outlook. *International Journal of Distributed Sensor Networks*, 12(1), 1-10.
- Wernerfelt, B. (1984). A Resource-Based View of the Firm. *Strategic Management Journal*, 5(2), 171-180.
- Wong, F. (1990). High-technology at work. *Perspectives*, 2(1), 17-28.
- Wright, P., Kroll, M., Kedia, B., & Pringle, C. (1990). Strategic profiles, market share and business performance. *Industrial Management*, 32(3), 23-28.
- Yalcinkaya, G., Calantone, R. J., & Griffith, D. A. (2007). An Examination of Exploration and Exploitation Capabilities: Implications for Product Innovation and Market Performance. *Journal of International Marketing*, 15(4), 63-93.

Yamin, S., Gunasekaran, A., & Mavondo, F. T. (1999). Relationship between generic strategies, competitive advantage and organizational performance: an empirical analysis. *Technovation*, 19(8), 507-518.

Yin, R. K. (2014). *Case study research: Design and methods*: Sage publications.

Zahra, S. A., & George, G. (2002). Absorptive Capacity: A Review, Reconceptualization, and Extension. *The Academy of Management Review*, 27(2), 185-203.