ISBN 978-82-326-4686-9 (printed ver.)
ISBN 978-82-326-4687-6 (electronic ver.)
ISSN 1503-8181

Henrik Brynthe Lund

Doctoral thesis

Doctoral theses at NTNU, 2020:169

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Navigating emerging technologies and knowledge demands

System perspectives on knowledge development in Norwegian manufacturing industry

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Trondheim, June 2020

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Printed by NTNU Grafisk senter

Abstract

This thesis explores the development of technology and knowledge capabilities in Norwegian manufacturing industry, with an emphasis on two manufacturing clusters and their surrounding regions. Recent technological developments related to the concept Industry 4.0 has put technological and knowledge upgrading on the political agenda and has created a momentum for manufacturers to upgrade their capabilities. These upgrading processes demand close collaboration between firm and non-firm actors. As such, the thesis explores how non-firm actors such as national and regional institutions and organizations engage with manufacturers to develop firm capabilities and how these interactions lead to regional economic development. In its analysis, inspired by the pluralistic approach to theory within economic geography, the thesis employs three theoretical approaches from the field of economic geography; the cluster approach, the regional innovation system approach, and the global production network framework. The thesis finds that employing these system approaches to understand upgrading processes and related regional economic development provides a holistic understanding of the multi-scalar processes of technology and knowledge upgrading, which involves firm and non-firm actors from local, regional, national and international levels.

The main aim of the thesis is to provide insights on how firm and non-firm actors in a high cost country (Norway) are engaging in processes of technology and knowledge upgrading in face of rapid technological advances within the manufacturing industry. In addition to study ongoing processes within Norwegian manufacturing industry and their impact on regional economic development, the thesis studies how existing, historically developed regional capabilities have been developed in the post-war period (1945–2019), providing vital background knowledge for understanding recent developments. In so doing, the thesis aims to contribute to theorizing within economic geography by exploring and developing existing system approaches.

The thesis consists of two parts. The first part consists of five chapters that outlines the thesis' empirical and theoretical background, describes the overall research design and methodology, and the overall contributions and suggests directions for future research. The second part consists of four individual research articles that addresses three different themes. The first theme concerns cluster dynamics and evolution and is covered by the articles *On the evolution of clusters and the role of state agency: An historical analysis of two defence-related high-tech clusters in Norway* and *Cluster absorptive capacity: the roles of intermediaries in technology*

upgrading of manufacturing clusters. The former longitudinal study analyses the role of the Norwegian state in developing the two Norwegian manufacturing clusters Kongsberg and Raufoss from state owned companies into clusters with distinct knowledge bases, while the latter explores how cluster intermediaries develop the two clusters' absorptive capacities as they facilitate the absorption of extra-local knowledge and spreading it to cluster firms. The second theme relates to the evolution of regional innovation systems. The article *The Importance of Vocational Education Institutions in Manufacturing Regions: Adding Content to a Broad Definition of Regional Innovation Systems* studies how vocational education institutions in manufacturing regions are key knowledge providers and how regional innovation systems are changing due to the co-evolution of technology, industry and education. The third theme relates to the broader discussion on the spatial division of labour, and, more explicitly, the reshoring of manufacturing activities. The article *Make at home or abroad? Manufacturing reshoring through a GPN lens: a Norwegian case study* studies how advanced manufacturing technologies act as a driver for manufacturing reshoring when matched with key regional assets such as knowledge and competence, organizational culture, key human capital and region-specific manufacturing competence.

Acknowledgements

There are many people who in one way or another have contributed to the finalizing of this thesis. To all of you, thank you.

There are, however, some that deserve a special thanks:

- Professor Asbjørn Karlsen at the Department of Geography for superb supervision, inspiring discussions, patience and collaboration in three of the articles in this thesis. I have truly appreciated your companionship on our travels in Norway and abroad.
- Senior researcher Markus Steen at SINTEF for supervision, comments and feedback on article drafts and for instructive collaboration in three of the papers in this thesis.
- The Department of Geography for providing a welcoming and including college. A special thanks to the administration for helping me out with all the practicalities.
- All the PhDs at the department for providing a good social and academic environment, particularly at the CAKE seminars. A special thanks to Samson Afewerki and Alexander Dodge for constituting the economic geography PhD "group", providing fruitful and interesting academic and non-academic discussions.
- All the PhD candidates I have met at courses, seminars and conferences throughout my PhD period. You have all contributed to reflection, inspiration and fruitful discussions.
- The SFI Manufacturing project for funding my thesis and arranging seminars and workshops where I have been able to meet and discuss with industrial partners and researchers.
- Rune Njøs for providing very constructive feedback and comments for my final seminar.
- My closest family for the everlasting support.
- Eir and Alfred for providing perspectives on what really matters in life.
- Lastly, Idun for enabling me to pursue my goals. I am forever grateful.

List of articles

This thesis contains the following four articles:

I. Steen, M., Lund, H. B and Karlsen, A. (2019). On the evolution of clusters and the role of state agency: An historical analysis of two defence-related high-tech clusters in Norway. *Submitted to a journal, December 2019.*

II. Karlsen, A., Lund, H. B and Steen, M. (2019). Cluster absorptive capacity: the roles of intermediaries in technology upgrading of manufacturing clusters. *Under review, November 2019*

III. Lund, H. B. and Karlsen, A. (2019). The Importance of Vocational Education Institutions in Manufacturing Regions: Adding Content to a Broad Definition of Regional Innovation Systems. *Industry and Innovation*: 1-20 http://doi.org.10.1080/13662716.2019.1616534

IV. Lund, H.B. and Steen, M. (2019). Make at home or abroad? Manufacturing reshoring through a GPN lens: a Norwegian case study. *Revised and resubmitted to a journal, November 2019.*

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PART I

1 Introduction

In the course of the last century, the manufacturing industry has undergone great technological changes and been subject to several geographical shifts. Industrial revolutions have been spurred by the implementation of new technologies which have changed both the manufacturing industry and society. The electrification of manufacturing in 1870s sparked the second industrial revolution and resulted in mass productions of goods, while the introduction of computers and electronics in production lines in the late 1960s led to the third industrial revolution. Along with the third industrial revolution came a global shift and a new spatial division of labour, where transnational corporations moved production from high-cost western economies to emerging Asian economies such as South Korea, Taiwan and China (Massey 1984; Hymer 1982; Vernon 1966). Recent technological developments within manufacturing have been associated with the concept Industry 4.0, which some claim constitutes the fourth industrial revolution. The advanced manufacturing technologies associated with Industry 4.0 (e.g. 3D-printing, enhanced automation and robotics, enhanced digitalization), and their potential for being connected through the Internet of Things into cyber-physical systems, are expected to challenge the manufacturing industry and its labourers. The former emerging Asian economies have become global industrial hubs and are predicted to reinforce their position, indicating a new global shift (Neilson, Pritchard, and Yeung 2014; Coe and Yeung 2019) within the manufacturing industry by implementing advanced manufacturing technologies. In a Norwegian context, the manufacturing industry has experienced substantial offshoring and outsourcing the last three decades. Within a manufacturing industry highly exposed to global competition, Norwegian manufacturers are challenged due to high production costs, often related to high labour wages. Technological upgrading that enables rationalization is therefore imperative for competitiveness of Norwegian manufacturers and thus for regional economic development. However, implementation and development of advanced manufacturing capabilities demands financial resources and key human resources that possess the appropriate skills, competences and knowledge needed to remain useful in a modern, high-tech manufacturing industry.

This thesis explores current and historical technology and knowledge upgrading processes in Norwegian manufacturing industry, particularly emphasising the role of non-firm actors in these processes. The thesis pays particular attention to the Industry 4.0 concept (Kagermann,

Wahlster, and Helbig 2013; Schwab 2016), which despite having gained widespread attention in media and amongst policy and decision makers, has received limited academic attention within the social sciences in general, and economic geography in particular (some notable exceptions are Morgan 2019; Götz and Jankowska 2017; Reischauer 2018). By exploring ongoing technological upgrading processes in manufacturing industry in Norway, and how non-firm actors contribute in this regard, the thesis contributes with novel insights on how the I4.0 concept influences industry, education and regional economic development.

In light of Peck's characterization of the theory culture in economic geography as 'robustly polycentric and pluralist' (Peck 2015, 1), and the multifaceted empirical phenomenon at hand, this thesis draws on several theoretical and conceptual approaches from the broad field of economic geography. As such, the thesis employs the cluster approach, the regional innovation system approach, and the global production network framework to develop an analytical framework that is able to grasp the multi-scalar processes of technology and knowledge upgrading. The labelling of these processes as multi-scalar relates to how the processes depend on and are formed by dynamics and both firm and non-actors on local, regional, national and global levels. The thesis regards the three approaches as system approaches, as they are constituted by firms and non-firm actors and the relations between them. Whereas clusters and RIS are regarded as open-systems, where actors interact across system boundaries (e.g. cluster or region), the global production network framework connects actors across different systems (Trippl et al. 2015; MacKinnon 2012). The approaches emphasise the territorial dimension of knowledge processes, which are embedded in local contexts of actors, institutions and practices. As such, they are well-suited for studying regional economic development.

The thesis revolves around the three core topics knowledge development, technological change and innovation, which are analysed in relation to firm, industry and regional and national dynamics and institutions. In the following sub-sections I will first briefly introduce my motivation for doing this research and the context (background) that the study has been conducted in. Then I will present the main aims for the thesis, the research questions and themes that guide the thesis, and a brief overview of the research articles and how they relate to the research questions and themes. Finally, I outline the structure of the remainder of the thesis.

1.1 Background and motivation

My motivation for starting a PhD, back in August 2016, was based on a desire to return to the discipline of geography. After working as a teacher in primary school for two years, where geography is not an independent school subject, but relegated to one third of the social studies (along with history and social science), I missed the opportunity to employ the theoretical and methodological knowledge that I acquired as a master student. The fact that this entailed doing a PhD on knowledge and technological upgrading in the Norwegian manufacturing industry, was rather a fortunate coincident.

As my PhD is part of a Centre for Research Based Innovation (SFI) on manufacturing, the topic for my PhD project was already decided. The SFI is funded by the Norwegian Research Council and comprises 14 industrial partners within different industries (e.g. defence, automotive, aerospace and shipbuilding) and two research partners (the Norwegian University of Science and Technology and SINTEF).[1] Six of the industrial partners are located in the Raufoss and Kongsberg clusters, while the remaining 8 are scattered across Norway (south of the 63rd parallel). According to the script, I was to research the dynamics of territorialised clusters or innovation systems and their evolution in light of recent technological advances (often related to the term Industry 4.0) within the manufacturing industry. Although I had no previous experience with doing research on clusters or innovation systems, except for one or two courses from my bachelor and master studies, I found the topic intriguing. I also believe that growing up in Moss (southeast-Norway) has contributed to my interest in manufacturing. Moss used to be a typical industry town with a range of industries: pulp and paper, glass, textile and apparel, shipbuilding, construction (rock wool production), millwright and mechanical. In fact, my hometown is 'famous' for its smell, which was related to the pulp and paper production that closed down in 2012. However, in the period from 1980s to the early 2000s, most of the industrial activities were subject to reorganization, closure, and outsourcing and offshoring. I believe that this has led to an interest in trying to understand why some places, cities and regions, are able to forge ahead and develop their industries, while others lose out. Why is it that Raufoss and Kongsberg are able to continue to innovate and remain competitive in a global manufacturing industry, while e.g. Moss was left behind?

[1] See https://www.sfimanufacturing.no/partners.html for a detailed summary of the partners.

In addition to having an interest in understanding regional differences, I found the empirical field, manufacturing, interesting. In an oil and gas (O&G) dependent economy, Norwegian manufacturing industry has been forced to take a back seat in terms of public and political interest. However, the O&G industry has also contributed to the development of Norwegian manufacturing by constituting a large and demanding (requiring development and innovation) market with both the willingness and ability to pay. By developing contracts that demanded local content, the (initially) fully state owned Norwegian O&G industry ensured knowledge and technology spillovers from international companies to Norwegian suppliers, and from the Norwegian O&G industry to other industries (Sæther, Isaksen, and Karlsen 2011; Steen and Hansen 2014). Despite its positive impact on the development of the Norwegian economy, making Norway one of the richest countries in the world, the country received a hash reminder of its' O&G dependence when the 2014 oil crisis hit, which entailed (at its lowest) a more than 50% drop in oil prices (Hou et al. 2015). Subsequently, the unemployment rate spiked as the O&G industry had to lay off workers. The 2014 oil crisis sparked discussions on what Norway and Norwegian industry should subsist on when the world transitions from fossil to renewable energy sources and the demand for O&G is reduced. The manufacturing industry has, as one of several industries, been identified as a potential future backbone in the Norwegian economy, where the improvement of technological and knowledge capabilities is regarded as essential (Ministry of Trade Industry and Fisheries 2017; Almås et al. 2019). The possibility to research both historical and contemporary developments within the Norwegian manufacturing industry, in an era where technological advances are taking place at an accelerated speed, provided me with great opportunities, but also challenges.

1.2 Main aims

The main aim of this thesis is to provide insights on how firm and non-firm actors in a high cost country (Norway) are engaging in processes of knowledge and technology upgrading in face of rapid technological advances within the manufacturing industry. Furthermore, I aim to provide insights on how these upgrading processes can lead to (uneven) regional economic development and potential geographical shifts within the global manufacturing industry. In so doing, the thesis aims to contribute to ongoing debates on how manufacturers in high cost economies, such as Norway, are challenged by technological advancements (often related to Industry 4.0) (Schwab 2016; Schwab and Davis 2018; Morgan 2019; Coe and Yeung 2019) and how implementation of advanced manufacturing technologies could lead to enhanced

competitiveness and innovativeness. The thesis particularly emphasises how these technological developments influence territorialised knowledge development processes, and how non-firm actors contribute to knowledge, industrial and regional development. In mid-2016, when I started working on this thesis, there were very few studies within the field of economic geography that investigated the Industry 4.0 concept and its potential influence on local and regional economic development. Since then, however, the topic has begun to permeate the field where a few recent studies have emphasised different aspects of the concepts (Götz and Jankowska 2017; Ciffolilli and Muscio 2018; Hervas-Oliver et al. 2019). Despite an emerging interest amongst economic geographers, there is a substantial potential to investigate the impact of the Industry 4.0 concept and related technologies and its influence on technological and knowledge development. This thesis, then, contributes to the field of economic geography by contributing with empirical studies on the influence of I4.0 on knowledge and technological upgrading in a high cost economy.

Theoretically, the thesis does not provide a new approach or framework for studying knowledge and technology upgrading processes. My ambition is rather to contribute to the further development and refinement of existing theoretical concepts and approaches within economic geography by applying and testing them in new empirical contexts (George and Bennett 2005). I find that the approaches – clusters, regional innovation systems (RIS) and global production networks (GPN) – at hand differ in terms of types of relations they cover, but are related in the sense that they are systems approaches suitable for studying regional economic development. Furthermore, the three draw on, albeit different, characteristics from relational, evolutionary and institutional economic geography. Subsequently, as a result of the thesis' attraction to evolutionary approaches, it aims to contribute to the debate on cluster dynamics and evolution (Trippl et al. 2015) and the evolution of regional innovation systems (Asheim, Grillitsch, and Trippl 2016; Boschma and Frenken 2018). In this regard, the thesis particularly emphasises the role of non-firm actors such as educational institutions, research institutes and the state, which thus far has been paid limited attention to within evolutionary economic geography (Trippl et al. 2015; Hassink, Isaksen, and Trippl 2019; MacKinnon et al. 2019).

The empirical scope of the thesis is restricted to Norwegian manufacturing industry in general, with a particular emphasis on the clusters, and surrounding regions, at Raufoss and Kongsberg (see Figure 1). Although this entails a particular emphasis on dynamics at the local and regional level, these local/regional economies are influenced by technological, political, economic and

institutional dynamics at both the national and global level, thus national and global dynamics and linkages are also included in the analysis. As a particular version of a coordinated market economy (Hall and Soskice 2001; Lie 2016), the Norwegian context represents a peculiar political economy which has had, and continues to have, an influence on the development of Norwegian manufacturing industry. The Norwegian state has been instrumental in the development of the Norwegian manufacturing industry by taking on the role as e.g. owner, R&D provider and policy maker (Lie 2016). As such, the influence of the state is highlighted, especially in A1 where we trace the development of the Kongsberg and Raufoss clusters' core knowledge bases.

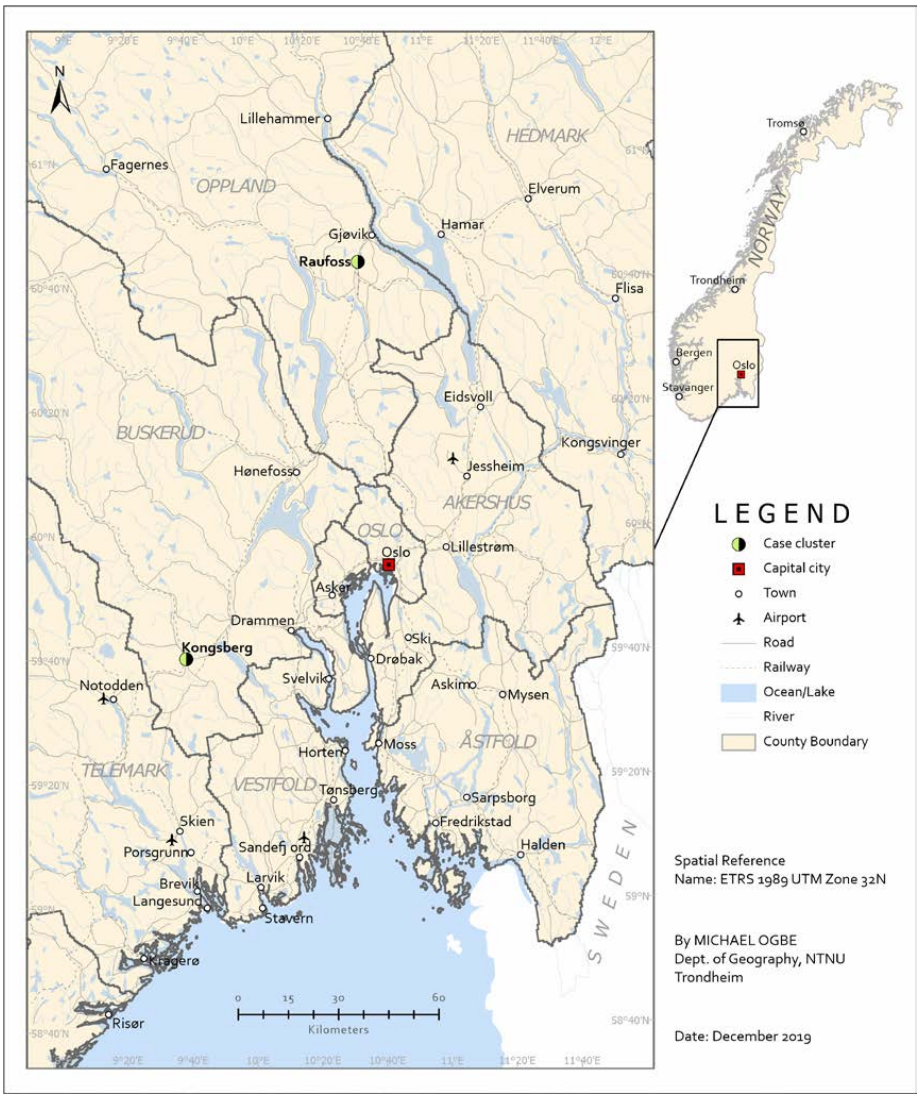

Figure 1 - Map of Norway and the case clusters.

1.3 The research questions, themes and articles

The four individual research articles address their own separate research questions (elaborated on below). In order to structure the thesis and illustrate how the four articles and the thesis connect and altogether contribute to the field of economic geography, the following research questions are addressed:

> Primary research question 1 (PRQ1): how does technological change within manufacturing industry influence knowledge demands and territorial knowledge development processes?
>
> Secondary research question 1 (SRQ1): what is the role of non-firm actors in knowledge development processes?
>
> Secondary research question 2 (SRQ2): how can advances in manufacturing technologies influence the current and future spatial division of labour?
>
> Secondary research question 3 (SRQ3): how can non-firm actors promote and direct industrial and regional economic development?

The thesis, and its four articles, focuses on different periods, geographies and aspects related to both ongoing and historical knowledge and technology development processes in Norwegian manufacturing industry. Therefore, they employ different theoretical and conceptual approaches and frameworks to study the influence of both firm and non-firm actors in developing Norwegian manufacturers' technological and knowledge capabilities, and how these efforts influence industrial and regional economic development.

The first theme relates to cluster dynamics and evolution (Martin and Sunley 2011; Trippl et al. 2015), and especially the influence of extra-local knowledge linkages and non-firm actors on these dynamics. The evolution of clusters is a well-studied topic within economic geography and there are several approaches that seek to illuminate it, e.g. the cluster life cycle perspective (Menzel and Fornahl 2010; Fornahl, Hassink, and Menzel 2015) and clusters as complex adaptive systems (Martin and Sunley 2011). However, the influence of non-firm actors on cluster evolution, and their role in facilitating extra-local knowledge, has yet to be properly

developed. This is the core topic in the articles *On the evolution of clusters: state interventions, knowledge specialization and innovation systems* (Steen, Lund and Karlsen 2019, submitted to a journal), and *Cluster absorptive capacity: two types of intermediaries in technology upgrading of manufacturing clusters* (Karlsen, Lund and Steen 2019, under review). The articles will from now on be referred to as A1/Evolution and A2/Absorptive.

In A1/Evolution we draw on the path development literature (Martin and Sunley 2006) and adopt the view of clusters as complex adaptive systems (Martin and Sunley 2011) to explore how particularly the Norwegian state has influenced the evolution of the Kongsberg and Raufoss clusters. The article's analysis is guided by the research question *what roles can states take in cluster path development?* Through a longitudinal study, A1 traces the historical development of the Kongsberg and Raufoss clusters with a particular focus on how state agency has influenced the evolution of the two clusters. A1 provides a retrospective analysis of how cluster and industrial development has been shaped by state agency at Kongsberg and Raufoss. Furthermore, it provides an understanding of how the state has had, and continues to have, a key role in developing the core cluster knowledge bases in the two clusters, which constitute core competitive advantages for cluster firms. As such, the article addresses PRQ1, SRQ1 and SRQ3.

Article A2/Absorptive relates to the same theme as A1/Evolution, cluster dynamics and evolution. By drawing on the conceptualization of cluster absorptive capacity (Giuliani 2005), the article highlights the influence of cluster intermediaries as providers of extra-local knowledge. Furthermore, A2 develops a refined conceptualization of the cluster absorptive capacity concept by pairing it with the concept of cluster intermediaries. The article addresses the research questions 1) *how and to what extent do cluster intermediaries facilitate extra-cluster linkages and provide new and vital knowledge among cluster firms?* And 2) *What roles can cluster intermediaries take in various cluster contexts in order to enhance absorptive capacities?* By studying ongoing knowledge development processes in the Kongsberg and Raufoss clusters, the paper emphasises how cluster intermediaries take on key roles in enhancing cluster absorptive capacities through facilitating extra-local knowledge. A2/Absorptive thus addresses PRQ1, SRQ1 and SRQ3.

The second theme relates to the evolution of regional innovation systems (RIS). In the article *The importance of vocational education institutions in manufacturing regions: adding content*

to a broad definition of regional innovation systems (Lund and Karlsen 2019, published in Industry and Innovation), from now on referred to as A3/Vocational, we focus on the co-evolution of industry, education and technology. RIS studies have been criticized for providing snapshots of well-functioning RISs. Subsequently, there is a call for studies that investigate how RISs are transformed in response to technological and societal changes (Boschma and Frenken 2018; Asheim, Grillitsch, and Trippl 2016). The article departs from the observation that there is a lack of studies that include vocational education institutions in the analysis of regional innovation systems, in spite of an existing broad definition (Asheim and Gertler 2005). Inspired by evolutionary economic geography, we analyze how vocational education institutions have changed both their content and organization to accommodate the knowledge demands that the implementation of advanced manufacturing technologies poses. The article addresses the research questions: 1) *What are the roles of vocational education institutions in the current technological upgrading of the manufacturing industry?* And 2) *How are different actors within the RIS engaged in forming new education programmes tailored for technological upgrading?* The article finds that vocational education institutions have become essential parts of the Kongsberg and Raufoss' regional innovation systems. A3/Vocational studies the transformation of regional innovation systems and improves our understanding of how regional innovation systems transform due to the co-evolution of technology, industry and education. By analysing how vocational education institutions upgrade their educational programmes in collaboration with local and regional industry actors, the article addresses PRQ1, SRQ1 and SRQ3.

The third theme relates to the broader discussion on the spatial division of labour, and, more explicitly, the reshoring of manufacturing activities. In the article *Make at home or abroad? Manufacturing reshoring through a GPN lens: a Norwegian case study* (Lund and Steen 2019, *revised and resubmitted to a journal*), hereafter referred to as A4/Reshoring, we study the drivers for manufacturing reshoring from low-cost to high-cost countries, such as Norway. Although guided by an empirical interest in the reshoring phenomenon, this theme is more theoretically oriented than the previous two, as it includes introducing and testing the applicability of the global production network (GPN) framework in the analysis of the reshoring phenomenon. A4/Reshoring employs an exploratory case study methodology guided by the research question *what explains manufacturing reshoring in a high-cost country such as Norway?* The article's point of departure is the observation that advanced manufacturing

technologies are potentially important drivers for reshoring and that the field of economic geography has yet to engage with the reshoring phenomenon. A4 argues that the existing literature (predominantly from the field of supply chain and business management – see e.g. Ellram, Tate, and Petersen (2013), Bals, Kirchoff, and Foerstl (2016) and Barbieri et al. (2017)) thus far has overemphasised the micro-level (firm) processes in explaining reshoring decisions, and paid to little attention to advanced technologies as drivers for reshoring (Barbieri et al. 2017). By employing core concepts from the GPN framework (Henderson et al. 2002; Coe et al. 2004; Coe and Yeung 2015) the article complements the existing literature by providing a more holistic understanding of the multi-scalar process of manufacturing reshoring.

A4/Reshoring explores the drivers for manufacturing reshoring to Norway. The article identifies advanced manufacturing technologies as a key driver. However, the technology must be matched with key regional assets such as knowledge and competence, organizational culture, key human capital and region-specific manufacturing competence. The article demonstrates how implementation of advanced manufacturing technologies enables manufacturing reshoring, which in turn enables manufacturing localization that go against the current spatial division of labour, i.e. moving production from low-cost to high-cost economies, thereby addressing SRQ2.

1.3.1 My contributions to the articles and the writing process

As the four articles are co-authored with my main supervisor Professor Asbjørn Karlsen (Department of Geography, NTNU) and my co-supervisor Senior Researcher Markus Steen (SINTEF Digital, Technology Management), I find it necessary to briefly describe my contribution to the articles and the writing process. As lead author of the articles A3/Vocational and A4/Reshoring I have been responsible for most of the empirical and theoretical work and the writing of the papers. Asbjørn (in A3) and Markus (A4) have contributed to data production (interviews), with feedback and discussion on further development of the papers, and to the writing of the papers. In article A1/Evolution and A2/Absorptive I have been the second author and have contributed with empirical work (interviews in both articles) and studies of historical volumes (in A1). Additionally, I have contributed to the development of the theoretical framework and the writing of the articles.

The writing process, particularly for articles A1 and A2, have been characterised by a team effort in terms of taking turns on writing the papers. This entails that the lead author (Markus in A1 and Asbjørn in A2), who has been responsible for the development of the theoretical

framework and the writing of the paper, started the writing process and then the paper was sent to a second author, which then developed the article further before sending it to the last author. This process was repeated several times before the lead (corresponding) author submitted the articles to journals for publication. I find that this way of writing papers is very instructive, as it provides a possibility to discuss and learn through the co-production of a paper, which I believe has enhanced the quality of the papers and their contributions to the field of economic geography.

1.4 Thesis structure

The thesis is comprised by two parts. Part I is divided into five chapters. This chapter introduces the background and motivations for this thesis, in addition to accounting for the main aims and research themes. The second chapter provides an elaboration on developments within the manufacturing industry. The third chapter discusses the theoretical underpinnings of the thesis, aiming to clarify the relations between the theoretical approaches employed across the articles. Chapter four discusses the overall research design and the use of qualitative methods. Finally, chapter five provides a summary of the main findings and contributions, their overall implications and directions for future research. Part II is comprised of the four research articles introduced in section 1.3.

2 Empirical background – the manufacturing industry

Manufacturing can be defined as 'any industry that makes products from raw materials by the use of manual labour or machinery and that is usually carried out systematically with a division of labour. In a more limited sense, manufacturing denotes the fabrication or assembly of components into finished products on a fairly large scale' (Encyclopaedia Britannica 2019b). Manufacturing is in turn a general term that is separated into different industry sectors such as automotive, electronics, machinery, aerospace and defence. As this thesis studies a range of actors within different industries, I (or we) mainly employ the general term manufacturing industry. However, in some instances, when we discuss particularities relating to certain industry characteristics, the industry sector is specified.

Altogether, the manufacturing industry has been a key driver for economic development and modernization processes since the onset of the first industrial revolution in the mid-18th century (Encyclopaedia Britannica 2019a). Innovation in terms of technological development and application has been essential to both the first, second and third industrial revolutions (see Figure 2). Whereas the steam engine and mechanization made up the radical innovations that spurred the 1st industrial revolution, the 2nd and 3rd were respectively driven by the introduction of electrical energy and mass production assembly lines and the implementation of computers and electronics enabling further automation and flexible production. The industrial revolutions can also be conceptualised as waves of development, as in Kondratiev's long wave theory. The theory conceptualises the long-term development of business and industry as waves that consist of approx. 50 years cycles. Each cycle develops in four stages – prosperity, recession, depression and recovery (Freeman and Louçã 2001). Thus far, we have experience 4 full cycles of development (see Figure 3) and are currently in the 5th development wave. As the industrial revolutions have played out, the geographical localization of manufacturing has shifted. More recently, political interest in the manufacturing industry has increased in the last decade following the introduction of the concept Industry 4.0 (originally *Industrie 4.0*), which has been predicted to be the fourth industrial revolution (see Figure 2 for a stylised illustration of the industrial revolutions) (Kagermann, Wahlster, and Helbig 2013; Manyika et al. 2012; Schwab 2016).

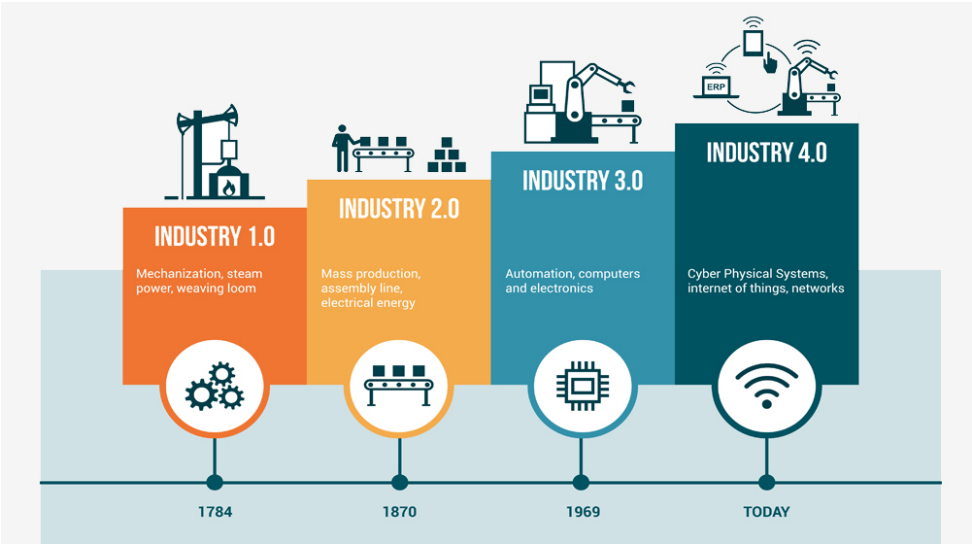

Figure 2 - Industrial revolutions. Source: SeekMomentum (2019)

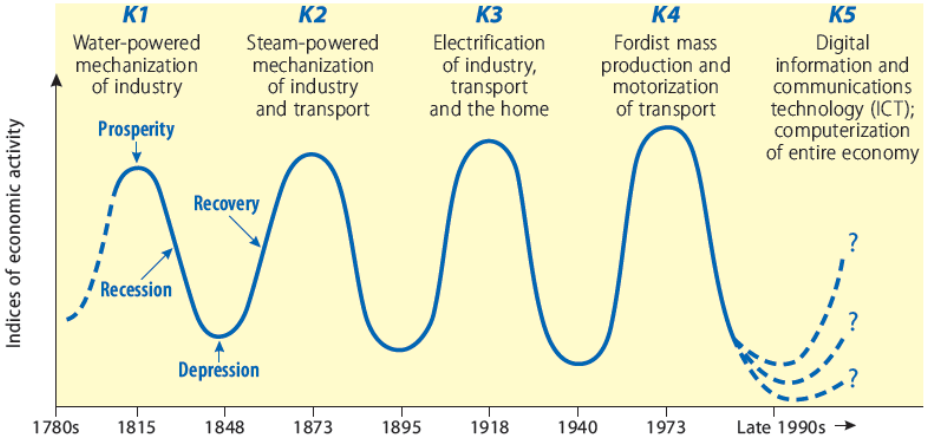

Figure 3 - Kondratiev's wave theory (K-Waves). Source: (Dicken 2015)

As mentioned in the Introduction, this increased interest in the manufacturing industry and recent technological developments related to I4.0, represents a potential momentum for industrial actors to undertake technological upgrading. In this regard, the thesis is timely as it connects to these recent industrial dynamics which are key topics on the political agenda. To illustrate the rising popularity of the I4.0 concept, Figure 4 provides a graph of the popularity of the Google search ‘Industry 4.0’ from January 2014 to November 2019. The graph cover searches that are related to the subcategory ‘news’ and clearly illustrates that the concept has gained increased media attention the last four years (2015–2019). The search term has a total of 11 700 000 hits on Google News (November 2019).

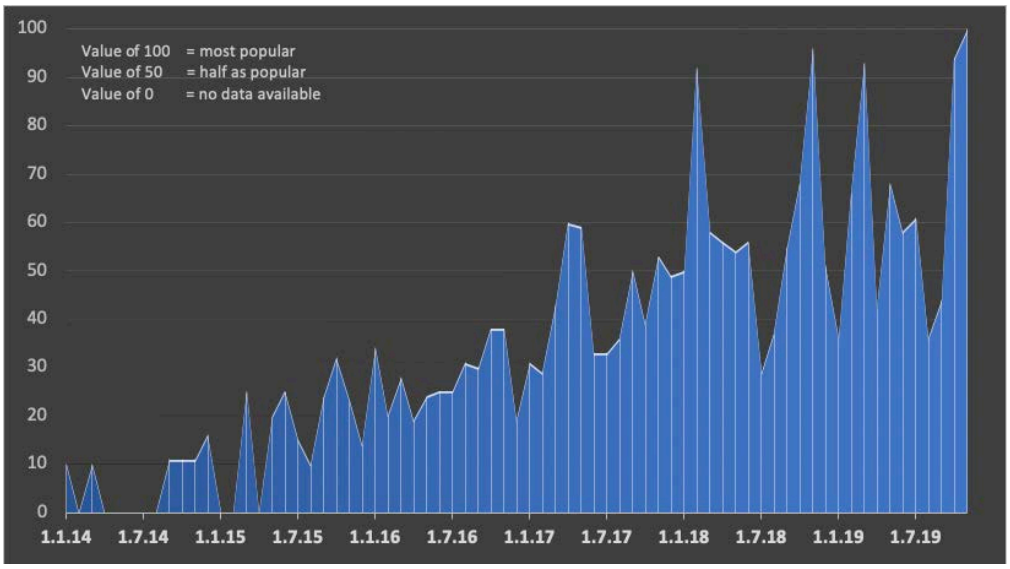

Figure 4 - Popularity of the search term 'Industry 4.0' related to news on Google (jan 2014–nov 2019). Source: Google Trends)

In order to understand the current changes within the manufacturing industry, it is necessary to elaborate on the historical development of the industry and its subsequent geographical shifts. In this chapter, I first elaborate on developments within the manufacturing industry the last century and the subsequent shift from the global North (Western Europe and USA) to the global South (Dicken 2015; Neilson, Pritchard, and Yeung 2014; Coe and Yeung 2019). Second, I expand on the history of Norwegian manufacturing and its influence on the Norwegian economy. Then I discuss the concept of Industry 4.0 and its influence on this thesis, before I develop on the ability of Norwegian manufacturers to adopt and implement advanced manufacturing technologies.

2.1 Recent developments

By the outbreak of the Second World War in 1939, 71% of the global manufacturing production was concentrated in four countries – USA, UK, Germany and France (Dicken 2015). With the onset of the third industrial revolution and automated mass production in the 1970s, production shifted towards emerging economies in Asia. Doreen Massey's seminal contribution *Spatial Division of Labour* (1984) analyses the geographical change of production and the social structures that formed it. In her work, Massey describes how low value-added production

operations were moved (even within companies) from high-cost to low-cost countries. This division of labour resulted in transnational corporations (TNC) retaining their headquarters, research and development and design units in the global North, while production units were moved to, or branch plants established in, the global South (particularly emerging Asian economies) (Massey 1984). Massey drew on previous work that had analysed the new international division of labour, such as Fröbel, Heinrichs, and Kreye (1980) and Hymer (1982), and Vernon's (1966) product-cycle hypothesis. Vernon's (1966) hypothesis suggested, based on studies of the competitiveness of US metropolitan regions, that products are invented in metropolitan areas (with access to core human and financial capital). While the manufacturing initially was conducted in metropolitan regions, it would be relocated to low-income regions or outsourced to low-income countries (Vernon 1966). Similarly, Fröbel, Heinrichs, and Kreye (1980) and Hymer (1982) identified a divide in functions and activities between metropolitan city regions, industrial cities and regions, and regions with no well-established industrial structures. Research and development and design functions were developed in the metropolitan region, skilled manufacturing was conducted in the established industrial regions, while footloose un- or semi-skilled production was dispersed. This division of labour benefitted from existing regional (economic) disparities which were amplified by new waves of investments that solidified the uneven division of labour. In addition to the continued development of regional disparities within western economies, outsourcing and offshoring became a core strategy for TNCs, enabling a maximization of profits by tapping into comparative advantages in emerging economies, especially low labour costs (Fröbel, Heinrichs, and Kreye 1980; Hymer 1982; Massey 1984).

The efforts of TNCs to maximise profits by outsourcing production to low-cost countries enabled an intensification of a Fordist mass production of standardised products, propelled by cheap labour producing bulks of standardised goods in a 'just-in-case' system (Dicken 2015). This 'just-in-case system' of production, characterised by a multitude of suppliers and lack of flexibility, sustained the spatial division of labour as described by Massey (1984) with suppliers mainly localised in the East (emerging Asian economies), keeping them at an arm's length (Dicken 2015). Heavily criticizing the sustainment of mass production and its negative effect on economic development, Piore and Sable (1984) promoted flexible specialization in their influential book *The Second Industrial Divide*. The authors argued that the system of mass production, heavily dependent on access to cheap energy, led to an unbalanced economy,

exemplified by the global economic crises that followed the 1973 oil crisis[2]. Piore and Sable (1984) proposed and identified a partial shift towards a post-Fordist system. This entailed a transition from mass production to flexible specialization, where skilled workers were augmented rather than replaced by technology and automation. The idea of flexible specialization, based on ideas from mass production, has influenced the manufacturing technique mass customization, which entails 'adapting products to a wide variety of demands' with the low production costs that are associated with mass production (Duguay, Landry, and Pasin 1997, 1189). Mass customization is an essential part of the visions related to Industry 4.0 (Gress and Kalafsky 2015; Schwab 2016). In spite of arguments against it (e.g. Piore and Sable 1984), mass production continued at a global scale, and the subsequent outsourcing of production from high-cost to low-cost countries has been a key feature of the global economy the last three decades. In order to tap into comparative advantages such as low labour wages, reducing production costs, TNCs outsourced or offshored production to emerging economies in Asia.

Japan was the first industrialised Asian economy. The country's economic development from the end of WWII till the early 1990s is referred to as the Japanese economic miracle (Francks 2015). The economic and industrial development of Japan was based on the combination of initial US aid and contracts, successful economic reforms, and investments in infrastructure. By the 1960s, Japan had become the world's second largest manufacturing economy, a position that was kept until the late 2000s when it was surpassed by China (see Figure 5). Since the opening up of the Chinese economy for foreign investments, following several economic reforms from 1978 and onwards, China has gradually become the largest manufacturing economy in Asia, and the world (see Figure 5) (Naughton 1995). The four Asian Tiger economies (often referred to as the Asian Miracle) Hong Kong, Singapore, South Korea and Taiwan also experienced substantial growth and industrialization in post-war era, from the 1960s and onward. While Hong Kong and Singapore have become global financial hubs, South Korea and Taiwan developed into world leading manufacturing economies within electronics (Pack and Nelson 1999; Castley 2016). Inspired by Japan's success, the industrial development in the two latter countries were, at least early on, dependent on foreign direct investments

[2] The 1973 oil crisis started when the member countries of the Organization of Petroleum Exporting Countries (OPEC) increased the price on crude oil from 3$ to 5.11$ per barrel. The decision was a reaction to the Yom-Kippur/Ramadan War between Israel and Egypt/Syria. In addition to the increased prices on oil, the OPEC countries cut 5% of production for each month Isreal remained in occupied areas.

(Amsden 1979; Pack and Nelson 1999). As such, TNC set up production in these countries and production was outsourced and offshored from Western economies. The rapid development (starting in the 1950–60s) of the economies such as China, Taiwan and South Korea, bears witness of the global shift in the division of labour, where (low skilled) manufacturing jobs were moved from the global North to the global South. Additionally, it alludes to yet another global shift.

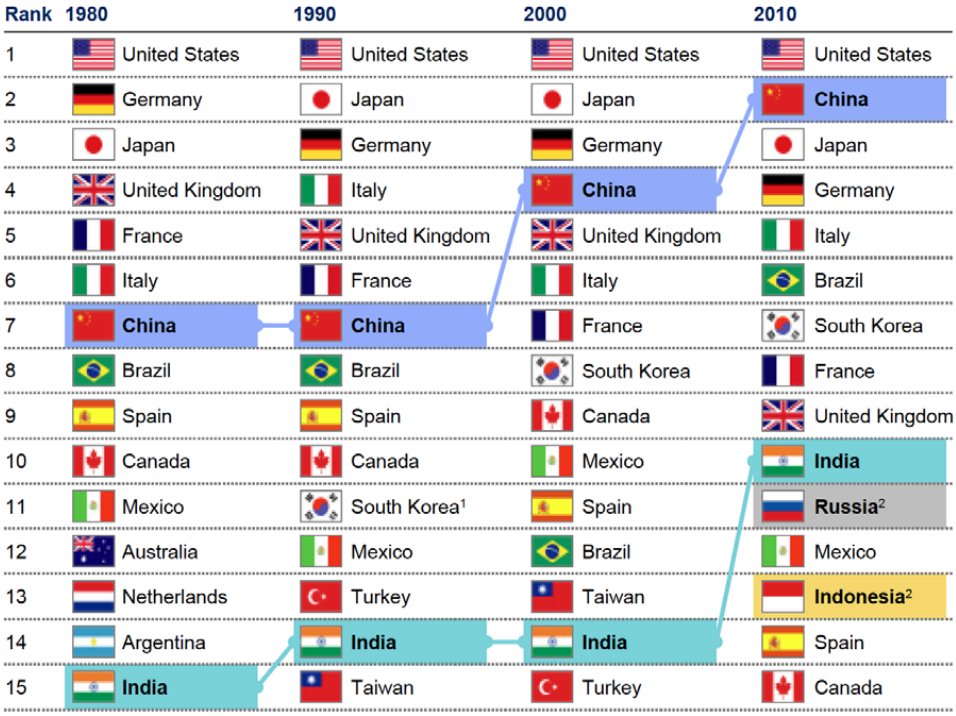

Figure 5 - Top 15 manufacturers by gross value added (1980-2010). Source: Manyika et al. (2012)

Reflecting the speed at which both societal, political and technological changes have unravelled the last three decades, yet another global shift is taking place within the global economy. Since the establishment of emerging Asian economies as the engines of the world, and China as 'the worlds factory', and the concomitant spatial division of labour as described by Massey (1984) and others, a 'new international division of labour' (Neilson, Pritchard, and Yeung 2014, 1) is unravelling. In this new division of labour, Asian economies such as South-Korea, Taiwan and China have become the production hubs of the world and now host a majority of the high-value added dimensions of production such as research and development (R&D), design, after

delivery services etc. (Dicken 2015; Coe and Yeung 2019). Table 1 illustrates how Asia has risen to become a manufacturing hub in 21st century, where 5 of the top 10 manufacturing countries are Asian economies, underpinning the recent global shift of production.

Currently, manufacturing constitutes a substantial industry sector on a global scale, employing approximately 23% of the world's labour force and making up for approximately 15,6% of the world GDP (2017 numbers) (World Bank 2019a, 2019b). The manufacturing industry is dominated by a few large developed and developing economies that, with a few exceptions, have had a rather stable development the last 40 years. Table 1 shows the top 10 manufacturers in the world in 2015 in terms of output in USD and percentage of global manufacturing. The four largest manufacturing economies in terms of manufacturing output in 2015 were China (20%), the United States (18%), Japan (10%) and Germany (7%) (West and Lansang 2018).

Country	Manufacturing Output (USD in billions)	Percent of National Output	Percent of Global Manufacturing
China	$2,010	27%	20%
United States	1,867	12	18
Japan	1,063	19	10
Germany	700	23	7
South Korea	372	29	4
India	298	16	3
France	274	11	3
Italy	264	16	3
United Kingdom	244	10	2
Taiwan	185	31	2

Table 1 - Top 10 manufacturing countries (2015 manufacturing output numbers). Source: West and Lansang (2018)

2.2 Industry 4.0

In recent years Industry 4.0 (I4.0) has become an influential concept in modern manufacturing. The concept, *Industrie 4.0* as it was originally labelled, was first introduced by a German specialty group advising the German government when developing a new manufacturing strategy (Kagermann, Wahlster, and Helbig 2013). The concept has resonated with actors within the manufacturing industry and politicians alike, and has since its conception been adopted by other governments in European countries and influenced manufacturing strategies and policies (Teknikföretagen 2013; Smart Industry n.d.; Ministry of Trade Industry and Fisheries 2017). I4.0 has been proclaimed as the fourth industrial revolution (Schwab 2016) and received massive attention. It figured as the main topic – '*Mastering the Fourth Industrial Revolution'* – at the 2016 Word Economic Forum (WEF) annual top meeting in Davos (Reyes et al. 2016). At the meeting, Klaus Schwab (2016), founder and Executive Chairman of the WEF – and author of the book *The Fourth Industrial Revolution* – was joined by Vice President of the United States Joe Biden on stage in a joint effort to convey the disruptive change that the world, in general, and the manufacturing industry, in particular, was facing. Based on the level of attention that I4.0 has received and the actions that the concept – or hype – generates, it appears as an interesting empirical concept. On the other hand, the concept is also intriguing in a theoretical sense, as it is the first industrial revolution that has been defined as such in advance. In regard to both the timing (starting in august 2016 – only six months after the WEF annual meeting) and the topic of this thesis, I4.0 has been a central concept in the sense that it has generated a momentum for technology and knowledge upgrading processes within Norwegian manufacturing. I therefore find it necessary to discuss the concept further here than what is done in the articles in Part II and provide an explanation of my understanding of it and how it has been employed in the thesis.

I4.0 works as an overarching concept that comprises all types of modern manufacturing technologies, such as 3D-printing, Big Data and the Internet of Things (IoT). Through sensors and the IoT, production lines should become Cyber-Physical Systems (CPS) where customers can monitor the production of their ordered products from start to finish thanks to online 'digital twins' (Schwab 2016; Gilchrist 2016). CPSs should be highly adaptable, meaning that the same production line can, by an easy and swift reconfiguration, produce any number of varieties of a product (mass customization). The revolutionary aspect of I4.0 is the combination of existing technologies through the IoT, which enables fully automated production lines that can be

remotely controlled or supervised by only a few operators. Essentially, I4.0 and Cyber-physical systems (CPS) has been predicted to influence manufacturing's organization, localization and supply chain management and coordination (Kagermann, Wahlster, and Helbig 2013). In terms of employment, I4.0 technologies are predicted to continue the trend in manufacturing, where jobs are highly susceptible for automation and computerization (Frey and Osborne 2017). In a Norwegian context, a study by Pajarinen, Rouvinen, and Ekeland (2015) predicted that 51% of industry jobs/tasks are highly susceptible for computerization. I4.0 technologies, then, could potentially challenge a large group of skilled workers (operators) and their job security (Gonzalez Vazquez et al. 2019). Notwithstanding the I4.0 associated technologies potential to change the manufacturing industry, I find the conceptualization of I4.0 as a fourth industrial revolution troublesome.

Disregarding the discussion on whether the next industrial revolution should be called the third or the fourth (see e.g. Rifkin 2013), defining Industry 4.0 as an industrial revolution, now (in 2019), is in my opinion problematic. It is necessary to recollect Freeman's (1987a, 130) definition of a change in techno-economic paradigm, i.e. industrial revolution, described as changes that 'have such pervasive effects on the economy as a whole that they change the "style" of production and management throughout the system'. Such changes are exemplified with 'the introduction of electric power or steam power or the electronic computer' (ibid. 130). Current technological advances within the manufacturing industry are of course essential for manufacturers and their competitiveness (as pointed to in A2/ Absorptive, A3/Vocational and A4/Reshoring), but the impact of sufficiently pervasive changes, legitimizing the labelling of ongoing process as an industrial revolution, is hard to trace both inside and outside the manufacturing industry. The dramatic reduction of jobs within manufacturing as proposed by Schwab (2016), Frey and Osborne (2017) and, most recently, Gonzalez Vazquez et al. (2019) remains hypothetical, as far as our findings from a Norwegian context is concerned. Concomitantly, technological upgrading within manufacturing appears as an incremental process (as illustrated in A2/Absorptive) and relies on skilled workers for implementation (as demonstrated in A/3Vocational). Therefore, I do not conceive I4.0 as an industrial revolution. Rather, I regard it as an important catch phrase – or hype – as it I) is sufficiently broad thus allowing for individual interpretations, which again makes the concept meaningful for a wide audience, while at the same time II) is too broadly and vaguely conceptualised, making it difficult to relate to (as pointed out in A2/Absorptive).

I believe the I4.0 narrative leads to (technological) expectations (Borup et al. 2006), amongst business leaders and policymakers, towards the *potential* (as pointed out by (Morgan 2019)) of the technologies associated with I4.0. These expectations generate a momentum for technological upgrading amongst business leaders, which in turn result in business decisions that lead to both technological changes (investments) and changes and challenges for those who work in production. All though there is great potential in current (I4.0) technological advances within the manufacturing industry, the labelling of them as an industrial revolution is, given the discussions above, premature. The thesis adopts a view of the I4.0 concept as a broad-based technological upgrading of the manufacturing industry.

2.3 Norwegian manufacturing's development and position in the global economy

Compared to leading western manufacturing economies such as the US and Germany, the Norwegian manufacturing industry has a relatively brief history. The industrialization of Norway had already started in the 19th century, and by 1900 the secondary industries[3] (including manufacturing, mining and power supply) employed 23% of the Norwegian work force. By comparison, the employment rate for agriculture, forestry and fisheries (the primary industries) was 47% that same year (Statistics Norway n.d.). In 1910, the two accounted for 23,7% (primary) and 23,4% (secondary) of the GDP (Skoglund 2005). Towards the mid 20th century, however, the primary industries declined, while the secondary industries experienced growth.

Drawing on favourable natural resources in form of e.g. easily accessible and cheap hydro power, Norway was successful in developing energy intensive process industries such as aluminium and nickel (SNL 2019a). Besides a period of stagnation following the First World War, secondary industries in Norway continued to grow until the outbreak of the Second World War (WWII) (SNL 2019c). After the end of WWII Norway experienced an economic growth period. At the core of this growth was the rebuilding and reindustrialization of the country driven by the Norwegian government, with financial help from the USA[4]. The establishment of NATO in 1949 was particularly important for the manufacturing industry, and especially relevant for this thesis, as it resulted in several financial aid programmes aimed at rebuilding

[3] There are no isolated data available for manufacturing industry in Norway until 1970. All available statistics combine the manufacturing, mining and power supply. As it is not possible to give an account of manufacturing's isolated impact on employment and GDP, I rely on statistics for the secondary industries.
[4] The European Recovery Program (known as the Marshall plan) was passed by the US Congress 2 April 1948, granting a total of 13,2 billion USD to help rebuild Europe (including the Soviet Union) (SNL 2019b).

the European defence industry. In a Norwegian context, this entailed increased production activities for Kongsberg Våpenfabrikk (KV – weapons factory) and the Raufoss Ammunisjonsfabrikker (RA – ammunitions factory), which became essential drivers for the industrialization of Norway (Wicken 2009). By 1950, the employment rate for secondary industries reached an all-time high of 30%, making up 27% of the GDP. Along with the process industry, the manufacturing industry was the economic backbone of the Norwegian economy before oil and gas was discovered on the Norwegian continental shelf in the 1970s. The O&G industry quickly became the dominant industry in terms of GDP (17% in 1985) and exports (38% in 1985) (Norsk Petroleum 2019), also forming a market for the manufacturing industry.

In line with global tendencies within the manufacturing industry, as discussed in section 2.1, Norway has experienced outsourcing and offshoring (Molberg 2004), a dismantling of manufacturing activities, and a subsequent decrease in employment rates since the 1970s (Statistics Norway 2019b). Figure 6 illustrates the drop in employment rates for Norwegian secondary industries (including manufacturing) from 371 000 in 1974 (peak year) to 231 000 in 2018, making up 8% of the employed labour force. Subsequently, the manufacturing industry's contribution to the GDP dropped from 18,3% in 1974 to 5,7% in 2018 (World Bank 2019b). In comparison, and reflecting the earlier statement on Norway being an oil and gas dependent economy, the O&G sector employed 51 000 workers directly (170 200 both directly and indirectly (von Brasch, Hungnes, and Strøm 2018)) and constituted 19% of the GDP (Statistics Norway 2019b). These numbers illustrate the manufacturing industry's relatively small size and modest impact on the Norwegian economy. However, on a regional level and in terms of regional development, the Norwegian manufacturing industry has a substantial impact.

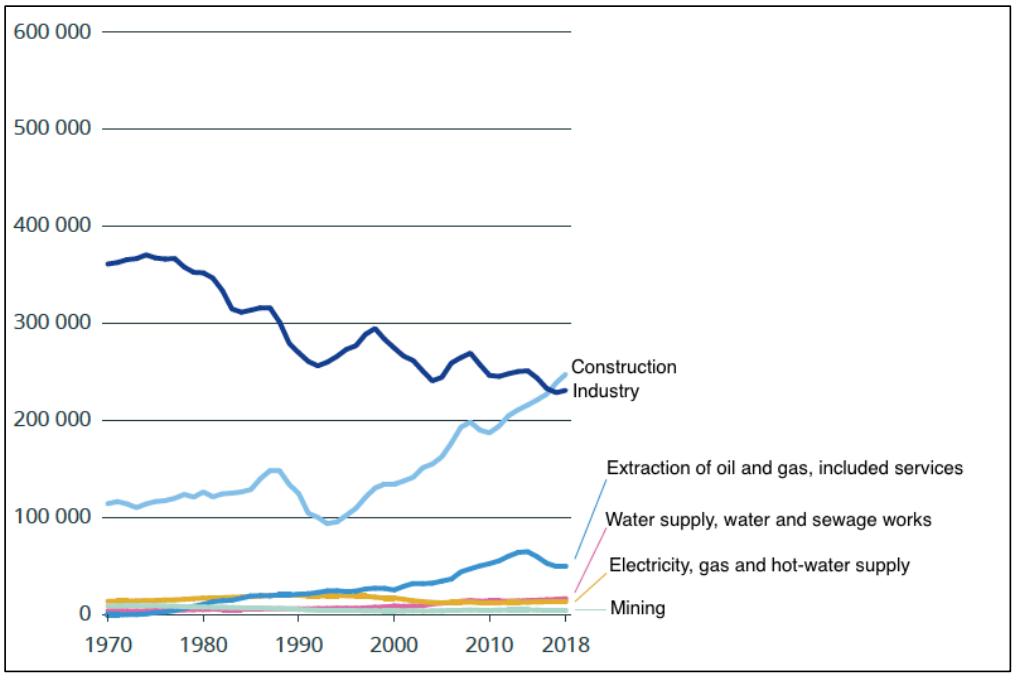

Figure 6 - Employment rates in the Norwegian secondary industries (1970-2018). Source: Statistics Norway (2019b)

2.3.1 Industry and innovation policies for regional development

The manufacturing and process industry continue to be, in addition to the primary industries, an important employer in the non-city regions. The regional distribution of the Norwegian industry also reflects its natural resource base. In the development of energy intensive process industries, such as the aluminium, the access to hydro power was essential. As a result, smelting plants were located in rural areas with beneficial natural conditions (i.e. high mountains and readily available water basins) for the development of hydroelectric power plants. Similarly, other industries, such as the origins of the Raufoss industry, were located near rivers and water falls that were used as power for production (Holmen and Wang 2005). Kongsberg, on the other hand, was established as a mining town in 1624 due to silver deposits. Later on, in the 19th century, the establishment of RA and KV was based on military strategic decisions, locating them further away from the Swedish boarder (see A1/Evolution for a more detailed elaboration). The dispersed localization pattern of Norwegian industry is also reflected in industry and innovation policies.

The Norwegian state has been essential in the development of both national and regional industrial capabilities taking on the role as e.g. owner, R&D provider, and policy maker (Wicken 2009; Fagerberg, Mowery, and Verspagen 2009; Lie 2016). The development of Norwegian industrial and innovation policies and tools, which have emphasised the further development of regional industries, has been instrumental in this regard. The state involvement must be seen in relation to the overall regional policy aimed at strengthening growth and economic development in the non-urban areas (Ministry of Local Government and Modernisation 2015). In regard to industrial development, one key example is the establishment of the Rural Development fund (DU) in 1961 (named the Industrial Development Corporation of Norway (SIVA[5]) today), which was essential in the development of Norwegian industry as 'the main vehicle for regional innovation support' in the post-war period (Benner 2003, 139). Several innovation programmes have been introduced over the course of the last two decades (see Jakobsen et al. 2012, for a detailed overview), some of which have been subject to analysis in economic geography studies (Isaksen 2009; Jakobsen et al. 2012; Njøs and Fosse 2019; Carlsson et al. 2014). The Norwegian VRI[6] programme was introduced by the Research Council of Norway (RCN) in 2007 and illustrates the regional emphasis of Norwegian innovation policy. The programme's theoretical foundations was the regional innovation system approach (Asheim and Isaksen 1997; Asheim 1995; Asheim and Gertler 2005) and constituted the NRC's 'new initiative towards research and innovation at a regional level' (Jakobsen et al. 2012, 135). The VRI was made up of 15 regional initiatives, covering all 19 (in 2007) counties in Norway, that aimed to bridge the gap between R&D institutions and regional industry actors by promoting 'company-driven innovation projects' and 'strategic R&D projects' (Research Council of Norway 2007).

A second innovation programme with a regional (and local) emphasis is the Norwegian Centre of Expertise (NCE) programme, which is of particular importance to this thesis focusing on cluster evolution and dynamics (in A1/Evolution and A2/Absorptive). Starting in 2006, the NCE programme is a collaboration between Innovation Norway[7], The Industrial Development

[5] A public enterprise owned by the Norwegian Ministry of Trade, Industry and Fisheries, that facilitates 'innovation by building, owning and developing infrastructure for industry, startups and research environments' (Siva 2019).
[6] VRI is the Norwegian abbrevioation for *Virkemidller for regional FoU og innovasjon*. The English title is *Programme for Regional R&D and Innovation*.
[7] Owned by the Norwegian Ministry of Trade, Industry and Fisheries (51%) and the county municipalities (49%) Innovation Norway funds start-ups and 'innovation and development of Norwegian enterprises and industry' (Innovation Norway 2015)

Corporation of Norway (SIVA) and the RCN, funded by the Norwegian Ministry of Trade, Industry and Fisheries (NCE n.d.). The NCE programme was established in order to 'strengthen innovation and internationalization processes in specific clusters' by bringing together and 'promoting collaboration between firms, R&D and educational institutions and the public sector' (Isaksen 2009, 1157). Today there are 13 NCE clusters, and an additional 5 clusters that continue to use their NCE status after the 10 year funding period ended (in 2016). Two of these are the Kongsberg (NCE Systems Engineering) and Raufoss (NCE Raufoss) clusters. As of 2014, the NCE programme became a part of the Norwegian Innovation Clusters (NIC) programmes, which provides funding for cluster programmes at different levels: Arena (early phase cluster projects), NCE (mature clusters with a national imprint), and Global Centres of Expertise (Norwegian clusters that have a global position) (Innovation Norway n.d.). The latest addition to the Norwegian innovation scheme that aims to develop existing regional capabilities is the Norwegian Catapult (Norsk Katapult) programme. The Catapult programme is funded[8] and governed by the same actors as the NCE programme. The aim is to create and develop 'a national infrastructure for innovation' within areas of the Norwegian industry sector with great economic potential' (Norsk Katapult n.d.-a). This infrastructure especially targets SMEs, which constitute 99,5% of Norwegian industry (Ministry of Trade Industry and Fisheries 2012). There are currently 5 Catapult centres, on *Manufacturing Technology* (located at Raufoss), *Future Material*, *Ocean Innovation*, *Sustainable energy*, and *Digicat* (Norsk Katapult n.d.-b). The Catapult on Manufacturing Technologies is especially relevant for this thesis as it is located at Raufoss, builds on the NCE Raufoss legacy, and aims to become a world class technology centre, consisting of several mini factories with an 'Industry 4.0 standard'(MTNC n.d.), which integrates all levels of education. As such, the Catapult centre embraces the thesis' core topics of knowledge development, technology and innovation, and reflects the current situation that many Norwegian manufacturers find themselves – in need of upgrading in terms of technological and knowledge capabilities.

[8] The Norwegian government has proposed a 125 million NOK (approx. 13,6 million USD) grant for the scheme in 2019, which is the equivalent to the 2018 grant.

2.4 Preconditions for implementation of advanced manufacturing technologies in Norway

When discussing advanced manufacturing technologies and their actual and potential influence on Norwegian manufacturing industry, I find it relevant to elaborate on how existing socio-economic, political and educational preconditions could facilitate the implementation of these technologies. These preconditions relate to characteristics of the existing economic system, the organization of working life, and the level of education.

It has been well established, in the Varieties of Capitalism (VoC) literature (Hall and Soskice 2001; Hall and Thelen 2008), that the design of an economic system has an influence on the role of the state (and vice versa) in terms of how (and to what extent) it interacts, collaborates and coordinate with economic actors, and as such contribute to economic development. Hall and Soskice (2001) identify two ideal types of political economies (hybrids are likely to occur in empirical contexts), the liberal market economy (LME) and the coordinated market economy (CME). In a LME, often exemplified by reference to the USA, coordination of relationships between firms and suppliers, labour and customers are taken care of by market mechanisms. The ideal is a free market, with limited or no state intervention. However, Mazzucato (2011, 2015) nuances this detached view of the state in LMEs by demonstrating the entrepreneurial role of the state in funding R&D and supporting the development of key enabling technologies such as ICT and biotechnology in the US. In what has been perceived as the archetypical LME, the US government continues to support industrial development, beyond correcting market failures such as basic research and public goods (e.g. defence and infrastructure industry), through e.g. providing public venture capital (the Small Business Innovation Research programme), and through public procurement (particularly related to defence product/goods) (Mazzucato 2013). In an ideal type CME, often exemplified by Japan and Germany, the state takes on a more active role than in LMEs and facilitates coordination and collaboration between economic and non-economic actors. Consequently, non-firm actors such as the nation state and regional and governmental agencies and institutions become important in regard to economic development. Furthermore, in CMEs the state takes on an active role in the development of its industries through policy interventions and innovation schemes (Hall and Soskice 2001). In Norway, defined as a coordinated market economy, the state takes on an active role and contributes to innovation and industrial development through implementing innovation policies (as demonstrated in section 2.3.1). Within the Norwegian 'variant' of an CME, the Norwegian

state has, both historically and currently, taken on an active role as a business owner. Historically, state ownership was decisive for economic development after WWII, and was extended when the O&G industry emerged in 1970s, resulting in the establishment of Statoil (today Equinor). Currently, the state is a partial owner in 5 of the 7 largest companies listed on the Oslo Stock Exchange (from 34–64% of company shares) (Lie 2016). The extensive collaboration between industry, state and labour in Norway has been conceptualised as the Norwegian model (Andersen et al. 2007; Ravn and Øyum 2018).

The Norwegian model, a variant of the Nordic model (Andersen et al. 2007) which is found in different forms in the Nordic countries, is characterised by the tripartite collaboration between state, employer associations and trade unions. Furthermore, the model is characterised by high levels of trust between employer and employees (Ravn and Øyum 2018). An expressions of this trust is found in Norwegian manufacturers, where the hierarchy in terms of decision power and organization is relatively flat, resulting in autonomous skilled workers that are willing and able to make decisions without consulting a superior engineer. In A4/Reshoring, we demonstrate how the organization of working life in Norway, with low levels of hierarchy and high levels of trust and autonomy, constitutes a competitive advantage for manufacturing firms and has contributed to the relocation (reshoring) of some firms and activities to Norway. The autonomy of skilled workers reflects well-qualified and well-educated workers, which are provided by a well-developed – free – education system that is able to educate a highly skilled labourers on all academic levels.

The education system is the responsibility of the Ministry of Education and Research (Ministry of Education and Research 2014) and the state funds c.84% of the total education expenditure, covering all levels of public education, from primary school to university (Statistics Norway 2019c). The overall functioning of the Norwegian education system, I will argue, is reflected in the level of education found in the population. In Norway, 37,2% of the population holds a high school diploma, whereas 34,1% of the population holds a university or university college degree (Statistics Norway 2019a). If we consider OECDs numbers for the economically active population, ages 25-64 (retirement age in Norway is admittedly higher), the numbers increase to respectively 38,9% and 43,5% (OECD 2019). Norway, then, is ranked as the top 12th OECD country in terms of tertiary education, well ahead of e.g. Germany where 29,1% of the population has a tertiary education (29th place). Conversely, Germany is ranked in 6th place in terms of upper secondary education (57,6%), while Norway is ranked as 24 (OECD 2019).

Evidently, although the Norwegian population is relatively well-educated, and education is uniformly available, the access to qualified and educated personnel is not uniform. Additionally, the statistics do not say anything about the quality of the education and how it fits with the existing and future needs within the manufacturing industry. This is discussed in A3/Vocational, where we identify a need for an upgrading of existing, or implementation of new, vocational education programmes in order to meet new knowledge demands posed by the implementation of advanced manufacturing technologies in production lines.

2.5 Summary

This chapter has elaborated on the empirical context of the thesis. The global, and subsequently the Norwegian, manufacturing industry has undergone profound technological changes and experienced subversive geographical shifts within the last century. From being an industry of the global North, manufacturing is now deeply rooted in Asian economies such as China, Japan and Taiwan and South Korea. Simultaneously, the mass customization mode of production has gained influence as an alternative to mass production, although the latter continues to be widespread. Current technological changes within the manufacturing industry are ushered inn under the banner of Industry 4.0 which narrative has created a momentum for technological upgrading in manufacturing. Although the thesis adopts a non-revolutionary understanding of the concept, the visions and technologies connected to it have created a momentum for technological and knowledge upgrading amongst manufacturers.

3 Theoretical background

The underlying theoretical ambition of this thesis reflects my rather pragmatic relationship with, and attitude towards, the use of theory and theorizing. By pragmatic, I mean empirically informed in selection of theoretical approaches, but also inspired by the pluralist traditions within economic geography where combinations of different theoretical concepts and approaches are employed in order to promote our understanding of the economic landscape (Peck 2015). In line with Swedberg (2016), the application of theory in this thesis is regarded as a process of producing insights into phenomena and adding to 'gaps' in the existing literatures. Theoretical approaches have been selected on the basis of which theoretical apparatus, within the field of economic geography and related disciplines, I (or we) found most appropriate to analyse an empirical question. This has certainly resulted in a wide application of theoretical approaches and frameworks, leading to the demanding task of binding the four articles together in the following sections.

The four articles that constitute the basis of this thesis (see *Part 2*) are independent units and have developed their own theoretical framework in order to answer the articles' research questions and provide novel theoretical (and empirical) insights to the field of economic geography. This chapter, then, will not provide an in-depth discussion of the theoretical approaches that have been employed in the articles. Rather, the chapter is intended to bridge the four articles and illustrate how they together make a greater whole. To do so, I first discuss the theoretical underpinnings (3.1) of the thesis and how it draws on notions from both evolutionary and relational economic geography. Second, I briefly discuss the theoretical approaches employed in the four articles, their origins, and how they relate to thesis' core topics (knowledge development, technology and innovation). Then I discuss how an emphasis on agency and the vital role of non-firm actors unify the four articles, before I situate the thesis within the broader field of economic geography.

3.1 Theoretical underpinnings

Economic geography's theory-culture has been characterised as 'robustly polycentric and pluralist' (Peck 2015, 1). The statement reflects how the field of economic geography (EG) has experienced several 'turns' – institutional (Martin 2000; Amin 2001; Gertler 2010), relational (Bathelt and Glückler 2003) and evolutionary (Boschma and Frenken 2006) – all of which have favoured 'some influences of the social and economic reality while neglecting others' in studies

of economic capitalist processes (Bathelt 2006, 223). Additionally, Peck's statement reflects both economic and non-economic geographers' disposition for borrowing and adopting theories from other disciplines within the social sciences, such as sociology and political science, which has resulted in a diversity of theoretical approaches within economic geography. In the following, I will briefly elaborate on the evolutionary, relational and institutional 'turns' within economic geography and discuss how they influence the theoretical frameworks and concepts employed in this thesis.

3.1.1 Evolutionary, relational and institutional economic geography

As I have a personal interest in history and a firm conviction that history – and geography (Massey 1989) – matters, the stream of literature within evolutionary economic geography (EEG) that has developed since the seminal contribution by Boschma and Lambooy (1999) has, despite its quantitative origins, had substantial influenced on this thesis that apply a qualitative approach. Inspired by works within the field of evolutionary economics such as Nelson and Winter (1982), Arthur (1994) and Fagerberg (2003), EEG's basic concern 'is with *the processes by which the economic landscape – the spatial organization of economic production, distribution and consumption – is transformed over time*' (Boschma and Martin 2007, 539 – emphasis in original). The evolutionary approach was introduced in addition to, and different from, the neoclassical and institutional approaches, yet drawing on the two in developing EEG (Boschma and Frenken 2006). Early contributions built on biological evolutionary concepts (variety, selection, adaptation and retention) and economic (path-dependence, lock-in) notions (Boschma and Frenken 2006), and especially the latter notions remain core topics of research within economic geography today. Evolutionary economic geographers have been preoccupied with analysing 'uneven geographical patterns, as embodied in agglomerations, centre-periphery patterns, clusters and networks' (Boschma and Frenken 2018, 214) and processes that lead to their transformation (diversification, industrial branching and path creation). The ability to explain 'the spatial evolution of firms, industries, networks, cities and regions' (Boschma and Frenken 2011, 295) has made the evolutionary approach an attractive one within economic geography. The early versions of EEG by Boschma and Frenken (2006, 2007), which were quantitatively oriented and had firm populations as units of analysis, have been complemented by Martin and Sunley (2006, 2007) and an enhanced emphasis on institutional and relational aspects, making EEG more context (empirically) sensitive. However, EEG has received criticism for overlooking the role of power and institutions (MacKinnon et al. 2009) and geographical political economy (GPE) has been proposed as a fruitful source of inspiration

(Hassink, Klaerding, and Marques 2014), emphasising evolution as an important aspect in economic geography rather than a separate EEG (ibid.).

The relational turn pays explicit attention to the importance of interaction between economic actors in space (Bathelt and Glückler 2003). As such, the relational approach to economic geography aims 'to formulate research questions which are associated with the analysis of economic relations using a geographical lens' (ibid., 128). By focusing on 'the people, firms, and other organizations which are involved in economic-decisions making', in addition to those who are influenced by these economic actions, 'relational economic geography enables a complex understanding of economic actions and its localised consequences' (ibid., 129) The unit of analysis in relational economic geography is not space itself, but rather economic processes, such as innovation, learning and collaboration, understood through a geographical lens. It is the geographical lens that captures the embeddedness of economic and non-economic actors and how these actors are influenced by the socio-economic and historical context prevalent in that territory (Bathelt and Glückler 2018). The perhaps most influential relational approach to economic geography is represented by the global production network framework (Coe, Dicken, and Hess 2008; Coe and Yeung 2015), which is the theoretical framework that this thesis employs which is most influenced by relational aspects.

The institutional turn in economic geography recognises that the evolution and current form of the economic landscape cannot be understood without a thorough understanding of the institutions that economic activities are dependent on and shaped by (Martin 2000; Amin 2001). The institutional turn was inspired by arguments on the importance of socio-institutional structures brought about by regulation theorists, and the emphasis on socio-cultural processes influence on the economic brought about by the cultural turn in economic geography (Crang 1997). Furthermore, it reflected an increased emphasis on 'institutionalism' in other social sciences, 'especially in economics, sociology and political science'(Martin 2000, 78). An institutional approach to economic geography, then, 'aims to explain the transformation of economic landscapes through an analysis of how institutions change along a path-dependent trajectory' (Hassink, Klaerding, and Marques 2014, 1301). In a call for a 'reconstituted' institutional economic geography (IEG) Gertler (2010, 6) argues for an evolutionary understanding of institutions, highlighting 'how individual institutions – as well as their interaction with other institutions – evolve and change over time'.

3.1.2 What kind of economic geography?

Entering the field of economic geography in 2016 (the beginning of my PhD candidacy) and reading theoretical approaches backwards, i.e. from most recent to initial contributions, evolutionary, regional and institutional economic geography (EEG, REG and IGE), at least in my reading of economic geography, seem quite similar and at some points overlapping. Hassink, Klaerding, and Marques (2014) have provided an insightful contribution on the intertwined turns, both critiquing the neoclassical approach's inability to account for emerging research objectives such as the socio-cultural embeddedness of firms and knowledge and competence creation within firms. In the following sub-sections I will discuss how the three approaches to economic geography connect, how they differ, and how they contribute to the theoretical developments done in this thesis.

The first, and perhaps most striking, similarity between EEG, REG and IEG is that evolution is an explicit part in all three approaches. It is obvious that 'evolution' is explicit in EEG. In REG, however, Bathelt and Glückler (2003, 133) build their conceptual framework around four pillars (or *ions*), where evolution constitutes one and its ability to provide analytical purchase for 'the implication of historical structures and processes on today's decisions'. History and time are thus prominent aspects in both approaches. This thesis also emphasises history and real time (Henning 2019), especially in A1/Evolution, where a longitudinal study of the development of the Kongsberg and Raufoss clusters is conducted. In IEG, studies of the evolution of institutions is a key undertaking and regarded as essential in order to understand the current economic landscape. This is a core topic in A3/Vocational, where we highlight how vocational education institutions change and co-evolve with technology and industry.

A second, and related, similarity concerns the emphasis on path-dependence in REG, EEG and IEG both taking into account the firm's social relations and its historical (path dependent) development. Aiming to explain how regional economies evolve over time, the path-dependence literature has been a prominent stream within economic geography the last two decades and resulted in numerous studies and conceptual refinements (Martin and Sunley 2006; Isaksen 2014; Steen 2016b; MacKinnon et al. 2019; Isaksen and Trippl 2016). Institutions have also been identified as key actors in path development processes. The geographical political economy approach (GPE) (Pike et al. 2009; MacKinnon et al. 2009; Pike et al. 2016) has possibly been the most influential approach in this endeavour, and in bridging IEG and EEG (Hassink, Klaerding, and Marques 2014). This is illustrated by MacKinnon (2009, 499) who

argues that path dependence is anchored in 'institutional and evolutionary economics which highlights the influence of past decisions and experiences in shaping how economic actors respond to wider processes of economic change'. Although Bathelt and Glückler (2003) include path-dependence as a key aspect in their conceptual framework, it is EEG which has become the approach to economic geography that has pioneered research within the path dependence literature (Hassink, Isaksen, and Trippl 2019). In A1/Evolution, an understanding of path-as-process is adopted and drawn upon in explaining the evolution of two manufacturing clusters, especially inspired by recent (GPE) contributions that emphasise the role of the state in path creation (MacKinnon et al. 2019). Article A3/Vocational touches upon the potential of path extension (Isaksen 2014) in the two regions and how advanced manufacturing technologies might prolong manufacturers' current development paths with regards to industry sector.

Although there are similarities between the three approaches to economic geography, there are also differences. Due to this thesis emphasis on knowledge (and technology) development processes, it is necessary to discuss how the approaches' understanding of knowledge differ. Social interactions, such as knowledge creation, have been considered as central in economic geography analyses (Storper 1997). However, the way in which knowledge and knowledge creation is understood in EEG and REG differs. Within EEG knowledge is regarded as something that is historically accumulated and constitutes the basis on which future knowledge absorbed (Boschma and Lambooy 1999; Boschma and Frenken 2006). EEG's perspective on knowledge is somewhat constraining, which is reflected in terms such as path dependence in general, and 'lock-in' in its more extreme version In REG, however, learning and knowledge creation is regarded as the result of social interactions between different agents, which in turn are embedded in existing social and economic structures (Bathelt and Glückler 2003). As such, REG is more open to learning and knowledge development through networks (both existing and potential), whereas EEG focuses more on limitations in the knowledge structures. In terms of knowledge development, IGE provides insights on how institutions, e.g knowledge institutions, and their interactions with other institutions evolve over time (Gertler 2010). In EEG, knowledge institutions are understood as path dependent as their educational provisions reflect the existing knowledge needs. However, an education institution does not necessarily lead to negative 'lock-in', where it is unable to adapt to changing knowledge demands. Rather, they support the industry through providing knowledge and competence, and as such, can contribute to path extension (Isaksen 2014). Furthermore, within EEG, institutions are also able to transform over time as they can co-evolve with firms (industry) and technology (as pointed

out in A3/Vocational) and provide knowledge that is relevant and sought after in the industry. This thesis adopts a relational view of knowledge and argues that evolutionary economic geography could benefit from adopting an understanding of knowledge as something that is continuously created and recreated by social interaction between different actors. Thereby, the thesis contributes to the debate on how EEG could be developed through 'conceptual exchange' with REG (and IEG) (Hassink, Klaerding, and Marques 2014, 1304).

To answer the initial question (in subheading 3.1.2), I find that this thesis relates to both relational, evolutionary and institutional economic geography, and adopts theoretical approaches and concepts from the broader field of economic geography in its analysis. In line with the polycentric and pluralistic theory-culture (Peck 2015) in economic geography, and as proposed by Hassink, Klaerding, and Marques (2014), I find that cross-fertilization between the different 'turns' within economic geography, and within the different related social sciences, fruitful. This can be read in in light of my previously declared pragmatic relationship with theory, which entails theoretical employment being based on what I (or we) find most useful in analysing an empirical phenomenon. This has resulted in the application of several concepts and theoretical approaches from the field of economic geography, which in addition to being discussed and justified in the four articles in Part II, are discussed in the following.

3.2 System approaches to understanding regional economic development

This section discusses the application and interconnection of theories and perspectives on clusters, regional innovation systems and global production networks. A commonality between the three approaches is that they have all been criticised for providing snapshots of well-functioning clusters, regions and production networks, not paying sufficient attention to long-term development and changes within these systems (Boschma and Frenken 2018; Trippl et al. 2015; Asheim, Grillitsch, and Trippl 2016; Barratt and Ellem 2019). As such, they have struggled to reveal dynamic processes within the economic landscape. However, by drawing on ideas and conceptions from relational and evolutionary economic geography, I find that the three are useful in terms of developing our understanding of changes and development within the economic landscape when coupled with evolutionary conceptions. In this thesis, a system approach is understood as an interconnected system constituted by firm (economic) and non-firm (non-economic) actors and the relations between them. These systems are conceptualised as open and interconnected, meaning that relations between actors are not restricted within one

system (Trippl et al. 2015). Rather interaction can take place between different systems and different scales. Figure 7 illustrates how clusters and innovation systems are regarded as open systems, with interaction between systems and actors within different systems, and how the multiscalar global production network framework transcends clusters and innovation systems acting as 'global pipelines' (Bathelt, Malmberg, and Maskell 2004; MacKinnon 2012), thereby connecting actors at different scales and within different systems. The characteristics of relations within the three system approaches do, however, differ. In the cluster approach and the GPN framework, relations are based on (more or less contested) economic transactions between firms, and between firms and non-firm actors within production networks. On the other hand, relations within the RIS approach are more focused on the exchange of knowledge and interactive learning between different actors within the system. As relations between actors within the systems are essential, I regard the system approach as relation approaches to economic geography. Although it is only the GPN framework that is defined as such (Coe and Yeung 2015), I regard the cluster and RIS approaches as relational as well. Furthermore, by combining relational and evolutionary conceptions, drawing on path development processes and notions of (co)evolution from EEG, emphasising how firm and non-firm actors, institutions, governments, and industry transforms over time, the system approaches are capable of revealing both long term changes (evolution) and current dynamic processes within the economic landscape.

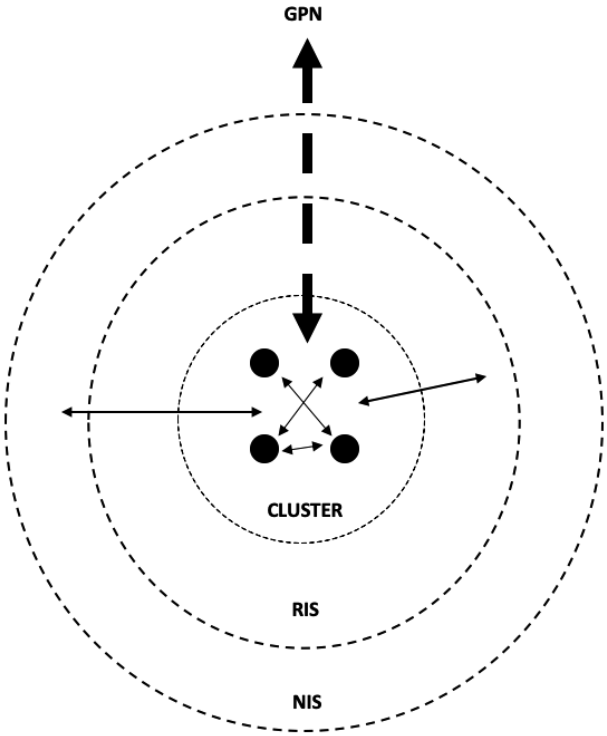

Figure 7 - Visualization of interaction between the system approaches employed in the thesis

3.2.1 Clusters

Since the seminal contribution on *The Competitive Advantage of Nations* by Porter (1990), the cluster concept has been one of the most influential theoretical constructs within economic geography and policy (OECD 1999; Martin and Sunley 2003; Ebbekink and Lagendijk 2013). Porter (2000, 15) defines clusters as 'geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions (e.g. universities, standards agencies, trade associations) in a particular field that compete but also cooperate.' These clusters are according to Porter (2000) apparent in economies on all scales, from national to local, and particularly so in 'advanced economies'. The competition and rivalry between cluster firms competing in the same industry and demanding customers are regarded as important drivers for innovation (Porter 1990). The literature differentiates between generalised (Jacobs 1969) and specialised clusters (Marshall 1920). The former is characterised by agglomerations of firms with limited interaction, and the latter is characterised by substantial

interaction and learning between firms that results in knowledge spill-overs (Porter 2000). It is the specialised cluster that has received widespread scholarly attention with an emphasis on intra-cluster and inter-firm dynamics such as collaboration and interactive learning (Bathelt, Malmberg, and Maskell 2004; Audretsch and Feldman 1996). The cluster concept has been heavily criticised. Martin and Sunley (2003, 11) problematise the entire concept and its 'intentional' fuzziness, especially focusing on the lack of geographical (ranging from local to national economies) and industrial boundaries. However, their final prediction concerning the future of the concept – that it will, like all fads, 'become unfashionable' (Martin and Sunley 2003, 29) – did not hit the target.

Geographers have adopted the cluster concept and employed it in studies on learning, knowledge and innovation dynamics (Isaksen 2009; Onsager et al. 2007; Kesidou and Snijders 2012; Harris et al. 2019). The underlying idea is that the geographical, cognitive, institutional, social and organizational proximity (Boschma 2005) that localised clusters enhances the ability to innovate. In line with the relational turn's emphasis on corporate linkages and relationships between firms (Bathelt and Glückler 2018), Bathelt, Malmberg, and Maskell (2004) conceptualised 'local buzz' on the cluster micro level. The concept covers both formal and informal interaction between cluster firms that stimulate collective learning and innovation, which is enabled by geographical proximity. The 'local buzz' is accompanied by 'global pipelines', which refers to strategic access to extra-cluster knowledge linkages to actors and clusters elsewhere and regarded as essential in order for clusters and firms to be innovative. In more recent contributions, the cluster concept has been criticised for oversimplifying the spectre of networks by reducing local interaction ('local buzz') to informal linkages based on dense social networks and global linkages ('global pipelines') to strategically selected and formal networks (Grillitsch and Trippl 2014; Trippl et al. 2015; Martin et al. 2018).

Previously dominated by snap-shot studies of successful clusters (Trippl et al. 2015), cluster research has within the last decade – influenced by perspectives and ideas from the 'evolutionary' turn in economic geography – shifted towards studying the emergence and evolution of clusters. In this stream of evolutionary economic geography literature, the cluster life cycle approach (Menzel and Fornahl 2010; Fornahl, Hassink, and Menzel 2015) and clusters as complex adaptive systems (Martin and Sunley 2011) have been prominent topics for research. By conceptualizing clusters as complex adaptive systems (however geographically

defined), one opens up for an evolutionary perspective on clusters, which are depicted as complex entities able to adapt to technological change and subsequent knowledge demands.

Firms' ability to take advantage of novelty is influenced by the absorptive capacity of the firm, i.e. their ability to recognise, assimilate and disseminate new knowledge (or technology) within the company. The absorptive capacity concept has also been aggregated to a cluster level (Giuliani 2005), where the cluster absorptive capacity has been conceptualised as more than the sum of cluster firms' absorptive capacity. However, others streams of literature have aggregated absorptive capacity concept to regions (Vang and Asheim 2006) and regional innovation systems (Trippl, Grillitsch, and Isaksen 2017). In this thesis, cluster absorptive capacity is recognised, in line with Giuliani (2005), as something more than the sum of firm capacities, and cluster intermediaries are proposed as detrimental to enhance clusters absorptive capacity. Furthermore, in A2/Absorptive, we find that the cluster absorptive capacity concept provides increased analytical purchase when investigating the development of clusters, as it provides insight on how actors within a cluster collaborate to develop their capabilities, which in turn results in the evolution of the cluster as a whole.

This thesis contributes to theoretical advancements within the evolution of clusters debate in A1/Evolution, which draws on contributions from the path development literature (Martin and Sunley 2006; MacKinnon et al. 2019; Henning 2019) to explain the relationship between state (non-firm actor) interventions and cluster evolution in two Norwegian manufacturing clusters. As such, A1/Evolution contributes to recent calls for research on long-term cluster evolution (Trippl et al. 2015). Additionally, A2/Absorptive touches on this line of research with a study of how cluster intermediaries contribute to the clusters absorptive capacity (Giuliani 2005) and facilitate implementation of advanced manufacturing technologies, which in turn influence the evolution of the clusters.

The cluster approach ties in with the somewhat corresponding conceptualizations in parallel debates. Despite some early contributions emphasising the overlap between the literature on clusters and innovation systems, e.g. Lundvall and Borrás (1999) who argued that cluster(s) constitute the core of a RIS, it is only recently that the interconnectivity between the cluster approach and regional innovation systems have been recognised and used in combination (Martin and Trippl 2017). In order to increase our understanding of cluster evolution as a place-

specific phenomenon it is essential to understand how they are formed by regional innovation systems (Trippl and Tödtling 2008; Trippl et al. 2015).

3.2.2 Regional innovation systems

The RIS approach is an adaptation of the literature on national innovation systems, which was developed, conceptualised and tested in the seminal contributions of Freeman (1987b), Lundvall (1992) and Nelson (1993). The NIS concept moved away from the idea of innovation as a linear process where investments in R&D lead to inventions that can be produced, marketed and commercialised. Rather, it acknowledges the innovation process as dynamic and interactive, where interactive learning and cumulative knowledge processes lead to innovation (Lundvall 1992; Asheim, Grillitsch, and Trippl 2016). Emphasising the composition of actors within an innovation system and the relations between them, the NIS and RIS approaches were developed in order to explain why there was substantial difference between nations and regions respectively in terms of innovation capacity and competitiveness. The RIS approach, pioneered by Cooke (1992) and Asheim (1995), adopted Lundvall's (1992) understanding of learning and innovation as core elements of economic development, and has been widely adopted within economic geography and innovation studies (Isaksen, Martin, and Trippl 2018) A RIS can be defined 'as the institutional infrastructure supporting innovation within the production structure of a region' (Asheim and Gertler 2005, 299) and consists of three core elements; 1) *Actors* that are made up of industries or firms within a region, and regional the support system of organisations such as education institutions, research institutes and other knowledge providing actors, 2) *Networks* that facilitate the interaction between the different actors within the RIS, providing a dynamic and interactive learning process, and 3) *Institutions*, both formal and informal, that influence the functioning of the RIS (Isaksen, Martin, and Trippl 2018). The RIS 'has become a key approach for explaining the uneven geographical distribution of innovation activities in space' and has had widespread influence on regional innovation policies (Isaksen, Martin, and Trippl 2018, 2).

The RIS is, similar to the NIS (Chaminade, Lundvall, and Haneef 2018), conceptualised as open systems (Isaksen, Martin, and Trippl 2018) and, as such, connect to other RISs and extra-regional actors within and beyond the NIS (as illustrated in Figure 7) (there is also a literature in global innovation systems, see e.g. Binz and Truffer (2017)). However, the RIS approach emphasises that learning and innovation processes are 'embedded in specific socio-cultural settings' (ibid., 2). The approach's regional emphasis, which remains prominent in academia

and policy (Asheim, Grillitsch, and Trippl 2017b), is based on the notion of the region and regional economy as 'a key component of national economic competitiveness' (Dicken and Malmberg 2001, 346).

A distinction is made between narrow and broad regional innovation systems (Asheim and Gertler 2005). A narrow conceptualization of RISs includes universities and R&D institutes, firms and research institutes (both private and public) as key actors within a RIS, and the collaboration between them as the key process for learning and innovation (ibid.). Within the narrow conceptualization, the science- and technology-based innovation model (STI) is central and analytic (codified) knowledge is regarded as the main contributor to innovation. A broad (borrowed from the NIS literature), conceptualization of RIS on the other hand, incorporates all aspects and actors within the economic structure that influence learning and innovation processes (Lundvall 2010). Within the broad conceptualization, synthetic (tacit) knowledge play a vital role and the doing-using-interacting (DUI) mode of innovation is prevalent.

Similar to the cluster concept, the RIS concept has been criticised for providing static descriptions of successful regions (Boschma and Frenken 2018; Phelps, Atienza, and Arias 2017) and a reorientation of RIS studies towards investigating RIS evolution has been suggested as an area for future research (Asheim, Grillitsch, and Trippl 2016; Boschma and Frenken 2018) with emphasis on how RISs change and transform due to technological and societal changes and globalization. A3/Vocational contributes to this theoretical development by studying the co-evolution of industry, education and technology, and how vocational education institutions are key actors in manufacturing regions that are implementing advanced manufacturing technologies. As such, the thesis adds to the debate on the evolution of innovation systems in evolutionary economic geography.

3.2.3 Territorial aspects of different types of knowledge

In this thesis, synthetic and analytic knowledge[9] is not regarded as dichotomies. Rather, the two knowledge types are understood as ideal knowledge types, which in practical industrial settings will (to different extents) be combined, and both individuals and firms rely on and even exploit different combinations of the two. An individual can have a predominant synthetic knowledge

[9] The third knowledge type, symbolic, is not discussed here as it primarily relates to creative industries (see e.g. (Asheim et al. 2007).

while at the same time being able to incorporate knowledge of a more analytical character, and vice versa. Manufacturing firms, on the other hand, might depend more on an analytic knowledge base when acquiring extra-local codified knowledge related to e.g. advanced manufacturing technologies, as pointed out in A2/Absorptive. However, in the implementation phase, the firm could rely more on synthetic tacit knowledge developed through experience from on-the-job training, as demonstrated in A3/Vocational. The two knowledge types have, at least in their ideal forms, different territorial aspects. Synthetic knowledge, or tacit (engineering-based) knowledge, has a (more or less) practical character, where know-how is developed through e.g. on-the-job training and experience. As such, synthetic knowledge is hard to codify (write down) and diffuse, and is to a larger degree anchored in a territory. Thereby, as it is difficult to replicate, synthetic knowledge constitutes a local or regional competitive advantages that local and regional firms can exploit (Maskell and Malmberg 1999; Malmberg and Maskell 2002). Analytical knowledge bases, or science based knowledge, then, is characterized by being codified and as such more easily diffused and globally available (Herstad, Aslesen, and Ebersberger 2014). However, the ability to exploit analytical knowledge depends on individuals' or firms' existing knowledge, which determines whether or not they are able to exploit the knowledge available to them (Laestadius 1998; Asheim and Gertler 2005; Asheim and Coenen 2005; Asheim, Grillitsch, and Trippl 2017a).

Recent studies suggest that a combination of knowledge bases (also including symbolic knowledge) is essential for innovation (Grillitsch, Martin, and Srholec 2017). In the two clusters that are studied in this thesis, Raufoss and Kongsberg, a combination of analytical and synthetic knowledge constitutes a comparative advantage. However, the Kongsberg cluster, with its core cluster knowledge base on systems engineering, relies more on analytical knowledge than Raufoss, which with its core cluster knowledge base on automation and material technology relies more on synthetic knowledge (see A1/Evolution and A2/Absorptive). These core cluster knowledge bases have been developed over a long period of time, and reflects the industrial histories of the two clusters. As such, they are anchored in the clusters and constitute territorial comparative advantages, which have been accumulated and refined for decades. The case of Kongsberg, with a systems engineering knowledge base, illustrates that also analytical knowledge can be highly territorialized. As such, the thesis counters Maskell and Malmberg's (2002) characterization of analytical knowledge as easily accessible and easily diffused over distance.

3.2.4 Global production networks

Inspired by the global commodity chain and global value chain frameworks (GVC) (Gereffi 1999; Gereffi 1995), the development of the global production network framework began with the seminal paper by Henderson et al. (2002). Together with the additional papers[10] by Coe et al. (2004) and Coe, Dicken, and Hess (2008) they constitute what is now termed the GPN 1.0, which has been further developed in the GPN 2.0 framework by Coe and Yeung (2015). Building on the relational 'turn' in economic geography (Bathelt and Glückler 2003; Yeung 2005), the GPN framework aims to explain how interaction and collaboration between multinational lead firms and suppliers in a value chain are influenced by the power relations that exists within a GPN (Coe and Yeung 2015). Compared to the GVC framework, the GPN framework broadens the scope of actors by integrating non-firm actors such as nation states, regional institutions, NGOs, and trade unions in the analysis of production networks. The relational aspects are reflected in the frameworks' conceptualization of regional development as '*a dynamic outcome of the complex interaction between territorialised relational networks and global production networks within the context of changing regional governance structures.*' (Coe et al. 2004, 469 - emphasis in original). The conceptualization of power introduces politics as a more explicit dimension of the GPN framework (in opposition to the cluster and RIS approaches). Power relations become essential in the analysis of bargaining and cooperation between different actors within a GPN, e.g. between institutions (national and local states) and multinational lead firms, which can be characterised by conflicts (see e.g. Bridge 2008, concerning resource-based development).

The GPN framework provides a multi-scalar approach to understanding 'the dynamic organizational and geographical complexities of the global economy' (Coe, Dicken, and Hess 2008, 289) through emphasis on the influence of local, regional and global social and economic processes on the development of the global economy (Henderson et al. 2002). The 1.0 framework identifies value, embeddedness and power as its core, interconnected, conceptual categories. The GPN framework (in line with the RIS approach) regards the sub-national region as 'the basic geographical building block through which patterns of economic growth and decline should be interpreted' (Coe and Yeung 2015, 18). The framework posits that the key to understand economic development is through analysing how economic actors are embedded in

[10] Peter Dicken's conceptions on the globalized economy in the influential book *Global Shift: industrial change in a turbulent world* (1986, and later editions) also inspired the development of the GPN framework.

their local context and influenced by the regional institutional framework (Coe and Yeung 2015), and how these regions connect with actors (on national and supra-national levels) within global production networks). Therefore, (both positive and negative) regional development is understood as the ability of a region to create, enhance and capture value, which is influenced by firms' embeddedness and power relations within the global production network (Coe et al. 2004; Coe and Yeung 2015). The framework captures the evolutionary aspects (dynamics) of the global economy through the concept of strategic coupling, which is the process of regions being coupled into, or decoupled from, a global production network. These coupling processes are defined as temporal and subject to change, and dependent on a positive interaction between regional assets and institutions and the needs of lead (multinational) firms (Coe and Yeung 2015). In A4/Reshoring, we combine MacKinnon's (2012) conceptual refinements of the strategic coupling concept with aspects of disinvestment and reinvestment (inspired by Werner 2016) to provide a refined conceptualisation of *partial* coupling process. Thereby, the thesis contributes to the literature on GPNs by providing a refined understanding of coupling processes, which have previously been conceptualised as abrupt processes – 'ruptures', i.e. a total retraction of economic activities from a region (Coe and Yeung 2015).

In a recent publication where they take stock of recent conceptual developments within the GPN literature, Coe and Yeung (2019, 776-7) recognise the reshoring phenomenon as a hype (which we to some degree sympathise with in A4/Reshoring) and question its potential impact on regional economic development in Western economies. On the contrary, the authors emphasise the potential of current technological changes (e.g. 3D-printing and increased digitalization) to 'reconfigure global production networks in significant ways' (Coe and Yeung 2019, 777), thereby reinforcing ongoing geographical shifts of production to China, Asian tiger economies and other emerging economies (Coe and Yeung 2019). I do not fully agree with the authors in terms of brushing of the potential influence of reshoring on regional economic development. Although this thesis provides an exploratory study (limited in number of cases) of the phenomenon by investigating under which conditions reshoring can take place (A4/Reshoring), we identify a potential for regional economic development in the regions where Norwegian manufacturers have reshored production. As such, we find that studying the reshoring phenomenon an intriguing research topic both theoretically and empirically.

Theoretically, this thesis contributes to the development of the GPN framework through applying the framework in the analysis of a new – to GPN research – phenomenon, i.e.

manufacturing reshoring. In A4/Reshoring, we claim that the multi-scalar GPN framework provides a more holistic understanding of the phenomenon, and as such provide an enhanced analytical purchase compared to previous firm-centric studies. Empirically, our (limited) explorative case study demonstrates that the reshoring can potentially have a substantial impact on a regions ability to create, enhance and retain value, and as such, regional economic development. Furthermore, I find that investigating the potential for reshoring due to advanced manufacturing technologies spans broader than merely exploring a few peculiar (highly interesting) case firms. Therefore, I find that article A4/Reshoring taps into a wider debate on the globality of the capitalist economy, the (new, if you like) division of labour, and how mature economies can leverage their educational, organizational, technological and institutional capabilities, and potentially reclaim a position within the manufacturing industry.

3.2.5 Interim theoretical summaries and reflections

Based on the theoretical discussions in the previous sections, Table 2 provides a summary of how the theoretical approaches employed in this thesis emphasises the three core aspects that the thesis is concerned with – *knowledge creation/development*, *technology* and *innovation* – somewhat differently. Knowledge creation and development is regarded as a key topic for analysis in all three approaches. However, *innovation* is not explicitly covered in the GPN framework. To my understanding, innovation is a subordinate process in the GPN framework, which is something that occurs within the local and regional economies that the actors within GPNs are embedded in. *Innovation* policy, however, is perceived as effective instruments that can contribute to upgrading within the global production network, i.e. moving to a higher position within the production network that entails enhanced value capture (Parrilli, Nadvi, and Yeung 2013; Coe and Yeung 2015). In sum, the theoretical approaches constitute a framework that is able to capture how knowledge demands and knowledge development is influenced by the implementation of new technologies, and how a range of actors, within local, regional and national economies, work to facilitate knowledge provision. Furthermore, the approaches capture how the development of technological and knowledge capabilities can result in comparative advantages in a global manufacturing industry. Additionally, the three approaches provide emphasis on the territorial dimensions of knowledge development processes, which is a key dimension of this thesis. The cluster approach emphasises the importance of geographical and relational proximity between actors within clusters as key in interactive learning between cluster firms. In the regional innovation system approach, the composition of different types of

actors (industrial actors and knowledge institutions) within the region forms knowledge development. However, being defined as open systems, the cluster and RIS approaches are simultaneously open for interaction with actors outside the region as well. In the GPN framework, the development (optimizing in GPN terms) of firms' knowledge capabilities are formed by their interaction with regional assets and institutions.

	Cluster approach	*Regional innovation system*	*GPN*
Knowledge development	Facilitated through different types of proximity. The reason why firm are co-located in agglomerations, because of spillover-effects. Has traditionally not paid sufficient attention to extra-local linkages.	Regarded as the core activity and core asset in a knowledge based global economy. Interaction between the two sub-systems of knowledge generation and knowledge utilization. Has favoured triple helix setup in knowledge creation	Captured on the firm level by the cost-capability ratio concept, where optimizing firms knowledge leads to greater value capture and regional economic development. Regional institutions and regional assets are regarded as decisive in developing a regions knowledge capabilities
Technology	Could be more easily developed in clusters because of proximity to collaborators and competitors and face-to-face interaction and learning.	One potential outcome of interactive learning and innovation processes.	Captured by the cost-capability ratio concept, investments in technology can lead to technological rents, enhanced value capture and reg. economic development. Closely connected to knowledge in terms of exploiting the potential of technology.
Innovation	Regarded as the localised manifestations of competitiveness .	Regarded as the key for competitiveness in a knowledge economy. Adopts a Schumpeterian view of innovation. Differentiates between DUI and STI modes of innovation.	Does not cover innovation directly. Innovation must be understood as something undertaken by actors in the regions/clusters, enabling them to couple into the global production networks and create, enhance and capture value.

Table 2 - Summary of how the theoretical approaches deal with the *core* aspects of the thesis

3.2.6 Agency and non-firm actors

In economic geography there has been expressed ‘a need to relate technological change and innovation’ to agency (MacKinnon et al. 2009, 131). The thesis studies how actors within systems on different scales react and adapt to changes in the industry related system. In this thesis, the term change relates to the implementation of new technologies in manufacturing industry, triumphed under the banner of Industry 4.0 (see 2.2). However, technology is not deterministic and does not have a life of its own. It is, from creation to implementation, driven by choices made by both firm and non-firm actors and embedded in institutional and social processes (Cohen and Zysman 1987; Dicken 2015). According to Dicken (2015, 75) technology should be regarded as enabling, making ‘new structures, new organizational and geographical arrangements of economic activities, new products and new processes’ possible, ‘while not making particular outcomes inevitable’. This thesis emphasises the actions of firm and non-firm actors and how they work and collaborate to accommodate emerging technology and knowledge demands. By analysing their choices and strategies for acquiring and implementing new technology and accessing extra-local and extra-regional knowledge, agency is ascribed to the actors, not the technology itself. Consequently, this thesis adopts a view that differs from actor network theory, which also considers the relationality and agency of objects such as technology (see e.g. Latour 2005).

Agency can be defined as ‘an action or intervention to produce a particular effect’ (Emirbayer and Mische 1998, 963). Within (especially evolutionary) economic geography, early contributions have primarily focused on the agency of firms in processes of technology upgrading and innovation, which in turn leads to (regional) economic development. As a consequence, the agency of non-firm actors such as nation states, knowledge institutions, research institutes, cluster organizations (as pointed to in A2) has been partly overlooked (Asheim, Boschma, and Cooke 2011; Dawley 2014; MacKinnon et al. 2009). The influence of non-firm actors has however become subject to conceptual development in recent contributions within economic geography, especially within the global political economy approach (see Pike et al. 2009; MacKinnon et al. 2009; Pike et al. 2016). RIS studies, often following a triple-helix script in the narrow definition of regional innovation systems (Asheim and Gertler 2005), have emphasised the agency of firms, academia and government. Other actors contributing to innovation processes have not been sufficiently analysed. In so doing, RIS studies have relegated the role of other non-firm actors within the innovation system. In article A3/Vocational, we advocate the inclusion of vocational education institutions in RIS studies,

in order to achieve a more holistic understanding of innovation processes related to the implementation of advanced manufacturing technology. Recent studies have conceptualised different levels of agency, e.g. individual and system level agency, that is sensitive to both firm and non-firm (system) agency (Isaksen et al. 2019). System level agency has been linked to RIS and identified as the ability of actors to influence change outside their organizational boarders (ibid.). The notion of agency has also been related to path development processes (see e.g. Jolly, Grillitsch, and Hansen 2019; Sotarauta and Suvinen 2018; Isaksen et al. 2019). As an example, Grillitsch and Sotarauta (2019, 3) propose 'a trinity of change agency' – innovative entrepreneurship, institutional entrepreneurship and place-based leadership – and 'how these separately and in combination contribute to regional growth paths.' By emphasising the role of (change) agents in developing e.g. clusters or regional innovation systems, these conceptualizations of agency capture dynamics and processes within structures and systems. As such, actors (and their agency) has the potential to transform existing structures through interacting with them, both from within, as entrepreneurs (Grillitsch and Sotarauta 2019), and from the outside.

3.2.7 Path development literature and system approaches

The path dependence literature (as mentioned in section 3.1.2) has gained a prominent position within economic geography (Boschma and Frenken 2006; Martin and Sunley 2006; Hassink, Isaksen, and Trippl 2019). The seminal contributions from e.g. David (1985) and Arthur (1994), employing the path dependence concept in analysis of the evolution of technologies within the field evolutionary economics, has inspired the development of an economic geography approach to path development (as it has in several other fields within social science (Steen 2016a)). The path development debate has gained a particular standing within evolutionary economic geography (see section 3.1.1) and inspired a wealth of studies (Steen and Karlsen 2014; Grillitsch, Asheim, and Trippl 2018; Martin 2010; Tödtling and Trippl 2018; Isaksen and Trippl 2016; Steen and Hansen 2018; Isaksen 2014). Subsequently, several conceptualizations of path development processes have been proposed. EEG assumes that established economic and spatial patterns are largely irreversible. As such, the path dependence and regional 'lock-in' concepts, i.e. a situation where (often specialised) regions are unable to adapt to industrial and market changes ultimately resulting in decline, have been central (Arthur 1994; Boschma and Lambooy 1999). However, in the early contribution by Martin and Sunley (2006), several 'un-locking' scenarios for path creation are identified, while more recent contributions, e.g. Isaksen (2014), conceptualise four different potential development paths for regional

economies (path extension, exhaustion, renewal and creation). A brief discussion of the literature here is necessary for two reasons. First, the thesis employs the path development literature in article A1/Evolution where we study the long-term cluster path development of the Kongsberg and Raufoss clusters, with an emphasis on the role of state agency in cluster path development. Second, several more or less recent contributions in economic geography argue for a 'cross fertilization' between the path dependence literature and the system approaches discussed earlier (see section 3.2) in order to enhance our understanding of the evolution of the economic landscape and the sub-systems that it consists of (Trippl et al. 2015; MacKinnon et al. 2019).

In their conceptualization of clusters as complex adaptive systems, as a critique of and an alternative approach to the cluster life-cycle approach (Menzel and Fornahl 2010), Martin and Sunley (2011) argue that clusters are able to adapt to both endogenous (e.g. cluster firm emergence and exit) and exogenous change (e.g. external shocks). As such, the authors suggest that there are several possible pathways for a cluster. In relation to the regional innovation system approach, notions from the path development literature has been introduced by e.g Trippl, Grillitsch, and Isaksen (2017) to improve our understanding of how regional development paths are formed not only by place-specific characteristics, but also by the attraction and absorption of extra-local knowledge. Recent studies that include RIS in their analytical framework have shifted from the more traditional (static) RIS analysis towards analysing how existing regional conditions and environments (defined as the preformation phase by Martin (2010)) restrict or enable path development and growth, and how these regional environments are transformed (see e.g. Miörner and Trippl 2017, 2019; Isaksen and Trippl 2016; Chaminade et al. 2019). Notions from the global production network framework have also been introduced to develop our understanding of path creation. A recent contribution by MacKinnon et al. (2019) develops a framework that stresses the interaction between five key dimensions, where agency is linked to strategic coupling (a key GPN concept) to mechanisms (the five 'de-locking' scenarios proposed by Martin and Sunley (2006)) of path creation.

The recent path development literature exemplifies how EEG can be develop by adopting perspectives from other approaches within economic geography, such as GPN (Mackinnon et al. 2019) and RIS (Trippl, Grillitsch, and Isaksen 2017), in order to provide analytical purchase in studies of ongoing, dynamic processes within regional economies and how they develop. I will argue that the recent developments within the path development literature illustrates

economic geography's pluralistic theory-culture. Cross-fertilization between approaches and frameworks, aiming to develop analytical frameworks that provides a better understanding of the drivers for regional economic development, appears to be a widespread strategy.

3.3 Summary: situating the thesis within economic geography

This chapter started out by pointing to the polycentric theory culture within economic geography, and has underpinned the introductory statement throughout by discussing how this thesis is draws on multiple approaches to economic geography. The thesis is influenced by several theoretical approaches and concepts (see Table 3) that lend themselves to analysing technological, knowledge-creation and innovation processes. By drawing on approaches from both evolutionary, relational and institutional economic geography, the thesis in many ways aligns with the field of economic geography as a whole, where theoretical impulses from within and outside the field are combined to achieve greater analytical purchase (Peck 2015; Hassink, Klaerding, and Marques 2014). However, despite a pluralistic theoretical approach, the thesis adopts more from the evolutionary approach as it emphasises historical developments, evolution of knowledge bases, and co-evolution of technology and society. Table 3 provides an overview of how the theoretical approaches and concepts employed in the different articles and illustrates how the articles overlap.

	Clusters	RIS/IS	GPN
A1/Evolution	X	*	
A2/Absorptive	X		
A3/Vocational		X	
A4/Reshoring		*	X

Table 3 - Overview of main theoretical approaches employed in A1-4.
(X = key approach/framework, * = secondary approach/framework)

In order to answer the research question(s), both those that are put forward in section 1.3 and those posed in the four research articles, a pluralistic attitude towards theory has been needed. The aim to understand processes of technological upgrading in Norwegian manufacturing and their influence on territorial knowledge development processes calls for a multiscalar theoretical framework, which allows for interaction between actors and systems on different geographical levels. In this regard, the combination of cluster, innovation system and global

production network provides a multiscalar apparatus that encompasses the multitude of actions of firm and non-firm actors in terms of knowledge development and technological upgrading. Drawing on well-established approaches within the field, I will argue that the thesis is well situated within the field of economic geographies.

4 Research design and methodology

In the following sections, I will describe the research design and my reflections concerning methodology. I will provide explanations for the methodological choices that I have made throughout my PhD period, discuss the strengths and weaknesses of the choices made, and discuss how these choices have influenced the four articles that make up the second part of the thesis.

4.1 Qualitative methods in economic geography

Research design can, at its most basic, be separated into *extensive* and *intensive* (Sayer 2010). Extensive research designs seek to identify patterns and regularities in data, often researching large data sets. Intensive research designs, on the other hand, seek to describe a single, or a small amount of, case(s) with 'the maximum amount of detail' (Clifford, French, and Valentine 2010, 11). This thesis lends itself to an intensive research design, as it aims to explain and understand changes within Norwegian manufacturing by studying a few selected cases. In order to produce data on the actual, qualitative, changes taking place within Norwegian manufacturing, the employment of qualitative methods is called for.

Although I was not well versed in the economic geography literature, I started out my PhD with a fairly solid grip on qualitative methods and application of such methods within studies in geography. This type of *a priori* knowledge and experience will necessarily guide the research process (Valentine 2001) and my choice to employ qualitative methods was surely influenced by my background and previous work. The use of qualitative methods is reflected in the research questions that this thesis answers (see 1.3), with an emphasis on 'what', 'how' and 'why' questions. As the theoretical ambition of the thesis is to explore the applicability of, and develop, existing concepts, frameworks and approaches (George and Bennett 2005), I have conducted several case studies.

4.1.1 Case studies in economic geography

The starting point for all types of empirical research, qualitative and quantitative alike, is developing a research design. The first point in developing a research design is developing the study's question, and the interrogative used in many ways decides the research strategy (Yin 2003). Yin (2003, 13) defines the case study approach as 'an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries

between phenomenon and context are not clearly evident'. The approach has a distinct advantage when 'a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control' (Yin 2003, 9). To my understanding, based on Yin's (2003) definition, case studies are highly relevant for economic geography as the aim of much of the research conducted within the field is to explain *why* global economic trends are manifested differently in different regions and *how* historical, social and economic processes within these regions result in uneven economic development (Boschma and Martin 2010). Furthermore, I will argue that case studies are suitable when studying clusters, regional innovation systems and global production networks, as they constitute distinct systems with a set of actors and relations. As mentioned earlier, the main ambition of my doctoral thesis is to explore how firm and non-firm actors within Norwegian manufacturing react and adapt to technological change and subsequent knowledge demands in order to keep industry globally competitive. In order to do so it is necessary to access knowledge about how and where firms acquire new knowledge and technology, how industry and education institutions collaborate in developing education programmes, and how regional institutions and policies influence firms ability to access and adopt new technologies and knowledge. The phenomena that I study can be described as being of a contemporary character as firm strategies and institutional environments change, though at different phases. Due to the contemporaneity of these phenomena, it is necessary to use research methods that are able to capture this, while at the same time being able to explain the context in which the phenomena are set. As such, the case study approach is suitable as it 'allows investigators to retain a holistic and meaningful characteristics of real-life events' (Yin 2003, 2). Researchers can chose to do single or multiple case studies, i.e. focusing their analyses on one or multiple real-life examples.

According to Yin (2003), a case study covers few units, where firms could be one unit, but a case study covers many aspects and variables of the studied units. In order to provide explanations on topics such as how regional innovation systems develop and clusters are able to absorb exogenous knowledge and technology, it is necessary to study multiple firms. However, it is equally important to study non-firm actors such as education institutions, support organizations, and nation states and the relationships between the different units within the case study. As such, when I refer to case studies in this thesis, and in the articles in Part 2, the cases are either firms (A4/Reshoring), clusters (A1/Evolution and A2/Absorptive) or regional innovation systems (A3/Vocational). In the two latter, the firms within the clusters and

innovation systems constitute some of the units, in addition to education institutions and support organizations.

Yin (2003) proposes three types of case studies. The *exploratory* case study is useful when investigating 'distinct phenomena characterised by a lack of detailed preliminary research' (Streb 2010) and is especially apt to discover emerging research fields and topics . *Descriptive* case studies are aimed at scrutinizing 'a sample in detail and in depth, based on an articulation of a descriptive theory' (Tobin 2010) and thereby adding to theoretical development. Lastly, *explanatory* case studies goes further than the previous two, as it in addition to explore and describe 'can be used to explain causal relationships and to develop theory' (Harder 2010). The three are to a large degree overlapping and complementary (Yin 2003), and this thesis draws on all three types of case studies. The articles A1/Evolution, A2/Absorptive and A3/Vocational are a mix of descriptive and explanatory, whereas A4/Reshoring is a mix of exploratory and descriptive.

Case study research can be conducted as a single or multiple case study. This thesis employs a multiple case study approach where multiple cases (firms, clusters or regions in the context of this thesis), which provides a richer and deeper understanding of the phenomenon researched (Yin 2003). Yin (2003) points out that even though both single and multiple case studies can be successful, multiple case studies are preferred due to their ability to explain, describe and explore more than a single case study. All the articles in this thesis adopts a multiple case study approach. A1/Evolution studies the Raufoss and Kongsberg clusters, A3/Vocational studies the Kongsberg and Raufoss regions, while A4/Reshoring studies 9 manufacturing firms in different locations within Norway. In A2/Absorptive, however, a comparative case study is conducted, where we compare the roles of the cluster intermediaries in the Raufoss and Kongsberg clusters. Employing a case study approach to study the systems surrounding the industry and the development of the manufacturing industry makes sense as the uniqueness of each system influences the overall functioning of the system. Understanding clusters (Martin and Sunley 2011), regional innovation systems (Asheim, Grillitsch, and Trippl 2016) and global production networks (Coe and Yeung 2015) as 'complex social phenomena' (Yin 2003, 2) therefore warrants the use of case study methodology when researching their dynamics. In order to understand the changes within the systems, it is essential to gain a holistic understanding – political, economic, historical and institutional – of the spaces/places where these systems are embedded. Without this understanding it is difficult to comprehend the present day functioning

of these systems. In terms of methodology, the case study approach is open to both qualitative and quantitative research methods. However, the prevalent source of data in case study research is the interview (Yin 2003).

4.2 Data production and analysis

The primary source of empirical data in this thesis is interview data. Reflecting the research process, which has been characterised by moments of discovery. Interviews were conducted in the period from December 2016 to January 2019. The data consist of 34 interviews with informants from e.g. corporate management, education institutions, cluster organizations, trade unions, a national industry association, an apprenticeship training office and a regional SME network organization (see Appendix A for a complete list of informants). The interviews have been conducted both in person and via Skype. Furthermore, the thesis is informed by observations at two national industry conferences and secondary sources such as reports, newspaper and other media articles, and historical documents (especially relevant for A1/Evolution). Table 4 displays the research process and periods of data production.

Time period	Place	Details
OCT 2016	Oslo/Gardermoen	National industry conference on the topic 'Industry 4.0'
DEC 2016 - JAN 2017	Raufoss and Kongsberg	14 interviews
NOVEMBER 2017	Raufoss and Kongsberg Trondheim	3 interviews 1 Skype interview
NOVEMBER 2017	Kongsberg	Workshop on the organization of vocational education and training, hosted by Buskerud County
OCT 2018	Oslo/Gardermoen	National industry conference on the topic 'The Future of Production in Norway'
JAN 2018 - JAN 2019	Trondheim	16 Skype interviews

Table 4 - The research process

Several trips to Kongsberg and Raufoss were made throughout the research process in order to conduct interviews, most of which were conducted with several articles in mind. Additionally, in order to save both time and funds, several interviews were conducted via Skype. For A4/Reshoring, due to the relevant firms being scattered around Norway, all interviews were conducted via Skype. Naturally, the use of Skype interviews influences the interview situation,

and potentially the outcomes and data that is being produced during the interview. However, as I conducted interviews with management executives, who are more or less used to talking to academics, and the Skype format itself, I believe that the digital communication did not make the data inferior to what could have been produced in a face-to-face interview.

4.2.1 Semi-structured interviews

Yin (2003, 89) describes interviews as being 'one of the most important sources of case study information' and has also become a preferred method amongst many economic geographers (Dunn 2007). Semi-structured interviews, described as a 'verbal interchange' where the researcher (interviewer) 'attempts to elicit information' from the interviewee (Dunn 2005, 79), are presumably the most utilised qualitative method (Kitchin and Tate 2000). They are characterised as being structured around a few central research topics and guided by a few predetermined questions while at the same time providing leeway for informant's digressions (Longhurst 2010). As one of many methods in qualitative research, interviews provides a means to explore the interpretations of actors, providing rich and deep data, which is unobtainable through quantitative methods such as surveys which are unfit to embrace on-going dynamic processes (Yin 2003; Valentine 2005; Flyvbjerg 2006). Interviews with company management has been a key approach to studies in economic geography for decades (Schoenberger 1991) as it gains valuable insights into strategies of the elite. Interviews with company management has also provided my thesis with valuable knowledge on how companies seek out, access and use new technologies and knowledge. However, the use of interviews in general, and interviews with management in particular, has been criticised.

Dunn (2007, 82) regards interviewing as 'inherently problematic, because the stories people tell about how they make decisions are often radically different from the ways those decisions were actually made'. Furthermore, she draws on the analogy of pufferfish to describe how informants, and particularly those working in management, react to researchers by 'inflating themselves to seem more intimidating' (Dunn 2007, 82) and consequently present a rehearsed version of stories relating to the topic at hand. This then provides researchers with data on how things should work rather than how things actually work. The critique of interviews as a research method is of course valid, and is something the I (we) as a researcher have to bear in mind. I also believe that we as researchers have to have a fundamental belief in informants, their intentions and their statements. Additionally, the thesis has interviewed three trade union representatives (See Appendix A) – representing the shop floor – thereby supplementing our

data with views and opinions that represent the non-executive voices within manufacturing. Furthermore, any potential bias of (executive management) informants' narratives (Dunn 2007) can be countered, and their statements validated, through triangulation of sources.

The term triangulation, or 'establishing converging lines of evidence' (Yin 2003, 98), entails achieving information on 'the research issue from (at least) two different points' (Flick 2004, 178). Yin (2003, 98-9) proposes four types of triangulation data-, investigator-, theory- and methodological triangulation. Researchers conducting case studies are encouraged to triangulate in order to substantiate the research findings (Yin 2003). In this thesis, triangulation has been done in two ways. Firstly, the articles have employed different sources of data, both primary data in terms of interviews and secondary sources such as reports, policy documents, white papers, historical volumes etc. (see 4.2.3.). Second, most of the interviews conducted for this thesis have been by multiple investigators (see Appendix A for a detailed overview). This is what is referred to as investigator triangulation, which strengthens the reliability of the study as it balances 'out the subjective influences of individuals' (Flick 2004, 178).

4.2.2 Observation

In the course of my PhD period I have conducted observations that have contributed to my understanding of the phenomenon studied in this thesis. I have conducted non-participant observations (Parke and Griffiths 2008) at two national industry conferences in 2016 and 2018, where the main topics were Industry 4.0 (2016) and modernization of Norwegian industry in general (2018). At these events, with approximately 1000 participants, and as such of a public character, the participants were unaware that they were being observed. Hidden observations have some ethical caveats. However, in my case, these caveats are avoided as what I took away from the conferences in terms of 'data' were notes taken from the talks given. The first industry conference in 2016 was especially useful for my research process as it provided insights on what the industry perceived as challenges and opportunities at the time. As such, the events provided insights on the narratives (Fløysand and Jakobsen 2017) on Industry 4.0 and technological development that industry actors are exposed and contribute to.

I (and Asbjørn) also conducted participatory observation (Laurier 2010) at a workshop at Kongsberg (2017) concerning the reorganization of the vocational educational system at Raufoss in particular, and in the Oppland county in general. My primary role at the workshop was as an observer. The other participants were aware that I was there to observe the event and

that my participation was related to my PhD work in the SFI. The participatory aspect of my observation was limited to posing a few questions related to the discussions that the other participants had. As such, I was a rather passive spectator. The take-aways from the workshop were fieldnotes that were written out during and the day after the workshop. The information gathered from my observations are not directly used in the articles, rather they contribute to a general understanding of the industry itself and challenges related to organization of vocational education at Raufoss and Kongsberg.

4.2.3 Using secondary sources in economic geography

A recent contribution by Henning (2019, 607) has pointed to the lack of 'real long time' and the absence of real history in evolutionary economic geography studies. In A1/Evolution, we address this shortage. The article relies on historical volumes on the history of the Raufoss and Kongsberg clusters as key sources of data when tracing the role of the nation state in developing the clusters' core knowledge bases. Henning (2019, 609) points to the 'historical validity problem', which entails the problem of evaluating the validity of historical documents. In our case, we have chosen to trust the accounts that the well-recognised professional historians who have authored the volumes provide us with, and trust that the interpretations that they have made based on the material available to them (typically historical documents from company archives) is correct. Henning (2019) suggests that geographers should learn from historians on the critical use of historical sources. Knowing that the authors of the volumes utilised in A1/Evolution had access to state company archives, we believe that the validity of the sources meet the standards of international academic publishing.

Secondary sources are invaluable in terms of getting a grip on what legislatures, policymakers and state institutions are doing (White 2010). This thesis has been informed by government white papers, policy documents and reports on industrial development and education. These documents have provided insights on e.g. how the government is preparing itself to cope with increased implementation of advanced manufacturing technologies and the challenges that follows. In A3/Vocational, for example, the recent 2017 Norwegian industrial policy (Ministry of Trade Industry and Fisheries 2017) and reports from the Ministry of Education and Research (2016) on the future of skilled workers in Norway provide key insights on how non-firm actors within the economy view recent developments within industry, economy and education. As the thesis aims to highlight the importance of non-firm actors in the development and modernization of the manufacturing industry, these public documents are invaluable for the

insight that they provide on these processes. However, the use of secondary data requires researchers to be critical. This entails reflecting on who the documents have been published by, acknowledging that the documents have been written for a different purpose, and interpreting the data in light of this (White 2010). Additionally, drawing on previous studies in form of articles or books provides a theoretical basis and understanding of the field. Reading up on media articles about the Norwegian manufacturing in general, or on particular firms within the manufacturing industry, also provides some insights on the workings of the industry.

4.2.4 Recruiting informants

As the thesis is part of a larger research centre (SFI Manufacturing – see 1.1), there are 14 industrial partners involved, 7 of which are located in the Raufoss and Kongsberg clusters. By being a part of the centre, gaining access to informants among the industrial partners was relatively easy, as the centre provided me with a list of contact persons within each company. For those firms who were not part of the centre (see Appendix A), I (we) accessed contacted informants via e-mail, where we presented the centre and a short description of the topics that we were interested in talking about (we did the same for the firms that were part of the centre). In the instances where we did not get a response, we repeated the request, and then moved on to calling if we did not get an answer. This way of recruiting is similar to what Valentine (2005) calls 'cold calling', yet it differs from the original concept as we initiated the contact by sending out information, providing the informants with an opportunity to answer before we called.

Some of the informants that we have interviewed were also proposed by other informants. This kind of 'snowballing' effect is very helpful, as informants within e.g. a cluster has a better understanding of who might be relevant to talk to than we do, as outsiders (Valentine 2005). Additionally, I find it easier to come into contact with new informants when I can refer to someone they know.

4.2.5 Data collection, processing and analysis

All interviews, both face-to-face and Skype, were recorded and transcribed[11]. The transcribed interviews form the main empirical basis of this thesis. The transcription process gave me a deepened understanding and an overview of the material that I find hard to achieve when

[11] Most of the interviews were transcribed by me, with a few exceptions where master students or external actors were hired to conduct the transcription.

reading material transcribed by others. All interviews, with the exception of two, were fully transcribed. By doing so, we counteract the potential of 'quote hoping' (Longhurst 2010, 86), where the meaning of sentences are changed by taking quotes out of their context. The transcription process also provided me with what Crang (2005, 220) refers to as a 're-familiarisation' with the data, meaning that I got re-acquainted with the interview data in a way that would not have been possible without the transcription process. Additionally, the analysis becomes easier as it starts during the data processing phase. Similar to how the relationship between data collection and analysis is described as being fluid (Yeung 2003), I would argue that the data processing and analysis is an equally fluid. When transcribing the interviews, I simultaneously created categories and themes that could be used in the analysis later on.

The analysis of the materials produced was an iterative process (Crang 2005; Creswell 2007) where the codes and categories were made in a fluid (Yeung 2003) process shifting from the material to theories, and back. That entails that the codes that were made often reflected one or more of the theoretical aspects that I wanted to discuss or explore in the articles. This is what Kvale and Brinkmann (2009) refers to as 'theoretical reading', a process which was repeated for all of the articles. The actual coding was done using the qualitative data analysis software NVivo. The rationale for coding the material was not to produce countable entities that could be quantified, rather the aim was to organise and make sense of the material at hand (Crang 2005). The key advantage, and the reason why I used qualitative analysis software at all is that it is quicker and less messy than using different colour markers on printed paper, especially when working with a large data material. Also, the NVivo software allows for easy access to the categorised and coded material and provides a useful function for conducting word queries in the databases crafted from interview transcripts, reports and white papers. Thereby, the software provides a better overview of the data material. The use of NVivo does of course not simplify the actual analysis, it does not 'magically produce results' (Crang 2005, 222). Applying my theoretical knowledge and knowledge of the field to make the connections between data and theory was essentially the challenging task that I had to conduct, in collaboration with my co-authors.

4.3 Trustworthy research: reliability, validity, reflexivity and ethics

The trustworthiness of any piece of research depends on validity, reliability and reflexivity (Kvale and Brinkmann 2009), and is underpinned by research ethics (Hay 2010). In this thesis,

the validity concept pertains to the adequacy of the theoretical approaches and methods employed to answer the thesis' overall aim and research questions. Given the aims of this thesis and the nature of research questions it sets out to answer (section 1.2) about how firm and non-firm actors within Norwegian manufacturing have, and currently are, undertaking efforts to upgrade technological and knowledge capabilities, the choice of qualitative methods is justified. The quality (validity) of the research can be established through what Yin (2003) refers to as external validity. The findings that this thesis provides (see section 5.1), based on qualitative methods, cannot be generalised in the same manner as quantitative studies can. Rather than statistical generalization, which entails sampling a representative population (common in quantitative studies such as surveys), qualitative case studies can pursue analytical generalization (Yin 2003, 2013), which entails extracting findings and ideas from one or several cases to other, similar, cases. In this thesis, we draw on the notion of varieties of capitalism (see section 2.4) and argue that our findings from a Norwegian coordinated market economy context could be representative for other CMEs (see A1, A2 and A3). Analytical generalization is also done in A4/Reshoring, where we claim that the implementation of advanced technologies has (when matched with key regional assets) enabled manufacturing reshoring to Norway, and that this could also be the case in other high-cost coordinated market economies.

The researcher will always have an influence on the research outcome as all decisions in relation to research theme and questions, informant recruitment, interviewing, and data processing and analysis are decided upon by the researcher. As such, I (or we) have influenced the outcome of the research process. It is essential that I recognise my influence on the process and clarify my positionality, i.e. how my identity in terms of educational background, gender, methodological preferences etc., influence the research process (Valentine 2005). It is therefore necessary to exercise reflexivity, which England (1994) defines as 'self-critical sympathetic introspection and the self-conscious analytical scrutiny of the self as a researcher'. This aspect of research has a particular role in certain methods of qualitative research as it entails building a relationship with informants. In this thesis, which has employed interviews as its main research method, it is necessary to reflect upon the intersubjectivity, which is closely connected to reflexivity and positionality, that arises during an interview situation.

Intersubjectivity refers to the relationship that develops between the informant and the researcher (Crang and Cook 2007). This relationship influences the interview and hence the data that is produced. Furthermore, there is a power relation between the researcher and

informant, that can influence the interview situation and outcome. The power factors can be influenced by age, gender, position within company etc. In this thesis, however, the main informants are company executives, or they have a role in the management of an organisation or education institution. In fact, and as pointed out by Kvale and Brinkmann (2009) and Schoenberger (1991), in communicating with these types of 'elite' informants, the power relation is more likely to tip the scale in favour of the informant. In the interviews conducted for this thesis I would say that the power relation between me (us) and the informants have been relatively equal, and the atmosphere has been friendly. However, there have been situations where questions about more basic and background information concerning the firm has been met with some discouragement and comments from informants about the triviality of the questions. Lessons learned from this is that by demonstrating knowledge and an understanding of the firm itself, and the context and industry in which it is embedded, helps gain trust among informants. Being well prepared elevates the discussion and in some cases resulted in the informants being thankful for being interviewed, as it provided a break from a hectic working day to reflect upon strategies for knowledge and technology development, and the lessons made in the past that the firm can take advantage of in the future.

I believe that the thesis at hand upholds all standards of ethical research in geography, meaning that I have (or *we*, when interviews have been conducted with co-authors and colleges) behaved 'with integrity' and acted 'in ways that are just, beneficent and respectful' (Hay 2010, 35). The interviews that have been conducted for this thesis have been, without exception, with interviewees who express themselves by virtue of their position within firms, institutions, unions etc. As such, they represent their employer, and have been asked to comment on firm matters, not personal opinions. Furthermore, all the informants have been anonymised to the extent that their real names are not used, rather their position within the company has utilised to give informants an identity. Even so, some informants have asked for some statements, of a bit more delicate matter, that have been made during interviews to be left out, or that they did not wish to be quoted. These wishes have, of course, been granted and the information has been left out. Examples can be comments on the culture within the interviewees organisation that could be recognised and potentially lead to discomfort for the informant in. I believe that this also signifies trust in me (or us), as researchers, as the informants were willing to share information, even though they did not feel comfortable being quoted. In A4/Reshoring, anonymity was especially important, as one of the firms interviewed, in order to secure continued good business relations, did not want customers and manufacturers in the previous

host country to read about how the firm had relocated manufacturing to Norway. Therefore, all names of firms and management executives were interviewed, under the reassurance that all information would be anonymised. This is perhaps the only article that has the potential to 'do harm', that is economic harm through potentially disturbing or ruining the existing business relations of one of the firms.

As stated in the introduction to this thesis (see section 1.1 Background and motivation), I believe that it is necessary for the Norwegian economy to develop industrial capacities other than oil and gas. In a future that in my opinion, along with many other Norwegians, should entail substantially less oil and gas extraction than what is the case in 2019, I think that the Norwegian manufacturing industry could play an important role. After having taken a backseat to the O&G industry for the last 50 year or so, I believe that a Norwegian manufacturing industry capable of producing sustainable goods could lead the way in a less oil and gas dependent economy.

4.4 Summary

This chapter has provided an account of the methodological choices that has been made during my PhD period. I have discussed and reflected on research process itself, on the collection, handling and analysis of interview data, on the use of qualitative methods in case studies, and on ethical issues related to qualitative research. The use of qualitative methods in this thesis has provided key insights on the challenges that implementation of advanced manufacturing technologies pose, and how firm and non-firm actors have reacted and adapted to these technologies. The use of qualitative methods has been warranted by the novelty of the studied phenomenon, i.e. on-going processes of technological upgrading in manufacturing industry and how qualitative methods provides data on the real-time and historical processes within firm and non-firm actors.

5 Conclusions and outlook

This chapter first presents a summary of the main findings in the four research articles that constitute PART II of this thesis. Second, the overall contributions of the thesis are discussed, thereafter a discussion on the direction of future research concludes the chapter.

5.1 Summary of the articles' main findings and contributions

The following subsections provide bullet-point summaries of the four research articles. The summaries illustrate how the articles engage with both retrospective, contemporary, and forward-looking aspects of technology and knowledge upgrading in Norwegian manufacturing industry. As such, the papers complement each other along a timeline: background, current processes and projections of future development.

5.1.1 A1/Evolution

- Contributes to the ongoing debate on cluster dynamics and cluster evolution by developing an analytical framework that draws on current debates on path creation.
- Finds that the cluster evolution debate has not paid sufficient attention to the role of non-firm actors in cluster evolution. Therefore, the article contributes to recent calls for a particular emphasis on the role of nation states in cluster evolution by analyzing the key role of the Norwegian state in developing the Kongsberg and Raufoss clusters and the core cluster knowledge bases.
- Contributes to recent debates on the importance on long real-time and history in studies within evolutionary economic geography by employing a longitudinal case study approach.
- Provides empirical examples of how the Norwegian state has taken on different roles as e.g. owner, R&D providers, market enabler and funder, and how this has shaped the development of the two high-tech clusters at Raufoss and Kongsberg

5.1.2 A2/Absorptive

- Highlights the influence of cluster intermediaries (organizations) as essential for cluster absorptive capacity in terms of their ability to facilitate extra-cluster knowledge and spread it among cluster firms.
- Contributes to the debate on cluster dynamics and evolution by developing an analytical framework that combines absorptive capacity and cluster intermediaries.

- The developed analytical framework is employed in the analysis of how cluster intermediaries in the Kongsberg and Raufoss clusters facilitate extra-cluster knowledge as cluster firms are faced with rapid technological advances within the manufacturing industry
- Provides a conceptual typology of cluster intermediaries and their potential influence on cluster absorptive capacities in various cluster contexts.
- Develops policy recommendations for future policy development, emphasizing the importance of context sensitive, future oriented and adaptive cluster organizations
- Illustrates how the cluster organizations at Raufoss and Kongsberg take on key roles as cluster intermediaries, and how these intermediaries facilitate extra-local knowledge from e.g. universities and through coordination research projects.

5.1.3 A3/Vocational

- Demonstrates how vocational education institutions at Raufoss and Kongsberg are collaborating with industry actors and other industry-related actors in order to provide educational programmes that meets the knowledge demands in both current and future manufacturing.
- Exemplifies how the organization of vocational education can be changed by developing industry-like training centres where students and apprentices can develop their skills
- Criticises the dominance of the narrow conceptualization of RIS in RIS studies and the empirical shortcomings regarding the broad conceptualization of RIS.
- Highlights the importance of skilled workers for implementation of advanced manufacturing technologies
- Contributes to the RIS debate by providing an empirical study that develops on the broad conceptualization of RIS
- Contributes to RIS and EEG literature by demonstrating how RISs evolve with the co-evolution of technology, industry and education institutions
- Argues for an adoption of broad RIS conceptualization in future RIS studies

5.1.4 A4/Reshoring

- Shows how the development of advanced, highly automated production lines has enabled manufacturing reshoring amongst some Norwegian manufacturers
- An explorative case study that investigates the drivers for reshoring of 9 Norwegian manufacturers.
- Introduces the reshoring phenomenon to the economic geography field.
- Argues that the global production network framework is suitable in studying the multi-scalar, highly complex reshoring phenomenon.
- Contributes to the literature on strategic coupling by proposing a refined conceptualization of partial coupling processes.
- Identifies advanced manufacturing technologies as driver for reshoring and explores the conditions for reshoring to take place.

5.2 Overall contributions

The main aim of this thesis was to provide insights on how firm and non-firm actors in a high cost country (Norway) are engaging in processes of technology and knowledge upgrading in face of rapid technological advances within the manufacturing industry. In doing so, the thesis has employed and contributed to the development of the cluster approach, the regional innovation systems literature, and the global production network framework. This has entailed both filling gaps in the existing literature (A3), contributing with novel analytical frameworks in ongoing debates (A1 and A2), employing existing literature in new empirical contexts (A4), and providing conceptual refinements of existing conceptualizations within the literature (A4). Furthermore, the thesis provides insights on how the I4.0 narrative has created a momentum for technological upgrading, and how this momentum has resulted in knowledge and technology upgrading processes that might influence regional economic development.

Theoretically, the thesis aimed to contribute to the development and refinement of existing theoretical concepts and approaches within economic geography. This has been done in several ways. Articles A1/Evolution and A2/Absorptive contribute to the ongoing debate on cluster evolution and dynamics in two ways. First, A1 provides a novel analytical framework for analysing cluster evolution by drawing on the path creation literature (Martin and Sunley 2006; MacKinnon et al. 2019). As such, it provides a framework that is able to capture the decisive role of the nation state in developing the cluster. A2, then, provides a novel analytical

framework by combining the cluster absorptive capacity concept with the concept of intermediaries (in our case cluster intermediaries). As such, we were able to provide an enhanced understanding of how knowledge demands related to recent technological advances within the manufacturing industry are facilitated by cluster intermediaries through accessing vital extra-local knowledge and disseminating this knowledge to cluster firms. The two articles, then, contribute to developing literature on and understanding of how non-firm actors have played, and continues to play important roles in knowledge development and industrial and regional development.

The thesis also contributes to a research stream within economic geography that has received limited attention compared to the established system approaches or the path development literature, namely the discussion on how cross-fertilization between EEG, REG and IEG (Hassink, Klaerding, and Marques 2014). This thesis contributes to this research stream by investigating how system approaches that have been developed within the different 'types' of economic geography can be employed to achieve a deeper, multiscalar understanding of knowledge development processes and particularly how non-firm actors contribute to these processes. Furthermore, the thesis argues for an adoption of a relational understanding of knowledge within EEG, as it allows for a more dynamic understanding of the concept – developed through social interaction between different actors – and it's related development processes. Consequently, building on the work of Hassink, Klaerding, and Marques (2014) and Peck (2015), supporting a pluralistic approach to theory and cross-feralization, the thesis contributes to the theoretical endeavour which aims to develop a better understanding of the processes that lead to (uneven) regional economic development.

As reflected in PRQ1, SRQ1 and SRQ3, the thesis has aimed to illustrate the role of non-firm actors in developing technological and knowledge capabilities amongst Norwegian manufacturers. As such, the thesis connects with ongoing debates on the role of non-firm actors in economic geography (Dawley, Mackinnon, and Pollock 2019; MacKinnon et al. 2019) and illustrates the diversity of non-firm actors that are involved in the processes of knowledge and technology upgrading. For example, through a longitudinal study of the Raufoss an Kongsberg clusters, A1/Evolution, explores the role of the Norwegian nation state in contributing to path creation and path development in two state owned companies. Concomitantly, the state contributed to the development of the core clusters knowledges on systems engineering (Kongsberg) and material and manufacturing technology (Raufoss). Article A2/Absorptive, on

the other hand, sheds light on the role of cluster organizations as intermediaries that, in different ways, facilitate extra-local knowledge for cluster firms, thus enhancing the clusters' (Kongsberg and Raufoss) absorptive capacities. Finally, in A3/Vocational we demonstrate how vocational education institutions have become key actors within the regional innovation systems at Raufoss and Kongsberg. These institutions provide vocational education programmes and thus candidates that are essential in enabling manufacturers in the regions to implement advanced manufacturing technologies. By demonstrating the importance of synthetic knowledge for technology implementation, innovativeness and competitiveness, A3 challenge the dominant understanding of knowledge within the innovation system literature, which thus far, empirically, has focused on industry-university relations and analytical knowledge. Altogether the articles A1–3 illustrate how different state, regional and local actors have contributed to the development local and regional manufacturing activities over a long period of time (WWII until today (2019)).

Another aim of the thesis, reflecting SRQ2, was to explore how technological advancements within manufacturing industry could lead to a geographical shift in production. In A4/Reshoring, we identify advanced manufacturing technologies as a driver for manufacturing reshoring to Norway. However, these technologies must be matched with key regional assets such as knowledge and competence, key human capital and region-specific manufacturing competence. The article finds that although reshoring is a limited phenomenon in terms of number of cases, both in Norway and other western economies, it represents an empirical phenomenon that goes against the trend in international division of labour experienced the last three decades. A4/Reshoring illustrates how high-cost countries can leverage their knowledge, technological, organizational and institutional capabilities to (re)claim a position within the global manufacturing industry. These findings also contribute to our understanding of how high-cost countries could retain manufacturing, as the development of capabilities that can enable reshoring would probably increase manufacturers competitiveness and potentially prevent offshoring and outsourcing of manufacturing activities.

Empirically, the thesis aimed to provide empirical knowledge on how manufacturing technologies are challenging Norwegian manufacturers, and how manufacturers and non-firm actors engage in facilitating knowledge demands within the industry. The thesis has investigated this from both local (A1 and A2), regional (A3) and global (A4) levels. Taken together, the articles provide novel empirical knowledge on technology and knowledge

dynamics within Norwegian manufacturing industry in general, and within the two main cluster in particular. The thesis demonstrates that knowledge upgrading is a topic of core concern for firms within manufacturing, and that collaboration between firm and non-firm actors is essential in order to develop education programmes and candidates, on all levels. Furthermore, it has demonstrated that this collaboration is essential to secure continued competitiveness and innovation within Norwegian manufacturing. This knowledge could be useful in future development of policies related to education, innovation and industry. More specifically, the articles illustrate the key role of policies in terms of allowing for and supporting regional specialization within certain fields of knowledges that reflect the local and regional industrial history (such as NCE Systems Engineering and NCE Raufoss). As Norwegian manufacturers find themselves faced with potentially radical technological changes, and subsequent changes in knowledge demand, future policies on education, innovation and industry should aim to enhance existing (historically developed) comparative advantages while simultaneously developing manufacturers abilities to accommodate future change. Based on the success of previous collaboration processes between firm and non-firm actors (as pointed to in A1-3), future policies should facilitate continued collaborations and emphasise the role of non-economic actors in industrial and regional development.

5.3 Directions for future research

Throughout the PhD period, several empirical and theoretical topics related to manufacturing industry and knowledge and technological upgrading within the industry, which merits further attention, have appeared. As a proponent for a pluralistic theory-culture (Peck 2015) within economic geography, I will argue that the thesis illustrates how a combination of theoretical approaches can contribute to a more holistic understanding of multi-scalar processes. Therefore, the thesis encourages future research within the economic geography field to continue to cross fertilise (Hassink, Klaerding, and Marques 2014).

First, there is a need for more in-depth studies on the influence of the I4.0 narrative on the configuration of production networks, innovation systems, clusters, policy makers, manufacturers and other non-firm actors. In light of recent claims made on how clusters are conducive for the implementation and development of I4.0 technologies (Götz and Jankowska 2017), there is a need for empirical studies to enhance our understanding of how geographical proximity influences the adoption and implementation of advanced manufacturing

technologies. Equally important, studies on adoption and implementation of advanced manufacturing technologies in firms located outside clusters could provide insights on how the lack of geographical proximity influences technology upgrading. Such studies could additionally provide insight on how relation proximity (Boschma 2005), e.g. relations to other firms, research institutes or universities, could enable implementation of advanced manufacturing technologies, and potentially compensate for the lack of geographical proximity.

Although this thesis provides some reflections on the topic, I find that studies, in line with Morgan (2019), that more critically engages with the I4.0 concept, its origins, and its potential for both industrial and societal change are warranted. Considering the concept's popularity, and the attention that it has received, amongst decision and policy makers, I find that the influence of the I4.0 narrative on policies to be an interesting topic for future research. This could be conducted in multiple ways, however, I regard the literature on the sociology of expectations (Borup et al. 2006; Van Lente 2012) as a promising stream of literature, especially for research on how expectations towards I4.0 technologies amongst business leaders can influence investment decisions. Discourse analysis could be another promising approach to enhance our understanding of how the I4.0 concept, as a dominant narrative, influence industry and innovation policy development, but also how it influences policies that indirectly impact industrial development, such as educational policies. Although Morgan (2019) touches upon the role of agency when pointing out that consultancies are the primary providers of I4.0 narratives in policy development, the issue warrants further studies. A discourse analysis could contribute in this regard, and promote a better understanding of agency in relation to the I4.0 narrative by studying how it is portrayed and described, who the I4.0 advocates (actors) are and the political and economic forces behind it. On a more geographical note, there is a need for more studies (such as those in this thesis) that investigate how the I4.0 discourse manifests itself differently in different territorial contexts.

Secondly, I find that the reshoring phenomenon warrants further studies within economic geography as it essentially deals with the topic of (uneven) regional economic development. I find that the application of GPN framework could be a fruitful avenue for future reshoring studies as it can expand our understanding of the phenomenon by emphasising the entirety of drivers for reshoring (from the local to the global level). As argued in A4/Reshoring, we find that the GPN approach can provide a more holistic understanding of the phenomenon. Additionally, the reshoring phenomenon taps into a wider debate on the globality of the

capitalist economy. As such, it provides insight on how the division of labour is subject to change, and how mature economies can leverage their educational, organizational and technological and institutional capabilities and potentially reclaim a position within the manufacturing industry. In an environmental perspective, future studies on reshoring should incorporate perspectives on how the relocation of production to high-cost countries could influence the sustainability (e.g. CO_2 footprint) of manufactured goods and investigate if sustainability in consumer preferences and regulatory demands could be a driver for reshoring. Assuming that sustainability will become an important feature of future goods and products, similar to that of price and quality, Norway could – with green hydro power and relatively strict environmental laws – become an attractive host nation for manufacturing. Provided that CO_2 footprints become an important factor, manufacturing industry in general could become more regionalised (as the automotive industry) in order to limit transport emissions. In such a scenario (and in relation to their overall competitiveness), Norwegian manufacturers should, through education, innovation and industry policies, continue to improve their technological and knowledge capabilities in order to position themselves as potential manufacturers of sustainable goods for the European market.

Third, there is a need for further research on the development of vocational education, vocational education programmes, and the overall organization of vocational education. This taps into a wider societal debate in Norway, where vocational studies for many years have been regarded as second rated and associated with low societal status (Sjøberg 2014; Kind et al. 2016). In order to improve the status of vocational studies (in my case referring to technical studies related to manufacturing), there is a need to study both the organization and the implication of vocational education institutions and programmes. Based on our findings in A3/Vocational, I question whether the current organization of vocational education, which I will argue is characterised by a silo mentality (Gleeson 2013) where education and industry and commerce are thought of separately, is able to accommodate future knowledge demands. In this regard, studies that investigate the possibilities for, and potential of, improving collaborations between industry and vocational education institutions, that in turn provides policy recommendations regarding such organizational change, are warranted. One potential pathway for this type of research could be investigating the influence of geographical and relation proximity (Boschma 2005; Moodysson and Jonsson 2007) on industry-education collaboration. In A3 we identify vocational education institutions as a key knowledge provider in the Raufoss and Kongsberg regional innovation systems. Furthermore, we identify skilled workers (with

trade certificates) as essential in the implementation of advanced manufacturing technologies. These types of studies, in addition to campaigns and initiatives that have been initiated by the manufacturing industry, can contribute to nuance vocational studies' bad reputation and low status (compared to university-preparatory) amongst young people (Sjøberg 2014) by demonstrating the importance of labour with vocational education for competitiveness. As such, they could also contribute with insights on how to prevent a potential future lack of vocationally educated labour.

Finally, as stated in the introduction, I believe that the Norwegian economy should be less dependent on oil and gas extraction. In order to achieve that, while at the same time maintaining a well-developed welfare state, other industries have to be developed. I find that manufacturing, which was a substantial industry in 1974 (accounting for 18,3% of the Norwegian GDP), could reclaim its position. Therefore, there is need to further study manufacturing industry in Norway in order to provide insight on how to develop the industry further and potentially retain existing manufacturing industry. This entails both studies that lead to policy recommendations for education, innovation and industry policies.

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PART II

A1/Evolution

On the evolution of clusters and the role of state agency: An historical analysis of two defence-related high-tech clusters in Norway

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Submitted to a journal, December 2019.

A2/Absorptive

Cluster absorptive capacity: Two types of intermediaries in technology upgrading of manufacturing clusters

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Under review, November 2019.

Cluster absorptive capacity: Two types of intermediaries in technology upgrading of manufacturing clusters

Abstract

Specialized clusters are based on common knowledge resources and other positive externalities, but it is unclear how such resources develop over time. A case in point is how extra-cluster knowledge linkages are integrated into intra-cluster linkages by firms or other actors and subsequently shared with other cluster actors. To advance the understanding of cluster dynamics and renewal through knowledge exchange, the authors develop a refined conceptualization of cluster absorptive capacity by addressing the role of agency. Intermediaries link clusters to external knowledge sources and contribute to dissemination of knowledge among cluster firms, and the authors find this perspective relevant because manufacturing firms are facing rapid changes in technology platforms, such as those associated with 'Industry 4.0'. Additionally, the authors analyse processes of knowledge exchange and technology upgrading of two mature manufacturing clusters in Norway. The results show that the processes are supported by knowledge institutions and facilitated by cluster organizations in quite different ways. In the light of the theoretical discussions and findings from the two case studies, the authors propose a novel conceptual framework that combines two types of intermediaries and two types of absorptive capacities for investigating the role of non-firm actors in contrasting types of clusters.

Keywords: Cluster Dynamics, Absorptive Capacity, Extra-cluster Linkages, Intermediaries, Technology Upgrading, Industry 4.0

1 Introduction

Few theoretical constructs in the economic geography and regional science literatures rival the cluster concept in terms of academic interest and popularity among policymakers (Porter 2000; Ebbekink and Langdijk, 2013; Trippl et al., 2015; Isaksen 2018). Scholars in the field typically assume that cluster firms effectively share knowledge between them via various localized knowledge spillover mechanisms (Audretsch and Feldman, 2004). Recent contributions to the cluster debate emphasize that cluster firms and organizations need to source extra-cluster knowledge and develop extra-regional linkages in order to stay competitive (Bathelt et al., 2004; Karlsen and Nordhus, 2011; Kesidou and Snyjders, 2012).

Extra-cluster knowledge inputs are especially important in times of rapid and comprehensive technological change. Recent technological development, especially in terms of manufacturing technologies, has been associated with the term Industry 4.0 (I4.0), which creates a momentum for discussing how cluster firms should engage with technological upgrading. I4.0 technologies are predicted to have significant implications for the organization of production both within firms (Schwab, 2016) and in value chains and networks. For firms facing accelerated technological change, it appears urgent to develop organizational capabilities to implement these new technologies. Capabilities for technology upgrading have largely been analysed on the individual firm level (Crescenzi and Gagliardi, 2018), while less attention has been paid to the cluster level.

In their seminal contribution, Cohen and Levinthal (1990, p. 128) introduce the concept 'absorptive capacity', which refers to firms' ability 'to recognize the value of new information, assimilate it, and apply it to commercial ends.' The absorptive capacity concept has since been widely adopted in micro-level studies of knowledge flow, acquisition and exploitation in learning and innovation processes (Lau and Lo, 2015; Miguélez and Moreno, 2015). Giuliani (2005, p. 280) introduced the concept 'cluster absorptive capacity' (CAC), which she defines as 'the capacity of a cluster to absorb, diffuse and creatively exploit extra-cluster knowledge', which 'depends on the knowledge bases of its' firm members'. Giuliani's CAC concept places key emphasis on firms' absorptive capacity. Furthermore, 'the cluster absorbs external knowledge through "receptor" firms' that are referred to as technological gatekeepers' (ibid., p. 280).

Inspired by Laur et al.'s (2012) work on cluster initiatives as intermediaries, we suggest that other non-firm actors can be instrumental in the identification, assimilation and diffusion of external knowledge within clusters. As such, this paper offers a novel understanding of cluster dynamics (Trippl et al., 2015) and technology upgrading, by developing a refined CAC conceptualization. Additionally, the paper adds content to the absorptive capacity concept, which has been widely used (Trippl et al., 2017; Vang and Asheim, 2006), but insufficiently developed. To advance the understanding of intra-cluster and extra-cluster linkages in cluster dynamics, we investigate the role of

cluster intermediaries (CIs), which are organizations that facilitate and promote knowledge flows between industry and knowledge institutions (Clarke and Ramirez, 2013). Thus, CIs couple extra-local knowledge linkages to cluster firms and enable localized knowledge spillover processes.

Through a qualitative study of two clusters that are comparable both in size and industry sector, but different in terms of their predominant knowledge bases, we develop typologies of intermediary roles with regards to CAC. The key aim of this paper is thus to enhance the understanding of the different roles of CIs in linking extra-cluster and intra-cluster knowledge, and how CIs contribute to CAC. The paper addresses the following research questions:

How and to what extent do cluster intermediaries facilitate extra-cluster linkages and provide new and vital knowledge among cluster firms?
What roles can cluster intermediaries take in various cluster contexts in order to enhance absorptive capacities?

Empirically, we analyse recent developments with regards to knowledge development and technological upgrading in two high-tech manufacturing clusters in two towns in Norway. Historically, both towns – Kongsberg and Raufoss – were hosts to key state military-related industry activities (weapons and ammunition respectively). Both were initially single-company localities specialized in defence industries, but gradually diversified into high-tech manufacturing clusters within automotive, aerospace and offshore subsea industries. Currently, some of the key cluster firms are upgrading their manufacturing processes by implementing advanced manufacturing technologies in their production facilities and/or upgrading their products by utilizing novel combinations of materials. By comparing the two clusters in Kongsberg and Raufoss with regards to recent strategies and capabilities for technological upgrading (including advanced technology platforms associated with I4.0), we discuss the significance of knowledge bases, knowledge linkages and the related role of intermediaries. The paper contributes to a refined understanding of CAC and the role of CIs in cluster development.

The paper proceeds as follows. In the next section, we discuss the cluster concepts with regards to I4.0, inter- and extra-cluster-linkages, firm- and cluster-level absorptive capacity, and the role of intermediaries. Thereafter, in Section 3, we present the qualitative research design and a brief narrative of the two empirical cases. In Section 4 we analyse and discuss the clusters' and CIs' current efforts in skills and technology upgrading, and propose a typology of CIs. Finally, in Section 5 we present our conclusions.

2 Cluster, technology upgrading and Industry 4.0

Research suggests that firms located in clusters tend to have better innovation performance than non-cluster firms (Audretsch and Feldman, 2004; Delgado et al., 2014). Cluster firms' enhanced performance is related to linkages between cluster firms, social capital, trust, a shared knowledge base and common pool of human capital, and the presence of supportive institutions (Ebbekink and Lagendijk, 2013; Kesidou and Snyjders, 2012).

Porter (2000) defined clusters as geographical concentrations of interconnected companies, specialized suppliers, and associated institutions in a particular field that compete but also cooperate. More recently, the conceptualization of clusters has become less stringent and more flexible with regards to relational qualities, but narrower with regards to the territorial dimension (Malmberg and Power, 2005). Chapman et al. (2004, p.382) understand cluster as 'concentrated groups of inter-linked firms and organizations occurring at the local and regional scales'. Cluster research has emphasized different dimensions of clusters: The interrelated firms could be in the same industry and have customers or suppliers in the same value chain (Porter, 2000), have non-market based interactions (Marshall, 1920; Bathelt et al., 2004) and benefit from a common labour pool (Marshall, 1920; Malmberg and Maskell, 2002). These different cluster qualities and intra-cluster relations are regarded as vital for cluster firms to share knowledge, innovate, and upgrade their technologies.

The knowledge bases that cluster firms draw on are supposed to influence the novelty of their innovations. Analytical knowledge embraces scientific and codified knowledge, and is often applied when creating new products or new processes (i.e. radical innovation). Synthetic knowledge concerns hands-on practical knowledge, which is typically applied to solve specific problems occurring in interactions with clients and suppliers. For firms relying on a synthetic knowledge base, the dominating form of innovation is thus considered incremental (Asheim and Coenen, 2005). Radical innovations may have disruptive effects for clustered firms (Molina-Morales et al., 2019).

Since the early 2010s, the manufacturing industry has been confronted with what some call a new digital revolution, referred to as Industry 4.0 (Schwab, 2016). I4.0 is used as a generic concept to embrace various technologies that may radically change both the nature and spatial patterns of manufacturing activities. Although no common definition of I4.0 exists, there is consensus that I4.0 covers a range of technologies such as autonomous robots, the Internet of Things (IoT), cyber-physical systems, additive manufacturing/3D printing, Big Data, artificial intelligence, and machine learning (Schwab, 2016; Götz and Jankowska, 2017). The disruptive potential is found in the combination of some or many of these technologies. In sum, I4.0 is predicted to change business models and have transformative effects on the organization of production, logistics and distributions, and the governance of value chains and networks. Many I4.0 technologies could reduce production costs (e.g.

autonomous robots), which is essential for manufacturers in high-cost countries (Lund and Steen, 2019).

As a consequence of digital technologies' ability to ease interaction over longer distances, different value chain activities could become more geographically dispersed. As such, I4.0 may undermine some of the advantages of co-location provided by contemporary manufacturing clusters, as it reinforces the interconnection of firms across space, thereby creating international network associations (Alcácer and Cantwell, 2016). However, Götz and Jankowska (2017) argue that clusters are conducive to the development and implementation of new technologies (I4.0) because they ease interaction among multiple types of actors, including scholars and practitioners. Implementation of these new technologies requires a combination of synthetic knowledge and analytical knowledge. In manufacturing industries, skilled workers have a key role in workplace innovation. However, both skilled workers and the related vocational education system are challenged, as the actual discovery and introduction of these new technologies rely on analytical knowledge. In the face of emerging technologies, this emphasis on analytical knowledge must be reflected in educational programmes (Lund and Karlsen, 2019).

In clusters, the education system is typically well connected and adapted to the local industry (Lund and Karlsen, 2019) and mobility of skilled personnel provides knowledge spillover and territorially embedded knowledge bases (Malmberg and Maskell, 2002). Götz and Jankowska (2017) find location specific factors, such as an environment of collaboration and trust, favourable for the development of I4.0 technologies, particularly in early phase of testing and experimenting. However, Götz and Jankowska's (2017) emphasis on the internal qualities of clusters and cluster dynamics neglects recent attention to extra-cluster linkages and the need for extra-local knowledge to keep cluster firms innovative and competitive (Martin et al., 2018; Molina-Morales et al., 2019). Given that I4.0 is about combining different kinds of technologies and that specialized clusters rely on specialized competence and expertise, exploiting extra-local complementary knowledge sources seems inevitable in order for firms to achieve technological upgrading.

2.1 Intra-cluster and extra-cluster linkages

Bathelt et al. (2004) argue that the co-existence of key strategically developed extra-local knowledge linkages (referred to as global pipelines) and high levels of localized informal and formal knowledge sharing (referred to as local buzz), and their active coupling enable cluster firms' access to vital external knowledge while taking advantage of exclusive local knowledge. However, this line of argument has been criticized for reducing local interaction to informal social networks, and global linkages to strategically selected and formal networks, thus neglecting a wider spectrum of linkage forms (Grillitsch and Trippl, 2014; Trippl et al., 2015; Martin et al., 2018).

Knowledge exchange could take place on an international level through the value chain (customer-supplier relationships), mobility of skilled labour, formal collaboration between industry and R&D, informal networks in virtual communities, participation in temporary clusters, and foreign direct investments/foreign ownership, and at a local level, through formal collaboration and mobility in the labour market (Trippl et al., 2017; Martin et al., 2018). However, the cluster debate tends to emphasize local/regional and international level linkages and often disregards the national level as a frame for industry-R&D linkages and policy implementation (Isaksen, 2009; Sæther et al., 2011). The latter point resonates with the original cluster approach by Porter (1990) and the literature on national innovation systems (Lundvall, 1992; Nelson, 1993, Fagerberg et al. 2009). A reasonable understanding is that regional, national, international, sectoral, and technological systems of innovation are overlapping (Sæther et al., 2011; Grillitsch and Trippl, 2014).

Agency has recently been suggested to have a vital role in innovation systems: Grillitsch and Sotarauta (2019) use the concept 'institutional entrepreneurship', whereas Hassink et al. (2019) introduce the related concept of 'system level agency'. The latter scholars point to actors who are capable of influencing the broader local industrial environment outside their own institutional/organizational borders. These actors could be research institutes that collaborate with regional firms in order to enhance their competitiveness or cluster organizations that work to promote either networking and joint development or market-related activities among cluster members (Hassink et al., 2019). In our cluster context, we refer to these actors as 'intermediaries', and as such we argue that they contribute to the absorptive capacity of clusters.

2.2 Firm-level absorptive capacity

In their seminal contribution, Cohen and Levinthal (1990, p. 128) defined absorptive capacity as the ability of firms to 'recognize the value of new, external information, assimilate it and apply it to commercial ends'. Furthermore, an organizations ability to see and evaluate new information (absorptive capacity) depends on the organization's prior related knowledge (Cohen and Levinthal, 1990). Firms' absorptive capacity has typically been a subject for quantitative research, in which proxy indicators have been investments in R&D, number of scientists, share of staff with higher education background (as measures of innovation input), and patents (as a measure of innovation output) (Crescenzi and Gagliardi, 2018) (see Volerda et al., 2010 for a review). These proxy indicators are easier to measure for large companies, in which the division of labour is high and respective accounting is more accurate than in SMEs, in which employees may have multiple functions and are thus harder to categorize.

These quantitative measurements are biased by indicators targeting analytical knowledge typically held by managers, researches and experts. However, synthetic knowledge embedded in shop floor

practices is more challenging to capture in typical quantitative studies. By employing qualitative research methods when studying CAC, we could reveal in a better way the intra-organizational capacities of sharing knowledge and contribute a novel understanding of how intermediaries work with both local and extra-local firms and non-firm actors.

In sum, the firm's absorptive capacity relies on the expertise within the organization and the structure of communication within and between its subunits, as well as with the external environment (Cohen and Levinthal, 1990). This way of thinking also makes sense at an inter-organizational level, including a cluster level. As we move from the firm level to the cluster level of analysis, the conceptualization of absorptive capacity increases in complexity. This aggregation calls for further conceptualization of CAC.

2.3 Cluster absorptive capacity

Relatively recently, the absorptive capacity concept has appeared in studies of higher meso-levels of society such as regional innovation systems (Trippl et al., 2017), regions (Miguélez and Moreno, 2015), and clusters (Giuliani, 2005). Whereas some business management studies recognize that clusters have favourable conditions for absorbing external knowledge, they still have the individual firms and their absorptive capacities as the only unit of analysis (Lau and Lo, 2015, Crescenzi and Gagliardi, 2018; Zou et al., 2018). Other contributions connect absorptive capacities directly to the cluster (Giuliani, 2005) or to the region (Vang and Asheim, 2006), arguing that cluster/regional absorptive capacity is more than simply the sum of the absorptive capacities of all the firms in the cluster or within the region.

Giuliani (2005) explains what determines CAC by focusing on firms' knowledge bases, which are defined by Dosi (1988, p. 1126) as a 'set of information inputs, knowledge and capabilities that inventors draw on when looking for innovative solutions'. In her CAC taxonomy Giuliani (2005) distinguishes between 'basic' and 'advanced' stages of CAC, understood as ideal types representing a continuum. Basic CAC clusters are characterized by firms with weak knowledge bases, have weakly interconnected intra-cluster knowledge linkages, limited external openness, and an absence of firms that can act as technological gatekeepers. Firms in clusters with advanced CAC have very strong knowledge bases, contribute by investing in in-house R&D, have dense knowledge linkages, and absorb knowledge from extra-cluster sources with the help of technological gatekeepers. Moreover, Giuliani (2005) adds an 'intermediate' level of CAC that has medium scores on the factors mentioned above.

However, use of the levels of weak, intermediate and advanced CAC risks disregarding other combinations of advanced and weak knowledge bases and intra- and extra-cluster linkages, thus neglecting cluster heterogeneity. Clusters with weak knowledge bases could, for example, be

compensated for by strong intra-cluster linkages and/or vital roles of gatekeepers, or vice versa. However, Giuliani (2005) stresses that clusters need technology gatekeeping, a process found in firms that have strong knowledge bases and making them capable of connecting extra-cluster knowledge and local knowledge systems (see also corresponding argument by Kesidou and Snyjders, 2012). We recognize that Giuliani does not make any distinctions between types of extra-cluster knowledge sources. In addition to her CAC taxonomy, we include the national innovation system as a level of significant extra-local knowledge linkages (Trippl et al., 2015; Chaminade et al., 2019). Furthermore, rather than adopting the term 'technology gatekeepers', which is primarily associated with economic actors, we opt for the term 'intermediaries', thus allowing for enhanced emphasis on the role of non-private intermediaries (Clark and Ramirez, 2013) in cluster development.

2.4 The role of intermediaries in cluster absorptive capacity

In addressing the role of agency in cluster dynamics and development, and given the firm focus in CAC studies to date, we include especially the role of local non-firm actors (Trippl et al., 2015; Bianchi and Labory, 2019). In our context, non-firm actors comprise knowledge and support institutions (including cluster organizations) that are vital for cluster development. Such institutions may work as intermediaries, creating arenas for knowledge exchange and building networks.

Intermediaries are regarded as brokers that 'connect and coordinate otherwise disconnected others' (Foster et al., 2015, p.436). In addition to this bridging work, intermediaries may also strengthen existing linkages. Intermediary organizations could have a vital role in building efficient regional technology-transfer systems between universities and firms, given that regional firms have sufficient absorptive capacities (Kodama, 2008). More specifically, they can coordinate projects, provide and diffuse knowledge, and help to adapt existing knowledge to new contexts (Clarke and Ramirez, 2013). Intermediaries are able to support the development of local assets such as workforce skills and competences through influencing, for example, regional and national policies on R&D and education (Smedlund, 2006). Through their influence on policy, intermediaries could be able to enhance the organizational support structure of the region (Trippl et al., 2017). Intermediaries will, to varying extents, be embedded in the clusters (Foster et al., 2015; Ter Wal et al., 2017). They should have field-specific competences and skills, as well as substantial knowledge about the region, which is important for their ability to recognize the needs of regional industry when facilitating interaction between production, development and research (Smedlund, 2006).

We understand CIs as organizations – both private and public – that promote overall CAC by linking clusters to extra-cluster knowledge sources, spurring technology transfer and organizing intra-cluster collaboration. In line with Clarke and Ramirez (2013, p.717), we define CIs as cluster organizations

and brokers that facilitate knowledge flows between industry actors and knowledge institutions, and thereby contribute to processes of learning and capability building in cluster firms. As such, CAC depends on cluster firms' previous knowledge, but leans on the intermediaries' ability to access extra-local knowledge and translate knowledge for intra-cluster diffusion.

Researchers who conduct studies of clusters should be aware of place-specific contexts (Giuliani, 2005) in order to recommend context sensitive cluster policies (Asheim and Coenen, 2005; Tödtling and Trippl, 2005). In the same way the role of intermediaries should reflect on and be well adapted to the cluster context. In light of this, we generalize our empirical findings by developing CI typologies with regards to the provision of human capital and skills, and with regards to the facilitation of R&D and innovation collaboration. On the basis of a context-sensitive qualitative case study, we are able to pair these ideal CI types with ideal types of clusters.

3 Qualitative methods: comparison of two mature manufacturing clusters

In our comparative approach we study two mature clusters that are specialized in manufacturing industries and situated in semi-peripheral locations. Our research design is in line with a multiple case study approach (Yin, 2014) in the sense that the two clusters have both similarities and differences. The respective clusters in Raufoss and Kongsberg have some commonalities regarding industry sectors, but differ with regards to firm sizes, structure of networks, support institutions, and cluster specific knowledge bases. Both clusters are defined by shared competences among the cluster firms rather than the industrial sector to which the cluster firms belong. The Kongsberg cluster firms have overlapping competences in system engineering (SE – i.e. design, develop and implement advanced systems), which is a legacy from the former weapons factory. Competences and expertise in material technology and automation unite the manufacturing firms in the Raufoss cluster.

This study is based on data from 22 in-depth semi-structured interviews with representatives from cluster firms (9) and several local and regional institutions and organizations. The interviews were conducted during the period 2016–2019. The participants were predominantly managers from cluster firms, cluster organizations and knowledge institutions (R&D institutes, university and vocational education providers). Our primary interview data are supplemented by secondary sources (reports and journal articles on the studied clusters), observation, and participation at workshops organized by SFI Manufacturing[1]. By combining data from previous studies on these two clusters by other researchers, with our own empirical material, we rely on what Yin (2014) refers to as data triangulation, to enhance the reliability of our findings. Our interview data concerning the clusters' key characteristics are supported by findings in previous studies (Onsager et al., 2007; Isaksen, 2009; Johnstad and Utter,

[1] SFI Manufacturing is a partner in the Center for Research Based Innovation scheme (2015–2023) funded by the Research Council of Norway.

2015). The data analysis relies on the coding of all of our sources of data which was done using the qualitative data analysis software NVivo, in which codes reflected theoretical concepts such as CI, CAC, and intra-cluster and extra-cluster linkages and knowledge bases.

3.1 Kongsberg case

Kongsberg is a medium-sized town by Norwegian standards, with 27,000 inhabitants, while the local labour market area compromises c.54,000 people (2019). The town of Kongsberg has its roots in a mining company, which was established in 1624 following the discovery of rich silver deposits in the mountains. Kongsberg has been identified as one of eight high-tech agglomerations in Norway.[2] and its development, along with other similar clusters in Norway, was dependent on the support of national political initiatives, public research institutions and public entrepreneurs (state-owned companies) (Onsager et al., 2007). Particularly during the 1960s and 1970s the state gave the core defence industry in Kongsberg a role in modernizing Norwegian industry. The agglomeration is thus a result of national industry and technology policies. Today, the Kongsberg high-tech agglomeration comprises c.20 companies and c.4000 employees, of this more than 70% employed in the five largest companies. Core activities are production of technological equipment and systems for the offshore, maritime, aircraft, automobile, and defence industries.

3.2 Raufoss case

The town of Raufoss is the administrative centre of Vestre Toten Municipality and has c.7500 inhabitants, whereas the local labour market area is currently home to c.70,000 people. The Raufoss cluster originates from Raufoss Ammunisjonsfabrikker (RA) (ammunitions factory), which was established in 1896. Similar to Kongsberg, Raufoss has played an important role in the development and modernization of Norwegian industry, and many of today's privately owned companies located in Raufoss have their roots in divisions that evolved within RA (Johnstad and Utter, 2015). The Raufoss manufacturing cluster has 5 core companies and a network (TotAl-gruppen) of 46 small enterprises, which mainly serve the core cluster companies, and together the companies and small enterprises have c.5000 employees. Today the cluster consists of 17 consortia firm partners. Raufoss firms, which typically have mass production, emphasize incremental process innovation (Karlsen, 2019), whereas Kongsberg firms rather focus on product innovation.

[2] Onsager et al. (2007) define high-tech agglomerations as having minimum 1500 jobs and 50% or higher employment in high-tech industries in the local labour market area than the national average.

4 Empirical analysis

In subsections 4.1-4.5 we first discuss how extra-cluster linkages influence firm-level absorptive capacities, and thereafter we elucidate the role of the cluster intermediaries and how they enhance CAC, before we discuss the findings.

4.1 Firm-level absorptive capacity

Departing from the recognition of CAC as something more than the sum of firm-level absorptive capacities (Giuliani, 2005), yet dependent on cluster firms' existing knowledge base, it is necessary to elaborate the absorptive capacity of the individual firms in Kongsberg and Raufoss in order to understand their respective CAC. In subsection 4.1, we discuss the influence of education levels and both parent company and value chain linkages on the cluster firms' absorptive capacity.

4.1.1 Employees' educational level and overall R&D

The Kongsberg cluster is characterized by an analytical knowledge base, which is also reflected in the specialization of the cluster. Isaksen (2009) found that the proportion of employees in core cluster firms in Kongsberg with university degrees was c.70%, which implied that the average education level in Kongsberg was much higher than the national average (Onsager et al., 2007). These employees are mainly recruited from the Norwegian University of Science and Technology (NTNU) or the regional university (University of South-Eastern Norway). By contrast, the Raufoss cluster is characterized by a synthetic knowledge base. Approximately 25% of the employees in the Raufoss cluster firms have a university degree. The remaining employees are primarily technicians from vocational colleges, skilled workers from vocational secondary schools, or workers with experience- and industry-based trade certificates (Johnstad and Utter, 2015). According to our interviews, both Raufoss and Kongsberg cluster firms emphasize short distances between top management and workers on the shop floor as favourable for participatory innovation processes.

By tradition, the Kongsberg core firms have had a high share of R&D expenditures: half of the firms have spent more than 10% of their turnover on R&D activities. The R&D expenditures have been much lower for the core cluster firms in Raufoss, where only two firms have spent at least 10% of their turnover on R&D (Isaksen 2009). We believe the latter relates to lack of in-house R&D departments in Raufoss firms, which has historical explanations (see Section 4.2)

Following the line of argument in the literature on firm-level absorptive capacity (Crescenzi and Gagliardi, 2018), the above figures indicate that each Kongsberg cluster firm has a high absorptive capacity, whereas each Raufoss cluster firm has a low absorptive capacity.

4.1.2 Parent company and value chain linkages

In order to improve a firm's capacity to innovate, it is necessary to access external knowledge sources (Crescenzi and Gagliardi, 2018). Such sources can be found along the value chain and within the

company structure of transnational corporations (TNCs). At least in principle, large firms can draw on more varied expertise within their organization, but may have difficulty in terms of coordination and socialization (Zou et al., 2018). Several of the Kongsberg and Raufoss cluster firms are subsidiaries or branch plants and find strength in being owned by a foreign parent company, as they benefit from competences and resources from the corporation's broader activities (Onsager et al., 2007). In Kongsberg, the head of research and technology at an aerospace manufacturer explained that they have a fruitful collaboration with their Swedish sister company, and that the parties draw on mutual advantages of considerable knowledge exchange (interview with head of R&D, 2017). In Raufoss, a company executive in an automotive branch plant, explained that they received help from their German parent company when implementing new robot technologies in production. The branch plant subsequently sent some of their employees to Germany for training and education (interview with company executive, 2016). The two examples illustrate how parent company linkages provide extra-local knowledge that improves the absorptive capacity of the cluster firms.

The cluster firms consider customers the most important source of knowledge for their innovations, particularly in the case of Kongsberg cluster firms, which deliver highly customized products in close interaction with their customers (Onsager et al., 2007). A component producer for an international defence industry takes part in customer organized workshops on topics such as robotization, digitalization and data capture (technical director, 2019). The core Kongsberg cluster firms draw on electronics firms and machining firms from the wider region of Eastern Norway and other suppliers dispersed around the country (Onsager et al., 2007) (interviews with business informants, 2016-17). In Raufoss, two local technology suppliers play key roles in implementing advanced manufacturing technologies in firms' production lines. A management executive at a defence and aerospace manufacturer claimed that it was 'a great advantage' to have the technology provider 'in the neighbourhood' (VP operations, 2018). Evidently, several external knowledge sources are important for the innovativeness of the cluster firms in Raufoss and Kongsberg. Given the respective dominant knowledge bases and supplier network structure, we may, as a point of departure, expect that individual cluster firms in Kongsberg are more directly exposed to cluster external knowledge impulses than are single cluster firms in Raufoss.

Whereas many quantitative studies base the CAC on proxies such as employees' educational level, R&D expenditure, and patents (Volerda et al., 2010; Crescenzi and Gagliardi, 2018), this qualitative study regards the function of cluster intermediaries (CIs) as essential in the development of CAC. Therefore, we explore the role of CIs in facilitating extra-cluster knowledge and their influence on CAC from the perspective of both the CIs and the cluster firms.

4.2 Cluster initiatives as cluster intermediaries

4.2.1 Historical linkages resulting in different CI function

The contrasting organization of the CIs in Raufoss and Kongsberg has historical reasons. The Kongsberg CI, (*Kongsberg innovasjon* – hereafter referred to as KI) ran the National Centre of Expertise in Systems Engineering[3] (2006–2016). After the NCE funding ended in 2016, KI became an innovation company and incubator, and continues to take part in national innovation programs[4]. However, the Raufoss CI (SINTEF Manufacturing – hereafter referred to as SM) has historical linkages to the internal R&D unit that existed within the state-owned ammunitions company. SM found its existing form after a demerger in the 1990s, when the former in-house R&D unit became a separate (applied) R&D actor within the Raufoss industrial park. SM (partially owned by the Raufoss industry) thus came to function as a common good – R&D provider – for all of the cluster firms (Johnstad and Utter, 2015). By contrast, the core Kongsberg cluster firms have kept their R&D personnel in-house since the disintegration of the Kongsberg weapon factory in the late 1980s.

4.2.2 Private intermediary – enhancing firm absorptive capacity

The literature on intermediaries makes a distinction between non-private and private intermediaries (Clarke and Ramirez, 2013). SM in Raufoss has been the 'public' cluster organization that coordinated the collaboration between firms in the Raufoss cluster in the NCE Raufoss[5] period (2006–2016), focusing on automation and light-weight materials which form a cluster specific knowledge base. During the same period, under different names, it was a privately owned R&D institution. In practice, it is hard to separate the NCE cluster initiative from the private R&D institute. According to a senior advisor at SM, this is intentional, and the idea is that they are supposed to go 'hand in glove', where 'NCE is the glove and SM is the hand' (interview with senior advisor, 2017). Thus, SM is a public-private intermediary, serving cluster firms in different ways. SM continues to take part in national innovation programmes.[6]

As a private R&D institute, SM provides the core cluster firms with access to laboratory facilities and experts/researchers on materials and automated production processes. Today, SM functions as the cluster firms' laboratory, which according to an R&D manager at an automotive cluster firm was of

[3] In 2006 a National Centre of Expertise (NCE) on Systems Engineering was established with financial support from the national support organizations Innovation Norway, the Research Council of Norway, and the Industrial Development Corporation of Norway (Siva).
[4] The cluster in Kongsberg (NCE System Engineering) has recently been integrated into the various national groupings such as DIGITALNORWAY – Toppindustrisenteret, NCE iKuben, and NCE Smart Energy Markets. Omstillingsmotor is a grouping of established clusters in Kongsberg, Raufoss and Halden that should accelerate process of digitalization and enhance the innovation capability in more than 200 SMEs in Norway.
[5] National Centre of Expertise on lightweight materials and automated production
[6] Initiated and controlled by SM, Raufoss currently hosts the Norwegian Manufacturing Technology Center (NMTC) as part of the Catapult Centre programme funded by the Norwegian Ministry of Trade, Industry and Fisheries.

key importance when they showed international customers and partners their 'R&D tool kit' (interview with R&D manager, 2017). As a private intermediary and R&D provider, SM contributes to enhance firms' absorptive capacity. SM also has an important function for extra-cluster firms. An aerospace manufacturer in the Kongsberg cluster explained that SM 'is an important knowledge and technology provider' (management executive, 2017) for the company, which collaborates more with SM and other Raufoss firms, than with firms within the Kongsberg cluster.

In addition to SM, there is a second intermediary in Raufoss, the TotAl-gruppen (Total group, TG), which is geared towards suppliers (small enterprises) located outside the industrial park. TG's primary function is to develop collaboration and joint action within a business network of 46 small enterprises. TG was established in 1998 – initially with 15 firms, many of them spin-offs from RA – in order to ensure stability for the suppliers in terms of access to customers. The manager of TG underlined that craft skills, including tacit knowledge, was essential for member firms' performance. However, some of the larger firms in the cluster are also members of the group, and thus contribute to the development of both the network and the suppliers. There is certainly a duality to this, as the collaboration also enables core cluster firms to, in some degree, take control of the development in their own supply chain, 'ensuring that all these suppliers are qualified to deliver to us [core cluster firms]' (representative at SM, 2017). This type of collaboration could have been more difficult if TG had not existed. We thus recognize TG as a subordinate intermediary that is connected to the main Raufoss CI, reflecting how territorially embedded the local manufacturing firms are.

Whereas SM has mainly facilitated network collaboration, particularly with regards to R&D, the efforts of KI have mainly been to enhance firms' absorptive capacity by providing the cluster firms with skilled candidates.

4.2.3 Enhancing firms' absorptive capacity through education and training

Systems engineering has its origin in American defence and since the 1960s it has been developed as a cluster specific knowledge base for the Kongsberg industry. This interdisciplinary field is about developing advanced systems and complex products for several industries. This legacy from the former weapons factory was highlighted in the cluster initiative's application for NCE Systems Engineering and has successively been a focal area for both higher education and research in Kongsberg. The most prevalent example of this is the development of a master's programme in systems engineering at the regional university in 2006, in close collaboration with core cluster firms, and the subsequent establishment of the Norwegian Institute for Systems Engineering at USN in 2012. The content is very much adapted to the needs of the cluster firms, which host the candidates during internships and often recruit candidates before they complete their degree (NCE SE 2016).

Supported by KI, USN operates alongside other providers of skilled candidates, on lower levels. Kongsberg Technology Training Centre (K-Tech) provides industry-relevant vocational education and apprenticeships. Three major companies established K-tech in 2008 to meet their need for skilled workers. Their workforce becomes technologically upgraded as the students are given access to up-to-date machinery and are provided with a training arena similar to that on 'real' production lines. The vocational college in Kongsberg has developed a new educational programme that covers topics such as the Internet of Things, industrial intelligence, autonomous systems, and Big Data, which are technologies that are expected to permeate future industry (Lund and Karlsen, 2019).

In sum, we recognize that the CI and supportive institutions in Kongsberg have contributed substantially to the renewal of educational programmes and training, and prepare cluster firms' knowledge base for the implementation of new technology. They are very much directed towards providing the industry with industry-relevant candidates in engineering and other skilled workforces with up-to-date qualifications. Provision of highly skilled candidates with skills in vital technologies is important for the absorptive capacities of core cluster firms. They demonstrate high ambitions with regard to the implementation of I4.0 technologies (interviews with business representatives from three key cluster firms, 2017-19). The lack of a united intermediary for coordinating providers of industry-relevant education and training at different levels of education reflect the more institutionally fragmented character of the cluster in Kongsberg compared with the more unified cluster and CI in Raufoss. However, in Raufoss the CI has been less successful in developing collaborations with regional and local education institutions, notwithstanding recent efforts at the vocational college (Lund and Karlsen, 2019).

4.3 Cluster intermediaries – facilitating extra-cluster knowledge linkages

4.3.1 SM – accessing actors in the national innovation system

By virtue of being a public intermediary SM has facilitated two Centres for Research-based Innovation (SFI), SFI Norman (2007–2014) and SFI Manufacturing (2015–2023) aimed at improving manufacturers' competitive advantage by implementing advanced manufacturing technologies and material technology in production. Four core cluster firms in Raufoss and one in Kongsberg participate in SFI Manufacturing and additional eight extra cluster firms participate in the centre coordinated by SM. In the ongoing SFI Manufacturing, key knowledge providers are NTNU (Trondheim) and SINTEF (Trondheim and Oslo). Thus, SM has a key role in accessing extra-cluster knowledge and technology on a national level. In line with Clarke and Ramirez' (2013) discussion on the role of CIs, SM also has a key role in business network formation. Some of the cluster firms' representatives reported that their participation in the ongoing SFI had enabled them to build relationships with firms located outside the cluster, which they could benefit from in future projects and collaborations (own interviews).

Within the SFI Manufacturing framework, SM has put I4.0 on the agenda. The interdisciplinary centre focuses on robust and flexible automatization, multimaterial products and production processes, and sustainable and innovative organizations. The projects include industrial robots as well as flexible and integrated production systems employing enabling digital technologies, and large-scale robotized additive manufacturing. Within this framework SM has organized related R&D projects, with various funding. Furthermore, on the initiative of SM, the state awarded Raufoss a Norwegian Catapult Centre in manufacturing technology. The centre will consist of six mini-factories equipped with I4.0 technologies and will work as an important learning arena for SMEs, larger companies, R&D, and educational institutions.

As Industry 4.0 is a fuzzy concept, it is no surprise that cluster firms have different and vague understandings of what I4.0 is about. For the firms, the common denominator is that it I4.0 refers to new technologies that may have disruptive effects. Key firms already have extensive application of autonomous robots and automated production lines, and two of them are quite advanced in these regards. As efforts initiated by SM are partly about implementation of more technologies (or more advanced versions) than they already have, the implementations at most appear as incremental innovations. A more limited number of core companies see the potential in additive manufacturing (3D-technologies), and few have taken initiatives and even fewer have implemented such technologies. Some of the business actors mentioned that I4.0 was about connecting different parts of the production process and even the supply chain, but technological integration of cyber-physical systems has not yet been realized. Although SM provides access to new knowledge, new technology and extra-local firms that potentially could be collaboration partners, and as such enhances potential CACs (on acquisition and assimilation of knowledge), these efforts do not automatically lead to realized cluster absorptive capacities (on transformation and exploitation of knowledge), to use the conceptualization of Molina-Morales et al. (2019). Firms' representatives highlighted the difficulties with constantly trying to keep up with what was happening in terms of new technology and related knowledge, when their time was 'eaten up by their working day and specific customer projects' and day-to-day goals in terms of production (head of development at a car component manufacturer, 2016 – authors' translation). According to the head of development, although SM could help to facilitate research project application and participation, it was difficult for firms in extremely competitive industries (e.g. automotive) to make long-term plans for technology implementation. In sum, as a CI, SM has pushed cluster firms' attention towards I4.0 and taken corresponding initiatives in R&D projects, but the actual (and potential) implementation of these new technologies lies ahead. We could thus conclude that SM has supported potential CAC, and that realized CAC is a matter of the future.

4.3.2 NCE SE/KI – linkages to primarily international universities

Isaksen (2009) argues that in Kongsberg core firms' strategic knowledge providers have been national (NTNU, SINTEF, Norwegian Defence Research Establishment) or international universities. A representative one of the core cluster firms in Kongsberg mentioned that they collaborated with NTNU on some projects (technical director of a defence and aerospace manufacturer, 2019), but that the collaboration mainly revolved around student recruitment. However, since the late 2000s, local knowledge institutions seem to have gained positions as providers of human capital, expertise and skills.

Through its engagement in developing the master programmes in systems engineering and establishing the Norwegian Institute for Systems Engineering (NISE), the Kongsberg CI has been instrumental in establishing relations with national and international universities. One of the key institutions in this regard is the Stevens Institute of Technology in the USA, which has been an important source of extra-regional knowledge for USN in terms of providing professors for teaching. According to an NCE SE representative, the relationship with Stevens was essential in order to provide master's courses. Simultaneously, the Stevens Institute of Technology, which was familiar with two of the largest firms in the cluster 'regarded Kongsberg as an interesting laboratory' with a diverse industry base (NCE SE representative 2017). Today, NISE also collaborates with Georgia Tech (USA) on model-based systems engineering, Stanford University (USA) on design and NTNU on 'lean product development' (representative of NCE SE, 2017).

In addition to developing education programmes, NCE SE initiated a three-year research programme that coupled the four cluster firms to USN and NTNU in Trondheim. The 'Knowledge-based Development' project aimed to improve the firms' efficiency in product development and resource utilization, and entailed identifying, sharing and exploiting best practices from the cluster firms' different industry sectors (NCE SE, 2016).

Despite having initiated some research activity, the lion's share of NCE SE's activities as a CI has revolved around providing cluster firms with master's candidates in SE and sourcing industry-relevant knowledge from national and international universities.

4.4 Summing up CIs and cluster external linkages

In, sum, we find that cluster firms in Kongsberg mainly rely on absorptive capacities at the firm level, whereas cluster firms in Raufoss to a high degree rely on CAC. The findings reflect how Raufoss and Kongsberg differ substantially. First, cluster firms in Raufoss typically utilize local suppliers, whereas key firms in Kongsberg mainly use extra-local suppliers. Second, and related to the respective network structures, the two clusters differ in their predominant knowledge base (analytical in Kongsberg versus synthetic in Raufoss). In line with Isaksen (2009), we recognize that cluster firms have varied access

to distant and proximate knowledge sources, dependent on the dominant type of knowledge bases. Cluster firms dominated by analytical knowledge bases are able to source knowledge nationally and internationally, whereas cluster firms characterized by synthetic knowledge bases rather source knowledge locally and regionally. Potentially, due to their employees' short cognitive distance to academics at R&D institutions, the Kongsberg cluster firms seem to have higher firm-level absorptive capacities in terms of inhouse R&D resources compared with the Raufoss cluster firms.

The clusters' contrasting structures are legacies from different outcomes of restructuring processes, in which Kongsberg cluster firms retained their internal R&D units, while Raufoss established SM as a common cluster R&D unit. However, they are also a result of the different knowledge bases that frame the respective cluster intermediaries' support for accessing vital extra-cluster knowledge sources.

Based on the clusters' contrasting legacies and knowledge bases, the CIs have taken on different roles. In Raufoss the local R&D institute works as both a public and a private intermediary (Clarke and Ramirez, 2013). As a private intermediary, SM engages with cluster firms in applied R&D projects, and as such it maintains local networks. As a public intermediary (e.g. in matters of public funding), SM couples to a wider, predominantly national innovation system. In Kongsberg the intermediaries focus on the educational systems and as such they provide core cluster companies with relevant candidates. Both university and key firm linkages are able to maintain international linkages and exploit foreign knowledge sources. Clusters characterized by synthetic knowledge bases should therefore be a target for CIs' support for accessing vital extra-cluster knowledge sources.

4.5 Discussing a typology of cluster intermediaries

In light of our empirical findings, we suggest two ideal types of CIs, each of which reflects and is well adjusted to the firm structure and sociocultural qualities of the respective cluster. First, we suggest two main types of CI functions/roles: (1) the human capital and skills providers that mainly work through the local labour market, and (2) the R&D and innovation collaboration facilitators that mainly work through networks of firms and non-firms (Table 1). The former (human capital and skills providers) are typically found in clusters consisting of firms that rely more on firm-level absorptive capacities and in which firm collaboration takes place more at arm's length. By contrast, R&D collaboration facilitators are typically found in clusters consisting of locally networked firms, where they are deeply involved in trust-based collaboration and where cluster firms rely more on cluster-level absorptive capacities.

Table 1. Typologies of clusters and intermediaries with regard to absorptive capacities

Cluster intermediary \ Cluster type	Extra-cluster networked firms drawing on analytical knowledge base	Intra-cluster networked firms drawing on synthetic knowledge base
Human capital and skills providers	**A**	B
R&D and innovation facilitators	c	**D**

A – This combination is typical. Given the high firm-level absorptive capacities in terms of R&D units staffed with highly educated employees, firms have a high demand for human capital provision and skills support in order to maintain and develop their firm-level absorptive capacity further.
b – This combination is less typical. Due to their limited division of labour and dominance of synthetic knowledge bases, cluster firms have a low share of employees with high educational levels. Cluster firms' demand for skills support and existing educational programmes is directed towards acquiring synthetic knowledge basically from training on the shop floor. In the face of new technologies, the cluster firms may have shortages of analytical knowledge bases on which to draw.
c – This combination is less typical. Cluster firms are less in need of local R&D and innovation facilitators due to their reliance on their own analytical knowledge bases and high firm-level absorptive capacities. Insofar as they are affiliated to TNCs or integrated into global production networks, they are able to exploit extra-cluster R&D networks on their own.
D – This combination is typical. R&D and innovation facilitators compensates for shortages in firm-level absorptive capacities. The CIs fit well with the trust-based network structure and territorially based firms typical for such clusters. As far as cluster firms regard the CI as a common good, the CIs are well adapted to the industrial and institutional context of the cluster, in which they may enhance CAC.

A and **D** appear as typical combinations of cluster intermediaries and cluster contexts. However, in real cluster contexts hybrid combinations may appear. Cluster policy should consider including both types of CIs. Based on our findings, we recommend that clusters firms (appearing in the **D** combination) should develop their absorptive capacities in form of high-tech expertise and skills in order to participate in and exploit R&D projects, not at least in the face of I4.0 technologies. This may

depend on CIs' ability to provide industry-relevant and skilled candidates (including the frame of the b combination). In practice, this means that policymakers and cluster intermediaries should learn from other cluster experiences when adapting their own models. External impulses are particularly timely in the face of new (disruptive) technologies.

However, from our study of cluster firms, we recognize some limitations in knowledge acquisition and particularly in the exploitation of the new technologies. In line with the conceptualization of Molina-Morales et al. (2019), most of the cluster firms in Kongsberg and Raufoss have built up potential capability, partly with help of CI initiatives. Several cluster firms have already realized their capabilities by implementing less advanced I4.0 technologies, such as industrial robots. More advanced I4.0-technologies, such as 3D-printing, are only exceptionally realized and then in a very limited number of firms. We agree with Götz and Jankowska (2017) that clusters may work as a favourable environment for absorbing I4.0 technologies, but with some conditions. For cluster firms, territorial embeddedness and trust-based relations and collaboration do not suffice in terms of absorbing these new technologies. Further cultivation and exploitation of extra-cluster linkages is essential. In case such linkages are limited, cluster intermediaries could create, stimulate and develop them.

5 Conclusions

As the roles of clusters and cluster initiatives continue to be of interest to both researchers and policymakers, this paper provides novel insights into how cluster organizations take on different roles as intermediaries, depending on institutional and contextual preconditions. The paper adds to the ongoing debate on cluster dynamics by proposing a novel conceptual framework, combining the intermediary and absorptive capacity concepts, for investigating the role of non-firm actors in different types of clusters. Furthermore, the paper suggests that the proposed conceptual framework is productive for investigating different types of manufacturing clusters and can form a basis for suggesting cluster policy measures.

In line with Giuliani, the paper recognizes CAC as a quality beyond the sum of firm-level absorptive capacities. We find that CIs and their knowledge linkages are essential to enhance CAC. Our paper makes a contribution beyond Giuliani's CAC typology, as our approach is more sensitive to various combinations of qualities related to absorptive capacities. One the one hand, we recognize that clusters with predominantly analytical knowledge bases on the firm level are in less need for cluster intermediaries. On the other hand, clusters with limited analytical knowledge could benefit from being compensated by the help of vital CIs.

We recognize that intermediaries rely on knowledge institutions and firms on multiple scales in their efforts to renew cluster firms. Whereas Giuliani (2005) does not make any distinctions on the scale of extra-cluster knowledge linkages, we find national innovation systems particularly significant for technology upgrading among cluster firms. This is probably typical in the context of a coordinated market economy such as Norway. With regard to varieties of capitalism, we would expect that there is fertile ground for CSs in coordinated market economies (CMEs) compared with liberal market economies (LMEs). CMEs tend to have institutional capacities for collaboration across firms, R&D institutions and educational providers that are well supported by state funding. Almost by definition, CMEs have sociocultural conditions for trust-based collaboration between firms and between firm actors and non-firm actors. Related to these CME characteristics, the Norwegian industry consists mainly of SMEs in which there are short distances between top management and workers on the shop floor – traits that are reflected in the two cases presented in this paper. Our findings may thus have limited relevance for economies consisting mainly of larger firms.

Concerning policy recommendations, cluster policy should carefully consider how cluster organizations could contribute to cluster development by taking on various roles as intermediaries. Such intermediaries should be sensitive to existing local contexts and, more importantly, they should be able to accommodate future needs for renewal. Policymakers at the national level could draw on local and regional institutions' and policymakers' key experience with and knowledge about regional industry in order to develop national cluster policies that better accommodate the diverse needs of the industry. Furthermore, arenas for knowledge exchange across clusters and between cluster intermediaries could be developed in order to stimulate discussion, learning and sharing of experiences.

In light of this study, the Norwegian context and more general literature on varieties of capitalism, we would expect that cluster intermediaries could operate under more favourable institutional conditions in CMEs compared with LMEs. The direction for future research should be to conduct international comparative studies on how cluster intermediaries interact with multiple scales of support institutions. This should include comparisons across varieties of capitalisms and across the dimension of firm-size structures.

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A3/Vocational

The importance of vocational education institutions in manufacturing regions: adding content to a broad definition of regional innovation systems

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Published in *Industry and Innovation*.

A4/Reshoring

Make at home or abroad? Manufacturing reshoring through a GPN lens: a Norwegian case study

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Revised and resubmitted, November 2019.

Make at home or abroad? Manufacturing reshoring through a GPN lens: a Norwegian case study

Abstract

The explorative paper investigates the drivers for the emerging trend of manufacturing reshoring from low- to high-cost locations. To date research on the reshoring phenomenon has been dominated by micro-level analyses of firms in supply chain management and reported in international business literature. The paper introduces reshoring as a research topic to the economic geography research field, arguing that it connects with the broader topic of regional development. To provide a better understanding of the reshoring phenomenon and to test the applicability of the global production network (GPN) framework in the analysis of the phenomenon, the authors analyse the reshoring of nine of Norwegian manufacturing firms. With the multiscalar lens provided by the GPN framework, the authors find that the implementation of advanced manufacturing technologies is a driver for manufacturing reshoring, but only when matched with key regional assets such as automation knowledge and competence, key human capital, and region-specific manufacturing competence. Additionally, reshoring decisions are influenced by extra-regional factors such as changes in the global economy and market fluctuations. Furthermore, the paper provides a refined conceptualization of strategic coupling processes by including acts of disinvestments and reinvestments performed by actors within global production networks. Accordingly, the authors advocate a more nuanced understanding, defined as partial coupling processes, in contrast to the predominant understanding of coupling processes as ruptures. This refined conceptualization provides enhanced analytical purchase when studying the reshoring phenomenon, as it illuminates the complexity of firms' production and sourcing strategies and the resulting implications for the economic landscape.

Keywords: reshoring, global production networks, advanced manufacturing, strategic coupling, embeddedness

1 Introduction

A key trend, especially over the last three decades, has been that many European and Northern American manufacturers have moved all or parts of their production activities to low-cost countries in Asia, Eastern Europe and Latin America (Neilson et al., 2014). Offshoring and outsourcing of production are conscious firm strategies to achieve comparative advantages (Blinder, 2006, Coe and Yeung, 2015, Stentoft et al., 2016), such as lower labour costs and access to emerging markets (Lonsdale and Cox, 2000). These processes of locational switch, which more recently have seen companies from emerging economies such as China move their production activities to less developed Asian economies such as Vietnam (Sirkin, 2019), have been central to processes of economic globalization (Dicken, 2015).

Offshoring and outsourcing from high-cost to low-cost countries remains the dominant modus operandi in global sourcing (Coe and Hess, 2013, De Backer et al., 2016) and therefore also continues to be a topic of interest within several research fields, including economic geography (Manning et al., 2018). However, a manufacturing reshoring trend has emerged in which high-cost country firms 'take back' manufacturing or service activities from low-cost nations. In this paper, we refer to the phenomenon of manufacturing repatriation as *reshoring*. The phenomenon is also known as *homeshoring* and *backshoring*. The reasons for the strategic decisions regarding locational or re-locational switch are many and vary across sectors and firms (Theyel et al., 2018). They include increasing production costs in emerging economies, growing digitalization in OECD economies, and miscalculation of total costs in decisions made prior to offshoring (De Backer et al., 2016, Barbieri et al., 2017).

This paper emanates from the observation that advanced manufacturing technologies potentially play an important part in reshoring decisions. Advanced and novel manufacturing technologies, often bundled under the rubric of 'Industry 4.0' (e.g. industrial robots and automation, the Internet of Things (IoT), Big Data, machine learning, and 3D printing), can have disruptive effects on the spatial and functional organization of manufacturing (Kagermann et al., 2013, Gress and Kalafsky, 2015). Investments in technology have been recognized as imperative for manufacturers in high-cost countries to remain competitive (Brennan et al., 2015). We propose that the ability to implement and utilize new manufacturing technologies is decisive (Lund and Karlsen, 2019), and that this ability is at least partly conditioned by the local, regional and national context in which firms (or firm subsidiaries) are embedded. Decisions to offshore or reshore (parts of) production will be contingent on firms' position in global production networks (GPNs) that are themselves dynamically evolving. We suggest that the GPN framework (Yeung and Coe, 2015) provides novel explanatory power to the intricate

processes of manufacturing reshoring. Our reasoning is that the GPN framework puts complex multi-actor interaction centre stage, while being highly sensitive to the multidimensional institutional embedding of various firm and non-firm actors in different places and at different scales (Coe and Yeung, 2015), and how this may change over time (MacKinnon, 2012, Yang, 2013).

There have been relatively few studies of technology and automation as enablers of manufacturing reshoring (Barbieri et al., 2017) and the reshoring phenomenon has received limited scholarly attention from economic geographers (Vanchan et al., 2017). This paper aims to introduce the reshoring phenomenon to the field of economic geography in general, and to the global production network literature in particular. We suggest that reshoring is an important and highly relevant topic for economic geography, as it basically refers to a process that has implications for the economic landscape and how that changes over time. To analyze our empirical findings we draw on the GPN concepts cost-capability ratio, embeddedness, regional assets, strategic coupling, and market imperatives. As such, we provide a novel approach to understanding the reshoring phenomenon that acknowledges intra-firm, inter-firm (value chain/production network) and (geographical/value chain) embeddedness aspects. We apply and test this framework in an exploratory study of nine manufacturing companies in Norway (a high-cost country). These nine companies have recently reshored manufacturing activities (partially or in full), suggesting an ability for high-cost locations to construct or reconstruct a comparative advantage in global markets. The firms are diverse and operate within different industries and value chains. The main research question that guides our analysis is *What explains manufacturing reshoring in a high-cost country such as Norway?*

To date, research on reshoring in the Norwegian context has focused on intra-firm strategies and processes influencing reshoring decisions from a supply chain management perspective (Nujen et al., 2018). Although reshoring is a limited phenomenon in numbers – both in Norway and other countries (Barbieri et al., 2018) – we see it as a highly interesting topic for industry, policy and research, not least because it bears witness to processes that counteract the dominant trends of outsourcing and offshoring in the organization of manufacturing (Coe and Hess, 2013, De Backer et al., 2016). As such, it also challenges the established spatial division of labour (Massey, 1984) in many manufacturing sectors, with research, design and development in the Global North and manufacturing in the Global South.

The remaining part of this paper unfolds in five sections. In the next section (2), we discuss the relevance of reshoring, elaborate on the concept and explanations of the

phenomenon, and thereafter present and discuss the GPN framework and develop our analytical framework. Section (3) outlines our methods and data, while our findings are presented, analysed and discussed in Section 4. In the final section (5), we conclude, discuss the usefulness of a GPN approach to understanding manufacturing reshoring, specify key questions for further research, and discuss policy implications.

2 Theory: a GPN perspective on manufacturing reshoring

2.1 Manufacturing reshoring: on the agenda?

Manufacturing reshoring has attracted attention from policymakers and governments in recent years. Some of the reasons for policy interest in reshoring and strengthening of domestic manufacturing industries are job creation (resulting in e.g. increases in tax revenues), exports, and R&D spending that has generated innovations and competitiveness (Stentoft et al., 2016). As a consequence, policymakers in some developed economies have been proactive in creating policies that instigate manufacturing reshoring.

The financial crisis of 2008–2009 has been identified as a starting point for the development of reshoring strategies in the USA (Tate et al., 2014). The Obama administration was particularly engaged in reshoring policies and put forward the 'Blueprint for an America built to last', whereas the 'Make it in America' initiative provided USD 40 million in grants for reshoring initiatives (The White House, 2012). Reshoring also figured prominently in the 2016 Trump campaign. However, there is little evidence to suggest that American manufacturers reshore due to policies implemented by the USA government. Instead, companies are relocating to the USA due to increasing prices and wages in the Global South (especially China), access to cheap USA energy, changes in customer demands, increased transportation costs, and increased risks associated with intellectual property rights (Margolis, 2018).

In Europe, the *Industrie 4.0* initiative in Germany has made EUR 200 million available for initiatives focusing on technology and innovation, which in turn may lead to a strengthened manufacturing industry and facilitate reshoring (European Commission, 2017). The European Commission (2010) identifies advanced manufacturing technology as one of six key enabling technologies, which are seen as the basis for increasing innovation and renewing/strengthening European competitiveness in the global economy. Merlin-Jones (2012) points out that the manufacturing sector In the UK has been catalysed by advanced manufacturing technologies, enabling some of the remaining UK manufacturers to succeed within certain niche markets.

Bailey and De Propris (2014, 393) call for ‘a more long-term, proactive and holistic pro-manufacturing industrial policy’ in order to persuade British manufacturers to repatriate manufacturing operations. Since the recession in 2008–2009, the policy debate in the UK has centred on ‘rebalancing’ the entire economy. With a relatively small manufacturing industry (8% of employment in 2016 (Vanchan et al., 2017)), the policy discussions have not gained traction.

In Norway, reshoring has received some attention from public bodies, industry organizations, media, and academia (Teknologirådet, 2013, Nujen et al., 2018). There is no explicit policy related to reshoring, and it is only mentioned in a brief passage in a recent Norwegian White Paper on industrial policy (Meld St. 27 (2016–2017) a, b). Norwegian industrial policy is rather focused on supporting research and innovation aimed at improving existing industries through initiatives such as Norwegian Innovation Cluster and Norsk katapult (national centres for prototyping and product development) (Norwegian Innovation Cluster, n.d., Norsk katapult, n.d.) to ensure that Norway remains an attractive host location for manufacturing (Meld St. 27 (2016–2017).

To summarize, manufacturing reshoring has to some extent made an impact on political agendas in high-cost countries. However, in order to inform policymakers and governments about the potential for and impact of reshoring, studies that recognize the phenomenon’s multiscalar dimensions and explanations are needed.

2.2 Offshoring and reshoring – a brief overview

Manufacturing relocation from high-cost to low-cost nations (i.e. offshoring and outsourcing) is a widely studied phenomenon, reflecting a key component in global sourcing strategies for firms in developed economies in recent decades (Blinder, 2006). The primary reasons for these processes of locational switch relate to competitiveness and the necessity of moving production – either to neighbouring countries, as in the case of Western European firms relocating to Eastern Europe, or to more distant lands (e.g. Southeast Asia) – in order to access cheaper labour and/or emerging markets (Lewin et al., 2009). These strategies have been manifested through foreign direct investments (FDI) and the establishment of new branch plants, the acquisition of existing manufacturers in new host locations, or the outsourcing of production to external suppliers.

Offshoring and outsourcing continue to be the dominant sourcing strategies for manufacturing companies today (Coe and Hess, 2013, De Backer et al., 2016). However, there is an emerging trend of reshoring, which refers to production being relocated from low-cost to high-cost nations. Previous studies of the reshoring phenomenon reported in the supply chain management (SCM) and international business (IB) literature primarily focused on *why* manufacturers reshored (Barbieri et al., 2017, Wiesmann et al., 2017). A number of reasons for the reshoring have been identified and they can be grouped into two main categories (Bals et al., 2016). The first category is related to intra-firm explanations, wherein reshoring occurs as corrections of *managerial mistakes* in the form of poorly informed location decisions, often based on inaccurate calculations in terms of total costs (e.g. labour, logistics/shipping) (Kinkel and Maloca, 2009). The second category is related to societal and/or economic changes, wherein reshoring occurs as 'a deliberate response to endogenous and exogenous changes' (Barbieri et al., 2017, p. 13), such as altered market conditions, rising costs in offshore locations, or increased digitalization in the home economy (De Backer et al., 2016). Additionally, Kinkel (2014) proposes that high levels of product complexity, customization, and small-batch production increase the likeliness of reshoring. With regard to digitalization, studies of the influence of advanced manufacturing technologies and automation on firm locational decisions have largely been neglected (Barbieri et al., 2017). However, we find this an important topic to address, not least because technology adoption alters firms' cost–capability ratios. In this study, we aim to advance the understanding of these factors in reshoring decisions. First, it is necessary to discuss briefly the different definitions of manufacturing repatriation, and how reshoring is defined in this paper.

There are several conflicting definitions in the SCM and IB literature aimed at describing the manufacturing repatriation process, reflecting how different aspects have been emphasized differently when defining the concept of manufacturing relocation (Barbieri et al., 2017). Furthermore, different terms are used for the same phenomenon, including *back-reshoring* (also including 'born global' firms) (Fratocchi et al., 2015), *backshoring* (Kinkel and Maloca, 2009), and *reshoring* (Gray et al., 2013). This conceptual fuzziness may lead to lack of clarity, as scholars also 'use the same term (for instance, reshoring) to indicate different concepts' (Barbieri et al., 2017, 8). As we aim to explore the reshoring phenomenon in a Norwegian context, where there is evidence of both full and partial relocation of production and different sourcing elements, we find the concept *reshoring* to be suitable for our purpose. Reshoring has been used as a general term for manufacturing relocation to a 'home economy' in recent literature reviews which various aspects of reshoring have been studied (Barbieri et

al., 2017, Wiesmann et al., 2017). In order to provide an understanding of recent manufacturing relocation to Norway, we define reshoring as the *relocation of manufacturing, including both sourcing and shoring strategies from a host location to a home location.* As such, the definition provides leeway for an explorative analysis of relocation decisions.

As mentioned in the Introduction (Section 1), we suggest that the GPN framework provides a novel approach to understanding both the explanations for and the implications of the reshoring phenomenon. Accordingly, we propose that the various forms of locational switch (e.g. offshoring, reshoring, insourcing, and outsourcing) are on-the-ground mechanisms that underlie different types of coupling processes between territorialized assets and the needs of key actors in global production networks (MacKinnon, 2012). Analysing these processes by using the above-mentioned key concepts from GPN thinking provides an extended understanding of the enabling factors that instigate manufacturing reshoring. Moreover, and contrary to the SCM and IB literature, the GPN perspective adds explanatory power to understanding reshoring beyond the firm level by devoting explicit attention to the influence of non-firm actors and contextual conditions (directly or indirectly) on firms' decisions.

2.3 Global production networks

The reshoring of manufacturing is essentially a location decision (Gray et al., 2013), which therefore has explicit geographical outcomes, and, we suggest, geographical explanations. To pursue this suggestion and to explore the reshoring phenomenon, we find global production networks (GPNs) a fruitful theoretical point of departure. In line with Coe and Yeung (2015), we consider the GPN 1.0 and GPN 2.0 'variants' as complimentary frameworks and combine concepts from them both in our analysis.

The GPN framework has been developed since the early 2000s (Henderson et al., 2002, Coe et al., 2004). Through disentangling the nexus of firm and non-firm actors efforts have been made to provide a heuristic framework for understanding the development of the global economy and its implications for regional development (Coe and Hess, 2011). The actions made by these firm and non-firm actors are targeted 'towards the creation, enhancement and capture of value'. Value creation is the process where economic surplus, or *rents* (Coe et al., 2004), is generated by transforming inputs or materials into new products or services. Whereas value creation is primarily done by firms, non-firm actors can contribute to value capture through subsidies, indirect investments or skill development. Value enhancement relates to how knowledge and technology can enable industrial upgrading, i.e. enable regions to claim a higher

position within a GPN and thus increase their value capture. Regional assets such as technology and experience based knowledge can be developed (often with supportive regional institutions) to ensure value enhancement for the region. Regional assets and institutions can also be tuned towards promoting value enhancement for GPN lead firms. Lastly, and most importantly in terms of regional economic development, the value capture concept relates to how value is retained within a territory or firm. The ability to capture value is imperative for the region in terms of achieving regional economic development (Henderson et al., 2002, Coe et al., 2004, Coe and Yeung, 2015).

The GPN 1.0 variant provides a multiscalar approach to understanding 'the dynamic organizational and geographical complexities of the global economy' (Coe et al., 2008, p. 289) by emphasizing local, regional and global 'economic and social dimensions of the processes involved in many (though by no means all) forms of economic globalization' (Henderson et al., 2002, p. 445). Particular emphasis is placed on the (regional) territorial development outcomes resulting from multiscalar GPN dynamics. GPN 2.0 was developed partly as a response to the tendency of GPN 1.0 and the global value chain framework to 'under-theorize the origins and dynamics of these organizational platforms' (Yeung and Coe, 2015, p. 29). The 2.0 approach provides a dynamic framework focusing on how GPN actors' (especially global lead firms) strategies are shaped by structural competitive dynamics, and how this shapes 'organizational configurations within and across different industries and localities' (Yeung and Coe, 2015, 32). The GPN (both 1.0 and 2.0) framework's emphasis on lead firms has been criticized and questions have been raised concerning its ability 'to capture globalization's complex dynamics' effectively (Murphy, 2012, p. 211). However, Coe et al. (2008, p. 90–91) argue that the empirical entry point to analysing GPNs is unimportant and insist that it depends on 'the specific focus of the research and the precise research questions that are being tackled'. In this paper, the case firms are both lead firms and industry-specific specialized suppliers. Thus, we provide empirical insights into traditionally less-studied structures of GPN, namely non-lead firm actors (Coe et al., 2008). In our effort to provide a novel approach to understanding the reshoring phenomenon, we employ five key concepts from the GPN frameworks: (1) cost-capability ratio, (2) embeddedness, (3) regional assets, (4) strategic coupling, and (5) market imperative.

In the GPN 2.0 approach put forward by Coe and Yeung (2015, p. 85), the optimization of cost-capability ratios – 'the optimization process that allows firms in global production networks to achieve greater firm-specific capabilities and value capture' – is a key concept.

Direct and indirect costs related to production are acknowledged as an important aspect that encourages firms to relocate production and services to low-cost economies, and the direct cost of labour wages is recognized as 'the most obvious arena for optimization' (Coe and Yeung, 2015, p. 83). In addition to this resource-based view of firms (Teece, 2009), the GPN framework incorporates firms' capabilities as essential when analysing their ability to function as actors, key or otherwise, in production networks. Coe and Yeung (2015, p. 84) argue that firm-specific capabilities and cost must be theorized alongside each other, 'to form a complete and actor-oriented view of the firm'. These firm-specific capabilities can be technology, knowledge/knowhow or organizational capacities. Firm capabilities are regarded as relative and dynamic, which implies that firms are able to develop their capabilities through learning, also with support from extra-firm initiatives such as education or skills upgrading programmes funded by public bodies (Coe and Yeung, 2015). The ability to improve firm-specific capabilities, and their potential to create, enhance and capture value, is influenced by national and regional socio-spatial and economic contexts. Therefore, in order to analyse enabling factors for firms' reshoring, it is necessary to understand how they are embedded in their host locations.

The embeddedness concept acknowledges how place-specific economic, social, and political contexts influence GPNs. Embeddedness is divided into three 'specific yet interrelated forms' – societal, network and territorial (Yeung and Coe, 2015, p. 17). Societal embeddedness highlights the relevance of economic actors' historic, institutional and cultural heritage, with its '"genetic code"', influencing and shaping the action of individuals and collective actors' (Hess, 2004, p. 176). In relation to GPNs, firms carry this 'genetic code' with them when they go abroad, while simultaneously being exposed to the foreign cultures of partner firms within the production network. Network embeddedness describes how relationships between actors, both individuals and organizations (governmental and non-governmental), form networks based on trust and interaction (Hess 2004). By contrast, territorial embeddedness 'captures how firms and organizations are anchored in different places' (Coe and Yeung, 2015, p. 18): it is the 'localized manifestation of networks or nodes in global networks' (Hess, 2004, p. 180). The social dynamics and economic activities in host locations where firms in GPNs are located can both enable and constrain their development. Such enabling factors are conceptualized as regional assets in the GPN framework.

Regional assets constitute specific endogenous advantages that are necessary preconditions for enabling firms or regions to become part of one or more global production

networks. In a reshoring context, the successful development of regional assets can result in regions reclaiming a position within global production networks, and as such enhance regional value capture. Examples of regional assets are technology, specialized know-how, industrial organization, and territorial politics and social relations (Coe et al., 2004, Coe and Yeung, 2015). Regional assets can be strategically developed in collaboration with regional institutions such as educational institutions, labour unions and state agencies, thus indicating import roles (harnessing and upgrading assets) for states and other non-firm actors. Of particular importance is the harnessing of regional assets in order to 'fit the strategic needs' of key actors in a global production network (Coe et al., 2004, p. 474). As such, they constitute the basis on which firms and regions are strategically coupled to global production networks.

In the processes of offshoring and reshoring manufacturing, firms deliberately move production from one location to another. In relation to this relocation, the concept strategic coupling gains relevance, as firms and regions can be coupled, decoupled or recoupled to GPNs with corresponding positive or negative effects on regional development (Yeung, 2009, MacKinnon, 2012). Reshoring refers to a phenomenon with a distinct temporality, as it must have been preceded by some form of offshoring or outsourcing. Therefore, understanding these processes of locational switch requires an approach that explicitly incorporates a temporal dimension. Firms and regions can couple to a GPN if their institutional or firm-specific capabilities can contribute to the overall functioning of the GPN. If a region or firm loses its relevance and influence in the GPN, it can be decoupled, which means there will be a rupture between the region or firm and the GPN. We understand embeddedness and strategic coupling as two interrelated concepts, where networks are embedded in regions through coupling processes in the production networks, and disembedded through decoupling processes. According to Coe and Yeung (2015, 20), strategic coupling has three important characteristics: (1) it is strategic, meaning that it needs 'intentional and active intervention' by both lead firms in the GPN and regional institutions; (2) it is time-space contingent, 'as it is subject to change and is a temporary coalition between local and non-local actors'; and (3) 'it transcends territorial boundaries as actors from different spatial scales interact'.

Offshoring and reshoring are real-world expressions of what MacKinnon (2012) refers to as decoupling and recoupling, adding an important evolutionary dimension to the dynamics of global production networks and territorial linkages. However, the conceptualization of abrupt coupling processes provided in the GPN literature (Yeung and Coe, 2015) does not provide sufficient analytical purchase in a complex reshoring context with multiple sourcing decisions

employed at different times. Therefore, inspired by earlier attempts at conceptual refinement (MacKinnon, 2012) and drawing on recent contributions by Werner (2016), we combine the aspects of disinvestment and reinvestment with the concept of strategic coupling to provide a more fine-grained conceptualization of *partial* coupling processes. Thus, we define *partial decoupling* as the result of disinvestments in a region that leads to a relative decrease in value creation and capture in that region. Subsequent *partial recoupling* refers to reinvestment in a region leading to a relative increase in value creation and capture in that region. The variations in value added activity in regions within GPNs are, as emphasized by Coe and Yeung (2015), temporal and subject to change. Furthermore, the variations are influenced by extra-firm factors such as fluctuations in particular markets and the global economy in general.

The GPN literature captures the market dynamics in the market imperative concept (Yeung and Coe, 2015). The market imperative is described by Yeung and Coe (2015) as being created in an interactive process between users and producers that results in market creation. Changes and the emergence of global production networks are then regarded as the 'organizational outcome' of market creation processes (Yeung and Coe, 2015, p. 95). When regarded as a process, the market is constantly evolving, thus GPNs are evolving, as shifts within the global economy translate into different local and regional outcomes. Shocks in the global economy, such as the 2008 financial crisis, have the potential to influence entire GPNs (Smith et al., 2014) and have been identified as drivers for manufacturing reshoring (Kinkel, 2012, Tate et al., 2014).

2.4 Approaching reshoring with a GPN lens

The geography of production has been a research topic for geographers since the seminal work of Marshall (1920) and Weber (1929) nearly a century ago. Furthermore, with the extensive offshoring and outsourcing of production from Europe and the US to developing economies in the 1980, the spatial division of labour (Massey, 1984) became a central topic within the subdiscipline of economic geography. However, the early contributions, as products of their time, focused on how states, social structures and division of labour within and across regions influenced the geography of production. Arguably, the global economy has changed considerably since the 1980s, notwithstanding the fact that non-firm actors such as national states continue to play a key role in the geography of manufacturing (MacKinnon et al., 2019). Thus far, production in 2019 has been considerably more complex and functionally fragmented (Coe and Hess, 2013) than that of earlier times, with networked activities facilitated through

increasingly advanced ICT and improved transportation, and other changes enabled by new technologies such as the change from mass production towards mass customization (Gress and Kalafsky, 2015). In order to fathom these complexities, we must change the concepts we employ to study shifting economic landscapes.

In order to encompass the complex, multiscalar dimensions of production, and to study the 'new international division of labour' (Neilson et al., 2014, p. 1), we employ the outlined global production network framework (see section 2.3) in our analysis. The framework allows for the inclusion of actors from different scales, firm embeddedness, and market dynamics such as customer pressure and time-to-market (Coe and Yeung, 2015) in the analysis, thus providing a more holistic understanding of the complex, multiscalar processes of manufacturing reshoring and its implications for regional economic development. As such, our paper complements the existing literature that focuses more on the micro-level (firm-level) processes and explanations for reshoring decisions.

3 Methods and data

Reshoring is an emerging trend and the number of possible cases in the Norwegian context is limited, as is apparently also the case in other countries (De Backer et al., 2016, Kinkel et al., 2017, Olhager et al., 2017, Barbieri et al., 2017, Coe Yeung 2019). A research methodology that is exploratory, allows for thick descriptions, and provides in-depth understanding of existing reshoring cases is therefore warranted. We employ an exploratory case study approach (Flyvbjerg 2006, Yin 2012), which is advantageous when investigating 'distinct phenomena characterized by a lack of detailed preliminary research' (Streb, 2010). As the explanations for the reshoring phenomenon are highly complex, context-specific and, we suggest, multiscalar, we employ qualitative research methods that provide holistic accounts of actors and their sectoral, political and spatial contexts (Clark, 1998). This research strategy provides opportunities for analytical generalization.

Our primary source of data is 11 in-depth semi-structured interviews with key informants in firms that have reshored production, conducted between March 2018 and January 2019. Identification and recruitment of case firms was based on a list of reshored firms published in Norwegian media outlets in 2016 and Eurofound's European Reshoring Monitor (Eurofound, 2016). The studied firms are located in different parts of Norway and operate within different industries. Our key informants were current and former CEOs (Chief Executive Officers), a COO (Chief Operations Officer), a CTO (Chief Technology Officer), and a VP

(Vice President) and PL (Project Leader) in nine firms (Table 1). Our questions revolved around topics such as motivations and explanations for the initial offshoring or outsourcing decision, the experiences gained from manufacturing abroad, the final reshoring decision, and if and how contextual matters provided incentives for reshoring. Through these interviews, we gained invaluable insights into the decision-making processes undertaken and the key rationales behind reshoring decisions in each firm. We also interviewed representatives from the Norwegian Confederation of Trade Unions (Landsorganisasjonen) and the Federation of Norwegian Industries (Norsk industri) to understand how innovation policy and policy instruments targeted reindustrialization in general and reshoring in particular.

The interview data were supported by secondary sources such as journal articles, media coverage and White Papers. The limited scope of manufacturing reshoring in Norway restricted the number of possible informants. To secure anonymity, firms have been given aliases and informants are referred to as the VP, PL, CEO, COO or CTO of their respective firm (Table 1).

Firms	***Informants***	***Market***	***Reshored from***	***Reshored production***
Aqua	CEO	Aquaculture	China	Moulded plastic components
Auto	Former CEO	Automotive	China	Aluminium car components
Construction	CEO	Construction	Poland	Building solutions for walls, floors and roofs
Marine	COO	Marine	Russia and Ukraine	Winches for anchor-handling vessels and offshore platforms
Maritime	CEO	Maritime	China	Anchor winches for smaller vessels
Offshore	CEO	Maritime and offshore	China	Heating, ventilation and air conditioning (HVAC) systems
Oil and Gas (O&G)	VP PL	Oil and gas	Arab Emirates and Ireland	Components for offshore jacket platforms
Telecom	CTO	Telecommunications	China	High resolution webcams for video conferences (assembly)
Telematics	CEO	Telematics	Lithuania	Tracking systems for vehicles and equipment (assembly)

CEO – Chief Executive Officers, COO – Chief Operations Officer, CTO – Chief Technology Officer, VP – Vice President, PL – Project Leader

Table 1. Industry informants' affiliation

The purpose of this paper is to explore the drivers for reshoring of manufacturing to Norway. As this is a relatively limited phenomenon, we interviewed representatives of the majority of firms that to the best of our knowledge (based on, for example, key informant interviews and media searches) have reshored production or parts of their production. Our sample of case firms are quite diverse (Table 2): some are lead firms within their (global) production networks, while others are specialized suppliers (e.g. Tier 1 in the automotive industry). It should be noted that the labelling of 'lead firms' here refers to firms' position in production networks that may not necessarily be global in scope. Born global firms refer to firms that internationalize from the off-set or near founding rather than in a more incremental and stepwise manner after first growing in the home location (Knight and Cavusgil, 2004). In terms of size, the case firms are relatively homogenous in that most of them are Norwegian-owned SMEs (small and medium-sized enterprises). As such, the selection of case firms are representative of Norwegian industry, which consists of 99,5% SMEs (Ministry of Trade Industry and Fisheries, 2012). From the description of firms in Table 2, it is evident that the initial reasons for offshoring of production (if there was any) were quite different. Correspondingly, the drivers for reshoring were and are different. We consider that this heterogeneity (in terms of embeddedness, value chains and industries) provides a rich basis for an exploratory study. In the next section, we analyse some of the important drivers for manufacturing reshoring as identified by the case firms.

Firm	*Type*	*Role in GPN*	*Workers (in NOR production site)*	*Revenue 2017 (in millions)*	*Offshoring reason*	*Internal drivers for reshoring (pull)*	*External drivers for reshoring(push)*
Aqua	Norwegian SME	Specialized supplier (industry-Specific)	33	$8.2	Lead firm outsourced production to foreign third-party manufacturer	Improved cost capability ratio (technology), proximity to market	Transportation costs, lead time
Auto	Foreign TNC, branch plant	Specialized (Tier 1) supplier	191	$68.6	TNC's decision to manufacture in Chinese branch plant for EU market	Improved cost capability ratio (technology), proximity to market access to skilled labour, access to regional competence	Transportation costs
'onstruction	Norwegian SME	Lead firm	111	$44.5	Licence production due to lack of equipment and	Improved cost capability ratio (technology), access to skilled labour	Transportation costs, lack of flexibility, difficult to do product development
Marine	Norwegian SME	Specialized supplier	146	$62.3	Lack of production capacity at home	Improved cost capability ratio (technology), increased production capacity due to technology	Changes in global economy (resulting in excess production capacity at home)
Maritime	Norwegian SME	Specialized supplier	110	$42.8	Acquisition of company with production abroad	Available production capacity and machinery	Unsatisfactory product quality, communication difficulties
Offshore	Foreign TNC, branch plant	Lead firm	119	$17.7	Low labour costs	Improved cost capability ratio (design thinking)	Rising production costs, customer demands on lead time
Oil and Gas	Norwegian TNC	Lead firm	800	–	Lack of production capacity, unfit production facilities (size), cost	Improved cost capability ratio (technology & design)	Transportation cost (raw materials and end product), transaction costs related to coordinating production abroad
Telecom	Norwegian SME	Lead firm	45	$1.7	Born global	Improved cost capability ratio (technology & design thinking), proximity to production site (enabling product testing and development)	Contract manufacturer unable to produce according to standards, transaction costs related to coordinating production abroad
Telematics	Norwegian SME	Lead firm	240	$45	Born global	Improved cost capability ratio (technology), proximity to production site (enabling product testing and development)	Language barrier related to coordinating production abroad

Table 2. Description of case firms

4 Analysis: manufacturing reshoring through a GPN lens

As discussed in Section 2, to explain why reshoring occurs, the SCM and IB literature has emphasized the 'internal environment' (i.e. firm-specific strategies) and direct costs related to labour wages and shipping (Barbieri et al., 2017). The scope of this paper does not allow for an extensive analysis of all of the empirically identified drivers for reshoring (see the summary in Table 2). Rather, we elaborate on the role of technology, knowledge, regional assets and market dynamics, which were identified by our informants as key rationales for manufacturing reshoring. In the following three subsections, we employ key concepts from the GPN framework (cost-capability optimization, regional assets and the market imperative) to analyse the drivers for manufacturing reshoring in our nine case firms. In the final subsection we discuss how different sourcing strategies led to a reconfiguration – through disinvestments and reinvestments – of some of the studied global production networks.

4.1 Technology and knowledge - optimizing cost-capability ratios

Norwegian manufacturers that operate in global industries are continuously competing on commodity prices. The most important factor influencing final product prices has traditionally been the direct cost of labour wages (Coe and Yeung, 2015). However, by investing in and implementing new and advanced manufacturing technologies – and thereby altering cost-capability ratios (Coe and Yeung, 2015) – firms in high-cost countries can counter the comparative advantage of cheap labour offered in low-cost countries. The former CEO of *Auto* explained that the owner, a foreign TNC, initially set up production for the European market in China. When the decision was made to move production to Europe, the owner did not want to move production to Norway due to high production costs. However, after comparing other locations in Eastern Europe with Norway, *Auto* proved that by investing in a fully automated production line in Norway and by optimizing their processes and fine-tuning their equipment they could reduce the number of workers per shift from 15 to 3, and produce four times faster than in the previous host location in China. Thus, by optimizing their firm-specific capacities (Coe and Yeung 2015) through investing in advanced manufacturing technologies, production for the European market was moved from China to Norway.

Advanced manufacturing technology was influential in several of the reshored case firms. The CEO of *Construction* explained that the firm was able to relocate most of its production from Poland to Norway after investing in advanced manufacturing technology in a

new factory that opened in late 2018. To equip the new production line, the firm has bought 'the best machinery available in Europe today' from Austrian, German, and Swedish suppliers (CEO, *Construction*). The firm follows a strategy of investing in the best possible technology as it wants to be the best on robotization, automatization and digitalization. Many of the same tendencies were described for *Aqua*, as its production line is 'fingerprint free' (CEO, *Aqua*), meaning there is no manual handling of the product from raw material to final product. The CEO explained that Aqua's production line, equipped with machinery from German, Austrian and Swiss suppliers, was fully automated and could be controlled and supervised remotely. Reshoring can also take place as a consequence of subcontractors' technology upgrading. *Telecom* reshored production to Norway due to the subcontractor's ability to automate production. The CTO explained that 'it is important that we work with [subcontractor] to reduce the cycle time and the number of workers on the line'. The CTO further elaborated that the 'focus on as few seconds as possible per worker per product is essential … If you can do that right, you can produce in Norway and compete globally'. Based on the above examples, it is clear that manufacturing reshoring to Norway has been enabled partly by advanced manufacturing technologies. Through investments in these technologies, the firms have optimized their cost-capability ratio (Coe and Yeung, 2015) and improved their relative competitiveness vis-à-vis competitors in more low-cost locations. However, other forms of cost-capability optimization have also been influential.

For *Offshore*, the development of design for manufacturability competence (i.e. reducing production costs by optimizing the product design) has enabled the firm to reshore manufacturing from China. The access to relatively cheap labour in China influenced the way *Offshore's* products were designed: 'the design we had on what we produced over there was made simple in terms of welding and assembling … you did not have to be very competent to put things together.' (CEO, *Offshore*).

Through increasing the product design complexity, *Offshore* made the assembly process more complex, but reduced the number of components that needed to be welded. The reduced welding time halved the number of labour hours, and labour hours was 'the one and only [factor] that makes it profitable to produce in China' (CEO, *Offshore*). The CEO added that by 'complexity' he was referring to changes in design that required workers to be able to read and understand technical drawings. In a similar manner, the CEO of *Telecom* underlined the importance of collaborating with the firm's Norwegian contract manufacturer to simplify its product design and optimize the assembly process. Thus, optimizing firm-specific capacities

(Coe and Yeung, 2015) in terms of knowledge and competence is also a driver for manufacturing reshoring.

The combination of investing in advanced manufacturing technologies and access to a knowledgeable and competent workforce makes it 'possible to run the factory with relatively few, but highly skilled workers' (CEO, *Construction*). Evidently, it is necessary for a firm to develop multiple firm-specific capabilities (Coe and Yeung, 2015) in order to gain a competitive advantage. However, these firm specific capabilities are not developed by the firms alone. In Norway, highly skilled workers, at all educational levels, are relatively accessible (albeit not uniformly across locations and regions) due to the Norwegian education system, which by providing key human capital can be characterized as a key regional asset.

4.2 Regional assets – enabling manufacturing reshoring

The regions where the studied firms are located hold certain comparative advantages by virtue of their history. The concept of regional assets (Coe et al., 2004) is highly connected to the concept of embeddedness (Hess, 2004). The particular assets that create comparative advantages for a specific region are the result of both firm actors' and non-firm actors' strategic development of those assets. Regional assets are often developed in collaboration with regional institutions (Coe and Yeung, 2015). The Norwegian education system, which in GPN terminology (Coe et al., 2004) can be considered a regional institution (i.e. a non-firm actor) is one such comparative advantage. The state provides free primary and secondary education, as well as free college and university education during which students are supported by student loans and grants. In this sense, firms' social and territorial embeddedness becomes influential, as the Norwegian education system provides highly skilled workers at all educational levels, from factory floor and up (Statistics Norway, 2018, Lund and Karlsen, 2019). This, in turn, is important for enabling firms to implement advanced manufacturing technologies in production lines. Collaboration between industry and vocational education institutions provides knowledgeable skilled workers with skills and competence to operate in a modern manufacturing facility (Lund and Karlsen, 2019). At *Aqua*, for instance, collaboration with the nearest upper secondary school is important. According to the CEO, the firm had at least two apprentices from the automation technician education programme at all times, which is substantial considering that the firm has 33 employees in total. *Aqua* has also supported the same upper secondary school by donating two industrial robots to ensure that the education programme and the specific competence that students acquire are relevant and fit the firm's

particular needs (CEO, *Aqua*). Thus, in practice, the responsibility for developing and maintaining the regional assets of industry-relevant vocational education and training is often shared by private and public actors. Furthermore, the development of these regional assets has contributed to the reshoring of manufacturing and led to enhanced value capture (Coe et al., 2004) and regional economic development. Another regional asset that is made visible on the factory floor and that has been identified as an enabler of manufacturing reshoring is the 'Norwegian Model'.

The 'Norwegian Model' is a version of the Nordic Model (Andersen et al., 2007) and describes the characteristics of collaboration between the state, business and labourers on the nation state level and the local firm level. The Norwegian way of organizing work is based on high levels of trust between employee and employer, relatively flat hierarchical (organizational) structures and collaboration across education levels and backgrounds. The Norwegian model can be characterized as a regional institution that has a positive impact on firms' competitiveness by increasing efficiency (Andersen et al., 2007, Ravn and Øyum, 2018). An egalitarian organization of production and highly autonomous skilled workers helps manufacturers to exploit workers' experiences and develop competence and skills on the shop floor, and thus produce more effectively. This was highlighted by the CEO of *Marine* when talking about working life culture and workers' inclination to report problems to their superiors: 'In this country there is a more easy-going culture, for example in terms of talking to the boss. It is not like that in many other places, where you do not say anything to the boss' (CEO, *Marine*). Further, the CEO of *Marine* explained that problems, for example in production, could be solved faster if operators informed and engaged their superiors. This is important in terms of productivity and limiting downtime. Thus, being located in Norway and embedded in a Norwegian social and economic context is in itself seen as a comparative advantage by some of the firms that have reshored. Additionally, a region's industrial heritage can provide a form of regional asset and contribute to manufacturing reshoring.

In addition, the opportunity and ability to draw on historically developed regional knowledge bases (Asheim and Coenen, 2005) is seen by reshoring Norwegian manufacturers as providing a comparative advantage. The former CEO of *Auto* underlined the importance of the region (and its history) where the firm is located as a key asset in enabling the reshoring of production:

> We have a special competence in aluminium. That is what enables us to produce competitive products … It is the competence in development, technology and R&D … and also the hub that we have here, where this kind of competence has been developed for 50–60 years, with aluminium components for the automotive industry. (former CEO, Auto).

This historically accumulated competence, which emphasizes the importance of regional characteristics and territorial embeddedness, is key to understanding how *Auto* has been able to couple to the GPN. The combination of explicit regional competence in material and processing technologies, the implementation of LEAN methodologies, advanced technologies and the ability to automate, all aided by working closely with key regional R&D institutions, were described as the main drivers for the reshoring of *Auto*'s production. The firm *Construction* is located in the same region as *Auto* and its CEO underlined the importance of recruiting labour from the region. He explained that many of their employees came from

> the [region] system, have worked at [firms in that region]. Firms that have done well, but also worked a lot with LEAN and automation. We have been lucky to be able to recruit industry, LEAN and automation people from that system … We have been lucky compared to others in terms of where we are located.

The quote emphasizes the importance of embeddedness (Hess 2004). The territorial embeddedness of *Auto* provides access to a certain type of competence that would not necessarily been available had production been located elsewhere, at least not without major investments in learning and competence upgrading. The regional competence (i.e. regional asset) has enabled the recruitment of workers with certain competence, which has contributed to the overall competitiveness of *Auto* and *Construction*.

Essentially, the optimization of firm-capabilities, as discussed in section 4.1, relies on the existence and development of regional assets that underpin firms' capability building. This can, in turn, increase firms' competitiveness and enable reshoring, which subsequently enhances regions' ability to capture value. However, this overall competitiveness needs also to be seen in relation to changing market dynamics and, as integral to that, the changing demands of key customers.

4.3 Market dynamics – customer demands

Factors that influence reshoring decisions are changes in the global economy, within specific markets, and in customer demands, all of which are captured by the market imperative concept (Coe and Yeung, 2015) in the GPN literature. Excess production capacity at home in times of economic instability has been found a driver for reshoring of manufacturing to high-cost countries (Kinkel, 2014, 2012, Wiesmann et al., 2017). From the mid-1990s until 2010 the Norwegian offshore oil and gas market experienced growth, which provided ample domestic business opportunities for *Marine* and other firms in that market. Strong market demand also led to outsourcing of production due to limited production capacity at home. However, the slow yet steady downturn in the offshore oil and gas industry from 2010, and especially since the onset of the oil crisis in 2014 (Hou et al., 2015), resulted in fewer contracts, and *Marine* experienced an excess in production capacity at home. In order to sustain jobs in the firm's home location, *Marine* reshored previously outsourced contracts from subcontractors in Russia and the Ukraine. The outsourcing of production worked as a buffer, creating stability for *Marine* by ensuring contracts within the company when the economic situation was beneficial and ensuring jobs in their home location through reshoring during market downturns and economic instability. While further market-specific changes resulted in reshoring for *Marine*, changing customer demands had a strong influence on the reshoring of *Offshore*.

Customer demands, or customer pressure (in GPN terminology), and time-to-market are identified as two of four key dimensions of the market imperative (Coe and Yeung, 2015). A combination of what the CEO of *Offshore* perceived as changes within the market and customer demands for shorter lead times on finished products contributed to *Offshore's* manufacturing reshoring to Norway. Referring to the situation when the firm decided to outsource production to China in 2008, the CEO explained that,

> the market was also a bit different then. It allowed us to take the time to get products from China to Norway … Before, we could allow ourselves to have a 26 weeks lead time. While in the economic climate that we have now [2018], the customers want to sit on their money for as long as possible … That has led to us being asked to have 10–15 weeks lead time instead of 26, and then the China option falls away. (CEO, *Offshore*)

Insecurity, due to market risks, among *Offshore's* customers has led to demands for shorter lead times, which entails a shorter time-to-market (Coe and Yeung, 2015). With increased customer pressure on lead time, manufacturing in China became difficult and led *Offshore* to reshore its production to Norway.

In the automotive industry, time-to-market is a key factor and a driver for the regionalization of the industry (Dicken, 2015). This was an important aspect in the decision to reshore *Auto's* production to Norway: 'The automotive industry demands that you globalize and are close to the market' (CEO, *Auto*). The total cost of transporting parts from Europe to China and finished components back to Europe, combined with the ability to automate production (see Section 4.1), enabled *Auto* to build a new production site and reshore manufacturing to Norway. Proximity to markets (including B2B) is thus, in combination with other drivers, an important aspect in manufacturing reshoring, especially in the case of mass-produced products with relatively low margins, as transport costs can erode the comparative advantage of low production costs.

It is evident that there are many drivers for manufacturing reshoring to Norway. It is also evident that the reshoring of manufacturing to Norway is enabled by the combination of various factors, such as the implementation of new manufacturing technologies, the availability of key human capital, the presence of other region-specific competences, rather than stand-alone factors. In turn, these reshoring processes influence the configuration of global production networks.

4.4 Coupling dynamics in global production networks

Processes of reshoring imply reconfigurations of global production networks. These processes then have certain geographical outcomes. Reconfigurations of global production networks introduce dynamics into the framework and have been conceptualized as strategic coupling processes (Coe et al., 2004). A further distinction has been made between decoupling, coupling and recoupling processes, which in the GPN literature often are portrayed as definite ruptures (Coe and Yeung, 2015). However, in our empirical context, with a complex landscape of different sourcing strategies employed at different times, conceptualizations of abrupt strategic coupling processes (Coe and Yeung, 2015) do not provide sufficient analytical purchase. Due to acts of disinvestment taking place within some of the GPNs studied, the coupling processes have entailed a reconfiguration of the networks through locational shifts of value-added activity, rather than ruptures (MacKinnon, 2012). Disinvestments have been identified as an important mechanism within previous GPN studies (Werner, 2016), yet the implications of disinvestments for strategic coupling processes have not been properly developed in studies of GPNs. Therefore, in addition to providing illustrative examples of distinct decoupling and

coupling processes (ruptures), we elaborate on *partial decoupling* and *partial recoupling* as refined analytical concepts.

Aqua and *Maritime* (see Table 2 for more details on reshoring processes) serve as illustrative examples of abrupt decoupling and coupling processes (Coe and Yeung, 2015). Due to advanced manufacturing technologies, *Aqua* outcompeted a Chinese manufacturer and became a key supplier for a Norwegian lead firm within the aquaculture industry. As the lead firm decided to source products from *Aqua* instead of from the foreign manufacturer, the foreign manufacturer was decoupled from the GPN and *Aqua* was coupled to the GPN. In a similar manner, due to product quality issues, *Maritime* reshored all of its production from China to Norway. The Chinese manufacturer was decoupled from the GPN, and *Maritime* was subsequently coupled to the GPN. In the following, we relate the processes of disinvestment and reinvestment to strategic coupling.

Similar to how Yeung and Coe (2015, 35) argue that outsourcing and subcontracting is an 'important capitalist dynamic' for lead firms to enhance value capture, we argue that this is also the case for suppliers within GPNs. These strategies entail a reconfiguration of the GPN through disinvestments (Werner, 2016) and reinvestments, which leads to processes of *partial* decoupling and *partial* recoupling. *Construction* and *Auto* serve as illustrative cases of such *partial* coupling processes. Due to a downturn in the pulp and paper industry in Norway, *Construction's* main market, and a simultaneous subsidization of that industry in Poland (in addition to lower labour costs), the firm moved the majority of its production to Poland in the early 2000s. This resulted in the closure of a company branch plant in Norway, and the moving of some production to the company headquarters, while the rest was outsourced to a subcontractor in Poland. As *Construction* maintained some production at home while outsourcing the majority to Poland, the Norwegian production unit was never entirely decoupled from the global production network. However, the disinvestment process, in reducing the value-added activity, led to a *partial decoupling* of the home location from the GPN. Simultaneously, the Polish subcontractor was coupled to the GPN. In 2018, after investing in advanced manufacturing technologies (reinvestments) at the firm's headquarter, *Construction* reshored the majority of its production to Norway. Subsequently, the firm's home location increased its value-added activity and *partially* recoupled to the GPN. As some production remained abroad, the disinvestment in the offshore location entailed a partial decoupling of the Polish subcontractor. With the exception of the initial coupling of the Polish subcontractor, the GPN has not changed in terms of actors/firms/regions coupling to the

production network. However, the GPN has undergone a series of reconfigurations through a series of disinvestments and reinvestments in the two regions. A similar story can be seen in the case of *Auto*.

In 2016, after initially locating production to its Chinese branch plant, the TNC owner of *Auto* decided to build a new factory with advanced manufacturing technology and to relocate the manufacturing of components for the European market to Norway. The relocation of production from a branch plant in China to Norway entailed a decoupling of the Chinese plant, as it was no longer part of the GPN serving the European market (it has continues production for the Asian market). The reinvestment in the Norwegian location resulted in an increase in the value added activity and a *partial* recoupling of *Auto* to the GPN. In this case, the GPN was changed in terms of the Chinese region being decoupled, and the Norwegian region gained more relevance in the GPN through reinvestments, thereby increasing its share of value added activity within the GPN.

The examples of *Construction* and *Auto* provide insights into how both lead firms and suppliers can enhance value capture (Coe and Yeung, 2015) through different modes of sourcing strategies. Furthermore, they provide empirical evidence for our more fine-grained conceptualization of *partial* coupling processes. Through disinvestments and reinvestments and subsequent *partial* decoupling and *partial* recoupling processes, with corresponding negative and positive regional economic outcomes, global production networks can be reconfigured with geographical shifts in value added activities and value capture.

4.5 The complexity of manufacturing reshoring

Our empirical findings mirror the heterogeneity of our case firms also in terms of their role and positioning in wider systems of production and consumption. This allowed for a broad exploratory analysis of the reshoring phenomenon. As such, this paper is well-suited to highlighting the multitude of drivers for the on-the-ground implications of reshoring. Most of the drivers identified in this study are in line with previously identified drivers for reshoring, such as product quality issues, transportation costs and corrections of unforeseen costs related to offshoring and outsourcing. However, our empirical findings also suggest that automation and the implementation of advanced manufacturing technologies are key drivers for reshoring. In turn, the ability to implement such technologies is at least partly conditioned by existing, place-contingent regional assets and competences, developed on the cluster, regional or national

level. As such, the study provides key insights into how the development of intra-firm and extra-firm capacities, such as key human resources, region-specific competence and a working life organization that promotes innovation, can enable reshoring.

By studying both lead firms and specialized suppliers, which traditionally have been less studied actors within GPNs, this paper illustrates how reshoring provides a viable sourcing strategy for multiple types of actors within GPNs. The complex sourcing strategies employed by both suppliers and lead firms emphasizes how firms can adjust their value chains in order to maximize value capture. In turn, these adjustments entail reconfigurations of GPNs through distinct (ruptures) and *partial* coupling processes. These geographical shifts in value added activity underline the complexity and the functional fragmentation of manufacturing in the 21st century. Furthermore, they illustrate how firms' sourcing strategies have implications for the established spatial division of labour, as firms are able to relocate low value added activities from low-cost to high-cost locations.

5 Conclusions

In this paper we have explored the drivers for reshoring in a high-cost context (Norway) and the applicability of the GPN framework for analysing the phenomenon. We consider that the GPN framework, through its multiscalar approach, provides a more holistic understanding of the reshoring phenomenon, and its influence on regional economic development, than previous firm-centric studies. The concept of cost–capability ratio (Coe and Yeung, 2015) provides analytical purchase in terms of explaining the development of firm-specific capacities such as investments in advanced manufacturing technology and improving firm knowledge, competence and knowledge relating to, for example, design for manufacturability. Furthermore, the reshoring phenomenon cannot be understood sufficiently without an explicit focus on firms' territorial embeddedness, both nationally and regionally. The case firms benefit from being embedded in certain regional contexts, as the societal and historical aspects of particular regions have enabled firms to harness regional assets, such as education and regional competence. However, reshoring is also influenced by extra-regional factors. Thus, market dynamics (Coe and Yeung, 2015) are important aspects in firms' reshoring decisions. Changes in the global economy result in changed customer demands, such as shorter time-to-market. The combination of intra-firm processes, especially the implementation of advanced manufacturing technologies, and extra-firm processes has enabled the studied manufacturers to reconstruct a comparative

advantage in global manufacturing industries in their home locations. Overall, we consider that the GPN framework is suitable for studying the reshoring phenomenon. However, we suggest a few additions to the notion of strategic coupling.

In a complex economic landscape, with different sourcing strategies employed simultaneously, the conceptualization of coupling processes in the GPN framework as ruptures does not suffice. Therefore, we propose the conceptualization of *partial coupling processes* as expressions of disinvestments and reinvestments in manufacturing locations. *Partial decoupling* refers to disinvestments and subsequent reduced value capture in a host region, whereas *partial recoupling* refers to reinvestments that lead to an increase in value capture in a region, such as a home region. This provides a more fine-grained conceptualization of coupling processes. We find this is more in line with the many nuances of the spatio-functional divisions of labour within the global economy, and it provides a better understanding of GPN dynamics over time, including not least how GPNs 'touch down' in particular territories in particular ways over shorter or longer periods of time. As such, future GPN research should consider the adoption of an expansion of the strategic coupling concept. It is beyond the scope of this explorative paper to follow the developments of these partial coupling processes in our empirical analysis. However, we regard this as an important topic for future research within studies of GPNs and strategic coupling processes. An additional, and potentially related, topic for future research is how power relations between firms and within networks influence reshoring decisions, which could entail undertaking a more extensive approach than what this paper has and e.g. study multiple actors within a global production network.

It appears that reshoring has yet to make any substantive impact in high-cost countries (e.g. the USA, Germany, the UK). In terms of policy, we argue that rather than implementing specific policies or policy instruments to facilitate reshoring, more generic innovation policies and tools focused on digitalization, robotization and skill upgrading might lead to an increase in the overall competitiveness and innovativeness, and thus stimulate manufacturing reshoring. Furthermore, and potentially more important in terms of value creation for the manufacturing industry in high-cost countries in general, such policies might make high-cost countries attractive host countries for manufacturing and retain some of the manufacturers that otherwise would outsource or offshore their production. Key dimensions could be variety in institutional contexts and varieties of capitalisms (i.e. differing set-ups of state-industry relations) and differences in national or regional innovation systems. While this issue is not developed further

here, we consider it an important aspect of the reshoring phenomenon that demands empirical investigation in different national contexts.

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Appendix A – List of Informants

Firm/organization	Informant(s) position(s)	Place	Month, Year
NTNU Gjøvik	Professor	Gjøvik	December, 2016(AME)
Neuman Aluminium Raufoss	Head of Development & Operations Manager	Hunndalen	December, 2016(AME)
Kongsberg Technology and Training Centre	General Manager	Kongsberg	December, 2016(AME)
NCE SE/Kongsberg Innovasjon	Subproject Leader	Kongsberg	December, 2016(AME)
NCE SE/Kongsberg Innovasjon	General Manager	Kongsberg	January, 2017(AME)
NCE SE/Kongsberg Våpenfabrikk	Former CEO (1977-87)	Kongsberg	January, 2017 (AME)
Fagskolen Tinius Olsen	Project Leader	Kongsberg	January, 2017(AME)
NCE SE/Kongsberg Innovasjon	Project Leader	Kongsberg	January, 2017(AME)
Kongsberg Automotive	R&D Manager	Raufoss	January, 2017(AME)
NAMMO	Chief Human Resource Officer	Raufoss	January, 2017(AE)
Fagskolen Innlandet	Department Manager	Raufoss	January, 2017(AE)
Benteler	Chief Human Resource Officer and HR consultant	Raufoss	January, 2017(E)
Opplæringskontoret i Raufoss and NAMMO	General Manager & Operations Manager	Raufoss	January, 2017 (E)

Fellesforbundet	Leader, vice-chairman and business manager of the local labour union	Raufoss	January, 2017 (E)
TotAl-gruppen	General Manager	Raufoss	November, 2017 (A)
NCE Raufoss/ SITEF Manufacturing	Project Leader/ Senior consultant	Raufoss	November, 2017 (A)
GKN Aerospace	Head of Research and Technology	Kongsberg	November, 2017 (A)
Raufoss high school	Principal	Skype	January, 2018
Kongsberg high school	Principal	Skype	February, 2018
"Aqua"	CEO	Skype	March, 2018 (M)
"Auto"	former CEO	Skype	March, 2018 (M)
"Construction"	CEO	Skype	April, 2018 (M)
"*Maritime*"	CEO	Skype	May, 2018
"Marine"	COO	Skype	May, 2018
The Federation of Norwegian Industries	Executive Manager and Head of Research and Innovation	Skype	September, 2018 ^
"Telecom"	CTO	Skype	September, 2018
Norwegian Confederation of Trade Unions	Secretary	Skype	September, 2018 (M)
"Telematics"	CEO	Skyep	September, 2018
"Offshore"	CEO	Skype	September, 2018
Nammo	Factory Manager	Skype	November, 2018 (A)
Hexagon Ragasco	Head of Engineering	Skype	December, 2018 ^^
Benteler	Customer Line Manager	Skype	December, 2018 ^^

"Oil and Gas"	Vice President and Project leader	Skype	January, 2019 [(A)]
Kongsberg Defence and Aerospace	Technical Director	Skype	January, 2019
TechnipFMC		Notes	2019[+]

[(A)] Asbjørn Karlsen (Department of Geography, NTNU)

[(M)] Markus Steen (SINTEF Digital)

[(E)] Eli Ullern Fyhn (SINTEF Digital)

^interview done by Markus

^^interview done by Asbjørn

+ notes from interview conducted by other researchers within the SFI

"<name>" = anonymised interviews