Innovation, Space, and Diversity

by

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Dedication

I dedicate this PhD thesis to the *United World Colleges* (UWC).

UWC makes education a force to unite people, nations and cultures for peace and a sustainable future.

“The virtue and the strength of UWC is that it provides small but powerful cells of innovation, catalysts for change, breaking barriers of habit and opening broader vistas of experience for both pupils and educationalists”.

- Nelson Mandela

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Innovation as a social, interactive process has been referenced throughout the papers cited in this PhD thesis. This thesis has been enriched through interaction with many clever people that I would like to take a moment to thank.

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Det er ein
som er så klok
at i lag med han
skjønar eg
kor dum eg er.
Så er det
ein annan
som er så klok
at i lag med han
er eg klok
eg og.

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October 2013; The NORSI Conference in Oslo, Norway, in September 2014; The Regional Innovation Policy (RIP) Conference in Stavanger, Norway, in October 2014; The NEON Conference in Stavanger, Norway, in November 2014; The DRUID Academy in Aalborg, Denmark, in January 2015; The Fourth Global Conference on Economic Geography in Oxford, UK, in August 2015; The Regional Innovation Policy (RIP) Doctoral Day in Strasbourg, France, in October 2015; The Regional Innovation Policy (RIP) Conference in Karlsruhe, Germany, in October 2015; The 3rd Geography of Innovation Conference in Toulouse, France, in January 2016; and the American Association of Geographers Conference (AAG) in San Francisco, USA, in April 2016. I want to thank Bengt-Åke Lundvall, who guided me in the direction of Christian R. Østergaard. Christian, our second meeting at the RIP conference in San Sebastián, when you read my conference paper and offered many constructive comments regarding its improvement, is something that I will never forget. Thank you for all of your valuable insights! I extend a big thank you to Bram Timmermans for engaging in enriching discussions with me during the PhD program. I look forward to conversing with you and Christian in the future. At the more recent few conferences, I have had the pleasure of meeting and conversing with Neil Lee and Thomas Kemeny. Thank you for your valuable input and stimulating discussions.

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DU VAR VINDEN
Eg er ein båt
Utan vind.
Du var vinden.
Var det den leidi eg skulde?
Kven spør etter leidi
Når ein har slik vind!
Hauge (1966)

Marte C.W. Solheim

September 2016

Contents

PART I

List of papers

This PhD thesis is a compilation of four individual papers

I. Solheim, Marte C.W. and Sverre J. Herstad. “On the differentiated effects of human resource diversity on organizational learning and innovation”. Under review in *Industry and Innovation* (Submitted 23.06.2016).

II. Solheim, Marte C.W. and Rune Dahl Fitjar. ”Foreign workers are associated with innovation, but why? International networks as a mechanism”. Published in *International Regional Science Review* online ahead of print 21.01.2016.

III. Solheim, Marte C.W. “Foreign workers and international partners as channels to international markets in core, intermediate and peripheral regions”. Published in *Regional Studies, Regional Science* online ahead of print 07.12.2016.

IV. Solheim, Marte C.W. and Ragnar Tveterås. “Do firms in upstream oil and gas sectors benefit from co-location?”

Short Summary

Background

This PhD thesis aims at combining different perspectives from the literature on organizational theory, innovation, and economic geography and addresses how firms[1] communicate and connect within the contexts of innovation processes. The literature concerned with organizational theory has had a tendency to overlook the significance of external surroundings and rather overemphasize within-firm relations and capabilities[2]. On the other hand, the literature on economic geography sometimes fails to consider that firms are heterogeneous leading to studying firms in a static manner.

The thesis aims at contributing to the existing body of literature that connects these approaches by looking at how firms organize their innovation activities in relation to their contexts and how firms create external knowledge linkages. This in turn reflects firms' internal competences, as firms' internal capabilities guides firms' ability to find new knowledge, connect to partners and innovate, hence their absorptive capacity (Cohen and Levinthal 1990, 67).

At the same time, the external environment influences firms' internal competence. The underlying mechanism is that people are inseparable from their environments because "environments only exist through the people behaving in them *knowing* them" (Schneider 1987, 439). One premise is thus that innovation is an interactive process where people with different competence meet in order to solve problems (Østergaard, Timmermans, and Kristinsson 2011, Bathelt, Malmberg, and Maskell 2004, Lundvall 1992). There is a need for increased understanding of how these interactive processes are organized, which actors are involved, and how these activities play out in

[1] The terms "Firms" and "Organizations" are used interchangeably throughout this PhD thesis. This PhD thesis departs from the definition of firms and organizations understood broadly as consisting of cautious arrangements and the conscious coordination of people working together in order to reach a common goal (Miles 2012). Moreover, this PhD thesis builds on that organizations and/or firms have fluid boundaries (Coase 1937, Williamson 1985) that are influenced by the environment and vice versa (Storper et al. 2015).

[2] The author is, however, conscious of the awareness raised in organizational theory away from the "internal processes of organizations and towards the organization-environment interface" (Håkansson and Snehota 1989, 188).

space, gaining such understanding by both considering firms' internal and external knowledge and competence. One example is that having diverse human resources could lead to reaching an equally diverse marketplace (Cox 2001) and access to broader knowledge, which in turn is important for innovation (Laursen and Salter 2006).

This PhD **aims** at gaining insight on the interdependencies of firms and external knowledge linkages in innovation, particularly focusing on the role of diversity. The overall research question is: how does **diversity** and **space** affect **innovation?**

This PhD thesis comprises four individual papers:

I. Solheim, Marte C.W. and Sverre J. Herstad. "On the differentiated effects of human resource diversity on organizational learning and innovation". Under review in *Industry and Innovation* (Submitted 23.06.2016).

II. Solheim, Marte C.W. and Rune Dahl Fitjar. "Foreign workers are associated with innovation, but why? International networks as a mechanism". Published in *International Regional Science Review* online ahead of print 21.01.2016.

III. Solheim, Marte C.W. "Foreign workers and international partners as channels to international markets in core, intermediate and peripheral regions". Published in *Regional Studies, Regional Science* online ahead of print 07.12.2016.

IV. Solheim, Marte C.W. and Ragnar Tveterås. "Do firms in upstream oil and gas sectors benefit from co-location?"

Research Design: Data and Methods

The four individual papers take advantage of different data and methods. Paper I and III draws on large and unique datasets that consist of public enterprise registers gathered on an annual basis covering all employer firms and all workers in private sectors in Norway. These data are often referred to as Linked Employer – Employee Data (LEED). The LEED are then merged with an extended version of the Community Innovation Survey (CIS). Paper II builds on the survey data from approximately 500 firms in Norway with more than ten employees, covering all sectors and regions. Paper IV takes advantage of a panel data set consisting of 1500 firms in the Norwegian upstream oil and gas industry. All of the four individual papers aim at measuring different aspects of innovation at different stages in the innovation process. The simplified definition of innovation is: a "new idea, device or method" or "the act or process of introducing new ideas, devices or methods" (Merriam-Webster 2016). Innovation is both the process of e.g. developing new markets and/or new products, or new methods of production, as well as the outcome: e.g. increase in value added, or a new product.

Although innovation is not a chronological process without any setbacks or loops (Kline and Rosenberg 1986), the innovation process goes through stages that are distinct in time, i.e. patenting, product and process innovations, and launching these product in markets and an increase in revenue at the bottom line caused by innovations. In Paper I, innovation is measured in three ways: firstly by the decision to engage in systematic development work, secondly by patent, and thirdly by product and process innovation. Paper II measures innovation by product innovation (and new-to-market product innovation) and process innovation (and new-to-industry process innovation). Paper III measures innovation by looking at whether firms have launched goods and/or services in international markets. Paper IV measures the effects of industrial agglomeration on firms' value added, where increased innovation is an important underlying factor leading to increased productivity for firms that are geographically co-located. Hence, all of the four individual papers offer a distinct and different outlook on innovation, including product innovation, effects on productivity, and new processes or underlying mechanisms of collaboration and market entry. Various econometric analyses are employed in the different papers, and mostly similar techniques are used.

Results

All of the four individual papers demonstrate that different aspects of *diversity* and *space* affect *innovation*. The results from paper I demonstrate that exploration (patent output) responds differently to the composition of firms' human resource bases than exploitation (new products & production processes) does. Moreover, the results demonstrate that exploration is dependent on diversity of human resources, whilst exploitation is more dependent on similar capabilities. Investments in innovation are important moderators of these effects. Paper II and Paper III investigates the role of foreign workers in firms and demonstrates some of the underlying mechanisms between foreign workers, international partners and innovation/export of goods and/or services to international markets. In Paper II, we find evidence that firms with highly educated foreign workers collaborate more frequently with international partners and that there is a positive relation between having a variety of international partners and the probability of product innovation and new-to-market product innovation (as well as new-to-industry process innovation). The results from Paper III demonstrate that firms in core, intermediate, and peripheral regions benefit from international collaboration and foreign workers in order to be present on international markets. The results stresses that firms in peripheral regions are not detached from the global economy, but are able to partake in able to tap into global economies by e.g. collaborating with international partners. Paper IV studies a particular industry, namely the upstream oil and gas industry in Norway, and finds that firms in this industry benefit from regional agglomeration through increased productivity as measured by value added. This is particularly so when firms within the same subsector are co-located. Knowledge spillovers leading to increased innovation are believed to be an important underlying factor driving agglomeration related productivity growth.

Conclusions

The four individual papers all demonstrate different aspects of the interdependencies between firms and their contexts while also highlighting the role of diversity. The papers demonstrate how diversity amongst actors contributes to some types of innovation, whilst other types of innovation are facilitated through similarity between actors. The results from paper I demonstrates how exploration (patent output) is more dependent on diversity in human resources, than exploitation where similarity in experience and educational background seems more important. The results from paper II demonstrates how diversity amongst workers, as measured by foreign workers, may contribute to new collaboration patterns, which in turn prove essential for product and new-to-market product innovation as well as new-to-industry process innovation. The results from paper III demonstrate that firms in core, intermediate, and peripheral regions benefit from collaborating with international partners and hiring foreign workers in order to be present on international markets. The results paint a varied picture of different dimensions of innovation in relation to different measures of diversity, but furthermore in relation to space and context. This provides an important element of not only increasing our understanding of the role of diversity in both core, intermediate, and peripheral regions, but also since past contributions have had a tendency to study globalization and diversity in cities, the results demonstrate the capability of benefitting of diversity across space. The results from paper IV demonstrate that close communication and substantial interaction between suppliers and buyers that permeate the upstream oil and gas industry proves pivotal in increasing value added. This is particularly the case when firms within the same subsector are co-located, further stressing the importance of similarity between actors.

1. Introductory Chapter

1.1 Innovation, Space, and Diversity

What are the central drivers for innovation, and how do they interact to impact the innovation of firms? These questions are based on the premise that developing robust and innovative firms and regional capabilities for innovation is an indispensable response to the challenges of globalization; more liberalized economies, far cheaper and accessible communications, and limited possibilities for firms and regions to hold on to competitive advantages.

In "Capitalism, Socialism and Democracy", Schumpeter (1943) argues in favor of innovation being at the heart of capitalism. More than 70 years has passed since this work was first published, and many of the arguments are still relevant today. The driving force behind innovation was then, and is still today, to gain competitive advantage over competitors (Dosi and Nelson 2010, Schumpeter 1943). One consequence of this changing global economy is that it has led to an increase in competition, and it makes high cost countries even more dependent on *innovation*, as firms in these countries cannot compete on cost alone.

Innovation does not happen in isolation, but increasingly in relation with others through a non-linear, interactive process (Kline and Rosenberg 1986, Lundvall 1992). People change jobs a lot more often now than before, and *diversity* in terms of experience and educational background has increased as well as the diversity in terms of foreign workers. Migration of workers influences work places as they might bring competence that is scarce in their new homeland (Kangasniemi et al. 2009), or they might provide a different view or a new outlook based on that foreign workers might have different experiences and/or heuristics (Østergaard, Timmermans, and Kristinsson 2011). A natural response is to ask the following: how does this changing and increased diversity affect innovation and innovation processes?

Innovation cannot be considered separately from its environment. Economic activity is unevenly distributed across the world, with a tendency for clustering (the creation of industrial districts, "milieu innovateur") in some areas (Marshall 1920, Morgan 1997, Cooke, Gomez Uranga, and Etxeberria 1997,

Aydalot 1986, Porter 2000). One of the benefits of such clustering is face-to-face contact in regions that are rich in social capital. This has been widely acknowledged as an important input to innovation activity (Caragliu, de Dominicis, and Groot 2016). Therefore, the arguments of globalization and of companies being increasingly "foot-loose" than before and the death of distance (Cairncross 1997) are challenged (Rietveld and Vickerman 2004). What are the underlying mechanisms of space and external knowledge linkages affecting innovation?

Based on these preceding arguments, it is important study how *innovation, space,* and *diversity* are interconnected, and this introductory chapter will focus on these three phenomena and how they are connected, understood, and "treated" in the individual papers of this PhD thesis.

The introductory chapter of the PhD thesis is organized as follows: the first part of the kappe[3] gives an introduction to the thesis as well as outlines the theoretical and empirical context of the thesis. Secondly, the research questions, contribution, and aim of the thesis are introduced. Thirdly, the discussion of the overarching theoretical contribution is provided before methodological comments, concluding discussion, and finally directions for future research are addressed.

1.2 Innovation

Etymologically, the term *innovation* originates from the Latin word "innovare", which means to create something new. Innovations could be new to the firm, new to the market, or even radically new to the world. Either way, innovation tends to happen incrementally within firms, and even though a single innovation is studied, it is most commonly a result of a long process that involved many interrelated innovations (Fagerberg 2005).

[3] The introductory chapter of the PhD thesis is at many Scandinavian universities referred to as "kappe". Kappe translates to "cloak" or a cape and aspires to outline the theoretical and methodological findings and challenges of the articles presented in the PhD thesis, as well as gives the candidate an opportunity to reflect on the PhD and provide a broader understanding of the PhD thesis than what was feasible in the papers themselves.

"The linear model" (Bush 1945, Maclaurin 1953) is based on the assumption that innovation goes through chronological and systematical stages. Kline and Rosenberg (1986) argue that the linear model has two different flaws: firstly, it is too focused on innovation stemming from science and scientific breakthroughs. Kline and Rosenberg (1986) hold that firms innovate because they have seen a need for something in the market. They reorganize and try to reach that target (developing something to fill that need identified), and Research & Development (R&D hereafter) does not necessarily start off as being the catalyst for the project. It often happens the other way around, and firms incorporate R&D after aiming firstly for something else (Fagerberg 2005). Hence, the distinction between invention and innovation becomes important here, as there is a distinction between the first occurrence of an idea (invention) and the actual attempt at carrying it out in practice (innovation) (Fagerberg 2005).[4] The second criticism against the linear model is that it disregards the loops that occur in the various stages, setbacks, failures, new attempts, and so on.[5] Hence, since it does not take these setbacks into account and mainly emphasizes the chronological stages innovations go through, it gives an overly measurable, straightforward view on how innovations occur in firms. Moreover, it provides an overly optimistic idea of the straightforwardness of an innovation process.

In an increasingly globalized world, and with the great development within communication technology, new opportunities arise. In addition to these new opportunities, these changes have led to harder competition and pressure, for example on traditional industrial production. The competitive advantage of firms are based on their capabilities to innovate and on interactive learning processes that are socially and territorially embedded (Asheim 2000, 426). Firms' ability to renew their businesses and be innovative is particularly important in high cost countries that are unable to compete on the same terms as low cost countries, due to, for example, the high wages and the high costs

[4] Schumpeter made the distinction between innovation, invention, and diffusion: "According to his definition, invention concerns the original development of some novel would-be process of production or product while the innovation entails its actual introduction and tentative economic exploitation. Diffusion describes its introduction by buyers or competitors" (Dosi and Nelson 2010, 91).

[5] There are many similarities between the innovation process and organizational learning, e.g. such as the single-loop versus the double-loop learning in organizations (Argyris and Schon 1978).

associated with production. This all adds to innovation becoming increasingly important for high cost countries that cannot compete on cost alone, but increasingly compete through good ideas and innovations.

The "network-based" model within innovation research stresses the idea that firms do not operate in isolation, but through extensive collaboration with its environment and in connection to other organizations and places. Innovation is by its very nature a systemic phenomenon (Edquist 2005), since it builds on interaction with different actors and environments (Fagerberg 2005) and with great emphasis on interactions between institutions and networks (Lundvall 1992). This line of research focuses on regional innovation systems and the concept of learning regions (Asheim, Boschma, and Cooke 2011a, Asheim et al. 2013, Asheim, Lawton Smith, and Oughton 2011, Asheim and Gertler 2005, Cooke 2001, Cooke, Gomez Uranga, and Etxeberria 1997). The main argument is that networks are important for innovation, and this PhD thesis connects with the idea of "open innovation", where innovation is seen as a combination of internal and external forces (Chesbrough 2003). Here the concept of "absorptive capacity" (Cohen and Levinthal 1990) becomes important, since this concept captures the (internal) ability to acquire (external) information and the capability to assimilate it, and apply it to commercial ends (Cohen and Levinthal 1990). Hence, this process depends on prior knowledge and diversity within the firm.

This PhD thesis departs from the idea that places and institutions constitute each other and that innovation is shaped by the environment. Innovation is also shaped by how firms` internal skill mix affects the potential knowledge and resources that may be reached and what kind of processes that are pursued.

1.3 Space

Innovation and innovation activities are unevenly distributed across *space* (Asheim and Gertler 2005, Florida 1995, Maskell et al. 1998). Some places have a dense concentration of economic activity and firms and others less so, and the functional (and social) characteristics of some areas define in turn the functional (and social) characteristics of other areas (Massey 1994). This is among other things caused by the regional path-dependency and the diversification of industries.

Moreover, spaces or places have been stressed as key drivers of innovation (Asheim 2000, Porter 2000, 1990) following the seminal insight by Marshall (1920) that "there is something in the air", and the idea that knowledge spillovers are geographically bounded (Feldman 1994). Hence, where firms decide to locate, has implications for the access to knowledge potentially available to them. Innovation is spatially concentrated, and geography is "a platform to organize economic activity" (Feldman and Kogler 2010, 381). The essence of these arguments is that "geography and place-specific interactions shape industries" (Feldman and Kogler 2010, 383).

This has implications for our understanding of innovation processes as must be understood in relation to the environment in which it plays itself out. This relates to what Feldman and Kogler (2010, 383) described as *terroir,* which may be translated into "dirt" or "sense of place" since it captures the total effect that the local environment has on the product (the knowledge "in the air", the traditions, the place itself), and occurs when "the total effect is more than the sum of its parts and the effect is difficult to replicate (…)". The effect is difficult to replicate also because people, organizations, and places are heterogeneous (Penrose 1959) and go through self-reinforcing processes of dependency where people and places constitute themselves (Massey 1994). This relates well to the ideas put forward by e.g. Florida (2008) of how places are spiky, and that where people decide to live, has huge implications to how their lives unfold, their career possibilities, the people they will meet (in that place), interactions and so on. We may also relate this to the thought put forward by Halfacree (2006, 44), because people and places are interconnected and constitute each other and space "is not something that "just exist[s]", waiting passively to be discovered and mapped, but is something created in a whole series of forms and at a whole series of scales by social individuals". This in turn affects innovation and what kind of innovation activity that will take place.

Agglomeration economies emphasize that firms and workers may gain economic benefits through being located in a cluster which is a "geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter 1998, 199). These commonalities and complementarities are based on the benefits of agglomeration through i.e. the "Marshallian externalities": labor market pooling, the creation of specialized suppliers and knowledge spillovers leading

to increased innovation. These externalities and knowledge spillovers are based on the assumption that firms have fluid boundaries (Coase 1937), and the geographical proximity facilitates collaboration due to trust amongst the actors involved (Morgan 1997). Hence, it has been investigated whether regions with a specialized industrial structure are more conducive to innovation and growth as compared to the regions that contain more diversified industrial structures (Glaeser, Scheinkman, and Shleifer 1992).

There is disagreement to whether specialization (drawing on Marshall and localization economies and the benefits from thick and specialized labor markets, regional knowledge spillovers, and specialized suppliers) is superior to urbanization economies, that is diversification of industries (drawing on Jacobs, 1969), which holds that firms benefit from a variety of sources. Moreover, this diversified regional structure triggers new ideas because of its diversity and variety of aspects. Complementarity becomes important here (Nooteboom 2000b), as does relatedness between firms and sectors. This has been exemplified by the fact that " it is unclear what a pig farmer can learn from a steel company despite the fact that they are neighbours" (Asheim, Boschma, and Cooke 2011b). Hence, there is a need for some sort of technological relatedness (Frenken, Van Oort, and Verburg 2007) and proximity (Boschma 2005) in order to facilitate communication and interaction between the actors.

1.4 Diversity

It has now been established that innovation is an *interactive* process and economic activity is unevenly distributed across space. Due to people and places constituting each other (Massey 1994), the industrial environment affects the career paths of individuals in these places (Florida 2008), which in turn affects diversity. Also, with the increase in migration, there has been an upsurge in diversity.

The literature on diversity is very diverse, but it can roughly be divided into two more general groups or perspectives (Horwitz 2005). The first perspective is the "similarity attraction perspective", which emphasizes social homophily, or the idea that people prefer to engage in relationships with other people that are similar to them (McPherson 2001). It is thought that this similarity eases

communication[6] and could lead them to execute tasks more efficiently. The "cognitive resource diversity" perspective, by contrast, emphasizes how diverse teams would have a larger and more diversified pool from which to draw ideas or solutions to problems, and hence will be able to outperform more homogenous teams (Hong and Page 2004).

To take advantage of diversity, the concepts of proximity (Boschma 2005) and cognitive complementarity (Nooteboom et al. 2007) become important. Hence, where actors are similar enough to being able to communicate, but different enough to provide something new. When the distance between the actors is too large, this may lead to higher communication costs, which could hamper innovation (Basset-Jones 2005). When the distance is too small, then there could be greater potential for "lock-in" and the chance that nothing new could be gained, which in turn also is not beneficial for innovation (Boschma 2005, Fitjar, Huber, and Rodríguez-Pose 2016).

These concepts of diversity operate at the individual level and at the firm level, and theories of unrelated and related variety (Frenken, Van Oort, and Verburg 2013, 2007) are important aspects in relation to space and innovation. "The goldilocks principle" provided by Fitjar, Huber, and Rodríguez-Pose (2016), aims at investigating the right distance between partners in order to facilitate interaction: not too far and not too close.

1.5 Short Recap

This PhD thesis departs from the discussions of organizations being colored by their environments and how environments or the *terroir* shapes innovation in firms. This PhD thesis sees innovation as an interactive process, and it acknowledges the importance of firms' internal as well as the external knowledge constructions. Moreover, it acknowledges how the internal skill mix affects innovation as well as firm`s external knowledge sourcing and compositions. The thesis seeks to provide insight into (some of) the interdependencies of firms and their external knowledge linkages in innovative processes, and aims to do so by particularly focusing on the role of diversity.

[6] Communication derives from the Greek word "communicare" or "communico", which means to "make common" or "to share".

1.6 Research Questions, Contribution, and Aim

This PhD thesis intent to combine different strands of literature, especially the literature on organizational theory, innovation, and economic geography. The thesis addresses firm's internal competence and it addresses how firms communicate and connect with their contexts in innovative processes. The literature concerned with organizational theory sometimes overlooks the external knowledge linkages that firms establish and overstresses the "within-firm" relations and capabilities. On the other hand, the literature on economic geography sometimes does not contemplate over firms being heterogeneous and considers firms in a very fixed manner. By combining these two, this thesis seeks to contribute, on the one hand, to the existing body of literature that connects these strands of literature by looking at how firms organize their innovation activities and how these are shaped by contexts and external knowledge linkages. On the other hand, by emphasizing how firms are heterogeneous entities where firms' internal capabilities are strongly related to their ability to find new (external and internal) knowledge, connect to partners, and innovate, hence their absorptive capacity (Cohen and Levinthal 1990).

This PhD **thesis aims** to gain insight into the interdependencies of firms and external knowledge linkages in innovation, particularly focusing on the role of diversity. How innovation and innovation activity transfer across space and the effects of diversity are main aspects, and this PhD thesis focuses on revealing the patterns and regularities of such.

The overarching **Research Question** for this PhD thesis is as follows: How do diversity and space affect innovation?

The underlying research questions within the various papers are as follows:

Paper I: *Solheim, Marte C.W. and Sverre J. Herstad. "On the differentiated effects of human resource diversity on organizational learning and innovation"*. Does diversity in people's worker-skill portfolio affect firms' innovation differently?

Paper II: *Solheim, Marte C.W. and Rune Dahl Fitjar. "Foreign workers are associated with innovation, but why? International networks as a mechanism"*. Do foreign workers (diversity) affect innovation in Norwegian firms? If yes,

how? What is the role of multiscalar innovation/international partners on firm innovation?

Paper III: *Solheim, Marte C.W.* "Foreign workers and international partners as channels to international markets in core, intermediate and peripheral regions". Do firms in peripheral regions use the same channels (especially focusing on foreign workers and international collaboration) as firms in core or intermediate regions in order to be present on international markets?

Paper IV: *Solheim, Marte C.W. and Ragnar Tveterås. "Do firms in upstream oil and gas sectors benefit from co-location?* Do firms in the Norwegian upstream oil and gas sectors benefit from agglomeration in terms of increased productivity? If yes, do we observe differences between the various sub-sectors?

1.7 Overview of the Papers

The content of the four individual papers will be briefly discussed in relation to the central theme and research question of this thesis.

The objective of the first paper, "*On the differentiated effects of human resource diversity on organizational learning and innovation"*, is to investigate whether different human resources affect aspects of innovation distinctively. It is concerned with the similarity attraction perspective and the cognitive resource *diversity* perspective on how human resources affects innovation differently. Innovation is measured by exploration (patent) and exploitation (product and process innovation) as well as the engagement in systematic development work. The educational and career paths of individuals reflect the composition of the industrial structure that surrounds firms in their locations underscoring the interdependencies of firms and their environments (*space*). The results demonstrate that exploration and exploitation depend on different input of human resource diversity. Moreover, the results underscores that exploration benefits from diversity of human resources whilst exploitation seems to benefit from having workers with related backgrounds.

The objective of the second paper, "*Foreign workers are associated with innovation, but why? International networks as a mechanism*", is to investigate

whether firms that are *diverse* in terms of having foreign workers innovate differently than firms that do not employ foreign workers. This paper is concerned with explaining how birthplace *diversity* in the workforce affects *innovation*. The results demonstrate that firms with foreign workers have more international partnerships, which in turn increases innovation. It henceforth demonstrates that innovation is an interactive process and is contextual and affected by the diversity and variety brought in by the associations of the firm.

The objective of the third paper, "Foreign workers and international partners as channels to international markets in core, intermediate and peripheral regions" is to investigate whether firms in smaller and peripheral regions are able to tap into the global economy (by selling goods and/or services in international markets). Moreover, by studying whether peripheral regions take advantage of the same channels (and by particularly focusing on foreign workers and international collaboration) as firms in core or intermediate regions do, in order to be present on international markets. The results demonstrate a positive association between foreign workers, international collaboration and firms selling goods and/or services in international markets, for firms in all regions. When subdividing foreign workers and international partners into more detailed categories, a more fine-grained picture is painted, e.g. a positive association between share of workers from EU15 - countries and presence in both European and other international markets, indicating that that these particularly acts as facilitators into international markets.

The objective of the fourth paper, *"Do firms in upstream oil and gas sectors benefit from co-location?",* is to investigate whether firms in the upstream oil and gas industry benefit from geographical proximity. It focuses on clustering of firms and underlines the interdependency of firms and their environment. It also underlines the importance of tacit knowledge facilitated by cognitive and physical proximity (Marshall 1920, Gertler 2003, 1995) that permeate the nature of the industry. The results demonstrate that firms in the Norwegian upstream oil and gas industry benefit from geographical proximity in terms of increased productivity as measured by value added; this is especially so when firms in the same subsector are co-located.

Paper no.	Title	Objective	Theory	Approach	Findings
I	"On the differentiated effects of human resource diversity on organizational learning and innovation".	To investigate whether different human resources affect innovation differently.	Innovation. Diversity/ Proximity. Organizatio-nal learning.	Econometric analysis of LEED + CIS data.	Exploration and exploitation depends on different input of human resource diversity.
II	"Foreign workers are associated with innovation, but why? International networks as a mechanism".	To investigate whether firms that have foreign workers innovate differently.	Diversity. Multiscalar innovation.	Econometric analysis of survey data.	Firms with foreign workers have more international partnerships, which in turn increases innovation.
III	"Foreign workers and international partners as channels to international markets in core, intermediate and peripheral regions".	To investigate whether firms in core, intermediate and peripheral regions use similar channels in order to reach international markets.	Multiscalar innovation. Diversity.	Econometric analysis of LEED + CIS data.	Positive association between firms, in all regions, and international ties and international market presence.
IV	"Do firms in upstream oil and gas sectors benefit from co-location?"	To investigate whether firms in the upstream oil and gas industry benefit from geographical proximity.	Agglomerati -on economies.	Econometric analysis of panel data.	Firms benefit from being co-located. Especially when firms in same subsector are co-located.

Table 1: Overview of contribution and aim of the PhD papers. Table inspired by Coenen (2006).

2 Theoretical Framework

This PhD thesis is based on the premise that *innovation* is an interactive process in which people with *diverse,* yet complementary skills (Østergaard, Timmermans, and Kristinsson 2011, Lundvall 1992) interact in order to solve something (Bathelt, Malmberg, and Maskell 2004) and that this process is affected by firms' environment (*space*) (Halfacree 2006, Massey 1994, Storper 1997, Marshall 1920).

This theoretical framework aims to cover the overarching theoretical framework of the PhD thesis that asks how innovation is affected by diversity and space. First, *innovation* will be discussed, secondly *space*, and thirdly *diversity*.

2.1 Innovation

In line with Schumpeter, who distinguished between five types of innovation: new products, new methods of production, new sources of supply, the exploitation of new markets, and new ways to organize business (Schumpeter 1934, 66), the former president and CEO of IBM, Sam J. Palmisano said that "innovation is about much more than new products. It is about reinventing business processes and building entirely new markets that meet untapped customer demand" (Teece 2009). Hence, innovation is ranging from the start of the innovation process (e.g. from the internal organizing or the initial idea) to the end (e.g. with new markets built, new products launched and/or increased value added). In other words, innovation is not only an outcome, but also a process.

This must not be confused with the "linear model" (Bush 1945, Maclaurin 1953), which has in the past tried to explain how innovation goes through chronological and systematical stages. These different types of innovations do occur at different times, but not in a linear and chronological way without setback and failures. Among the criticism that this linear model has gained, is that it is very science-oriented and it excludes the setbacks and failures and the serendipity of innovation (Kline and Rosenberg 1986). Serendipity does play a role in scientific discovery and in innovation, and an example of this is how

"Columbus did not find what he was looking for – but the discovery of the new world was hardly an accident" (Stephan 2010, 231). Innovation is also about internal structuring of resources and making new combinations of these existing resources (Schumpeter 1934).

This PhD thesis connects with the wide-ranging definition of innovation put forward by Edquist (1997) that innovations are new creations of economic significance. This is a broad foundation comprising new combinations of the existing resources as well as including radically new innovations.

2.1.1 Invention and Innovation

In the innovation literature, there is an important distinction between innovation and invention. Invention is the first occurrence of an idea for a new product or process, and innovation is the first attempt to carry it into practice (Fagerberg 2005). Innovation could be defined as "a process that involves the generation, adaption, implementation and incorporation of new ideas, practices and artifacts within organizations (Axtell et al. 2000, 266). Fagerberg (2005) argues that sometimes it is hard to distinguish innovation from invention, but that there is often a considerable amount of time between the two. These two concepts relate back to the internal structuring and restructuring of resources, as it is imagined that they depend on distinct input. Padgett and Powell (2012) argue that the distinction between innovation and invention is related to the source from whence they pull knowledge. Hence, it becomes apparent that combination of different types of resources and knowledge may lead up to different kinds of outcomes and distinct types of innovations. Innovation relates to spillovers from "adjacent domains, bringing together familiar practices, concepts, and ideas from proximate social worlds" (Powell 2016, 5). Hence, it is a process in which known elements are recombined, and it leads to improvements of the way things are done. They further argue that invention relates to transposition across distant worlds and that these introductions into foreign lands are much more likely to fail than if you stay within known areas (Padgett and Powell 2012). They argue that, when it takes root, invention creates new kinds of industries and organizations and remakes the economic

landscape. Hence, it has the capability to change the way things are done.[7] The arguments raised by Padgett and Powell (2012) is that innovation and invention depend on different resources, and the distinction between improvements of the ways things are done versus changing the ways things are done. Based on this distinction between innovation and invention, it is understood that resource allocation, knowledge, learning, and innovation are interconnected phenomena and that different kinds of output depend on distinct and varied forms of input.

2.1.2 Modes of Innovation

Knowledge lies at the heart of every innovation process, and jointly with learning, it is a premise for innovation activity. Knowledge has been considered the strategically most important resource and learning the most fundamental activity for creating competitive advantages (Asheim and Coenen 2005, 1174). This underscores the significance of knowledge and different kinds of knowledge in innovation processes.

Knowledge has regularly been concerned with the role played by tacit versus codified knowledge (Polanyi 1966). The codification of knowledge means that the knowledge is transformed into information that can be easily transmitted. Tacit knowledge, by contrast, is knowledge that cannot be easily transferred, because it is has not been stated in an explicit form. Hence, the only way to transform this knowledge is through extensive interaction or through a specific kind of social interaction (Polanyi 1966) facilitated by face-to-face interactions. This transmission of knowledge depends on the innovation activity, since different types of innovations depend on different kinds of human resources.

In the innovation literature, we often see the distinction made between the Science-Technology-Innovation (STI) and the Doing-Using and Interacting (DUI) mode of innovation (Jensen et al. 2007a). The STI is based on the production and the use of codified scientific knowledge and aims at generating scientific advances into novel "universal knowledge". Due to its character`s dependency on exploring new frontiers, the capacity of advancements into new universal knowledge often lies within specialized departments within firms, one

[7] This distinction made by Padgett and Powell (2012) carry similarities to the distinction between exploration and exploitation put forward by March (1991).

example being R&D departments. Moreover, investments and structuring of highly skilled resources in combination with advanced technologies and infrastructure, is essential within the STI mode of innovation. The DUI mode of innovation is based on an experience-based mode of learning (Jensen et al. 2007a). The DUI mode of innovation is reliant on reconciling already-existing knowledge to explicit contexts of application. Moreover, it is dependent on activating a wider range of skills and resources than the STI mode of innovation. This translates into taking advantage of ample resources within different levels within the organization, implying that it cannot solely rely on specific scientific understandings from more narrow and specific teams.

The DUI and the STI modes of innovation are significant because they enable an understanding of what kind of knowledge is critical in innovation processes. A combination of the two (DUI and STI) has been emphasized as ideal (Aslesen, Isaksen, and Karlsen 2012, Isaksen and Nilsson 2013, Parrilli and Alcalde Heras 2016, Jensen et al. 2007b). These modes of innovation interconnect to the distinct types of knowledge bases (Asheim, Coenen, and Vang 2007) because these are also based on trying to grasp what types of knowledge are important in different innovation processes. Knowledge bases are divided into analytical, synthetic, and symbolic types of knowledge, and embody an understanding of how knowledge and what kind of knowledge are fundamental in order to carry out innovation processes. It also demonstrates that innovation transfers across space and that innovation is socially and territorially embedded (Asheim 2000).

The STI mode of innovation entails cooperation between scientific-oriented actors within the firm and outside the firm, for example such as the interaction between R&D departments and universities. The STI mode of innovation "tend[s] to generate analytical knowledge (i.e. scientific principled, discoveries, and formulas) and, to a lesser extent, synthetic knowledge bases with a practical, engineering-based purpose" (Parrilli and Alcalde Heras 2016, 748). However, Asheim and Parrilli (2012) argue that the STI mode of innovation may also render from synthetic, applied research.

The DUI mode of innovation is generated by "the capacity of the firm to develop informal and formal exchanges internal to the firm, but also interactions with suppliers, customers and competitors" (Parrilli and Alcalde

Heras 2016, 748). Parrilli and Alcalde Heras (2016, 748) argue that these practices underscores how different types of interactions makes the platform on which the STI and the DUI mode of innovation may rest. Therefore, an important aspect is how different types of interactions foster different types of innovation and different types of knowledge bases[89].

2.1.3 Innovation & Proximity

Innovation occurs as a result of interaction rather than as a result of a solitary genius. There has been an increased focus on the role of networking in innovative processes, and this underpins a recognition that innovations are perhaps less the outcome of an individual firm`s isolated efforts than of networks (Nieto and Santamaría 2007).

Innovation is "network based", and it is an interactive learning process (Lundvall 1992), and by learning we may understand that, as something not only dynamic in itself, but also something that happens through interaction (Vygotsky 1962). A shared idea is that innovation is a social process (Van de Ven 1989) in which people with different but complementary ideas (Østergaard, Timmermans, and Kristinsson 2011) meet and interact in order to solve something (Bathelt, Malmberg, and Maskell 2004). As mentioned above, interaction between actors in innovation networks depends on the mode of innovation as well as the nature and complementarity of the partners involved.

This brings us over to the concept of proximity, as different aspects of proximity are vital for innovation. The different dimensions of proximity are interesting starting points for understanding how innovation and innovation activity can be organized (Mattes 2012). Proximity translates to "the state of being near", and "related" means "connected in some way" or "belonging to same group because of shared characteristics, qualities, etc." The French School of Proximity Dynamics had in the 1990s an important influence on the literature of innovation with the suggestion that proximity covers a number of

[8] It has been argued that, within the proximity dimensions, the nature and the complexity of use and transfer of knowledge is not taken into account (Mattes 2012). Mattes (2012) aims to do so by linking the five dimensions of proximity proposed by Boschma (2005) to the analytical, symbolic, and synthetic knowledge bases.

[9] Lundvall and Johnson (1994) also propose the distinction between four different kinds of knowledge: "know-what", "know-why", "know-how" and "know-who".

different dimensions (Torre and Gilly 2000, Boschma 2005, Kirat and Lung 1999). Boschma (2005) added to this discussion by building on the work of the French School of Proximity Dynamics, although both the approach and the division of proximity differ. Proximity has in the past been treated as a geographical construct, but is now considered in much more broad terms.

Boschma (2005) presents five dimensions of proximity (see table 2): cognitive, organizational, social, institutional, and geographical. All five are based on the idea of "too little" proximity and "too much" proximity, leading to distinct outcomes[10].

The key dimension within the *cognitive proximity framework* is "knowledge gap", where too little cognitive proximity, lead to misunderstanding and too much cognitive proximity, lead to lack of sources of novelty. A possible solution is a common knowledge base with diverse, but complementary capabilities (Boschma 2005). This lies at the core of innovation where bringing in people with different, but complementary skills is essential (Østergaard, Timmermans, and Kristinsson 2011). The key dimension within the *organizational proximity framework* is control, too little organizational proximity can lead to opportunism, and too much may lead to bureaucracy, with a possible solution being loosely coupled systems. Innovation is by its very nature systemic and a form of aiming to structure interaction and learning. Too much proximity may hamper innovation. Innovation is also not "the linear model" under which first comes R&D and then "the rest" follows. The key dimension within the *social proximity framework* is "trust" (based on social relations) and too little social proximity may lead to opportunism. Too much social proximity may lead to no economic rationale; with a possible solution being a mix of embedded and markets relations. This relates to the diversity of the similarity attraction perspective and the cognitive resource diversity perspective of trust and variety (see 3.3.1 for more detail on these concepts). The key dimension in the *institutional proximity framework* is "trust" (based on common institutions), where too little proximity may lead to opportunism, and too much institutional proximity may lead to inertia and lock-in. A possible solution is "institutional checks and balances" (Boschma 2005). The key dimension within the *geographical proximity framework* is "distance", where

[10] The following paragraph is based on the model p.71 and paper by Boschma (2005).

too little proximity equals no spatial externalities and too much geographical proximity equals lack of geographical openness, with a possible solution of establishing a mix of local and extra-local linkages (Boschma 2005).

These proximity concepts entail an important recognition of how innovation tends to occur where boundaries meet. Leonard-Barton (1995) and Carlile (2004) emphasize that a key ingredient when it comes to creating competitive advantage is to work across boundaries. The transfer of knowledge across boundaries fosters a shared language, and that is why the concept of diversity also needs to be understood in relation to the concept of proximity. The different dimensions of proximity entail the importance of having two thoughts in your head at the same time; the proximity dimension may act as complements and substitutes for each other.

	Key dimension	**Too little proximity**	**Too much proximity**	**Possible solutions**
1. Cognitive	Knowledge gap	Misunderstanding	Lack of sources of novelty	Common knowledge base with diverse but complementary capabilities
2. Organizational	Control	Opportunism	Bureaucracy	Loosely coupled system
3. Social	Trust (based on social relations)	Opportunism	No economic rationale	Mixture of embedded and market relations
4. Institutional	Trust (based on common institutions)	Opportunism	Lock-in and inertia	Institutional checks and balances
5. Geographical	Distance	No spatial externalities	Lack of geographical openness	Mix of local "buzz" and extra-local linkages

Table 2. *Five forms of proximity: some features (Boschma 2005, 71).*

Collaboration and potential new networks and innovation development practices should enhance innovation due to the increased amount of knowledge available to be shared as well as the possible compatibilities of knowledge in an alliance (Nieto and Santamaria 2007). Previous research (Amara and Landry 2005) also shows that firms that introduce more radical innovations are more likely to use a wider range of information sources. Similarly, Laursen and Salter (2006) find that firms with a broader search scope tend to be more innovative. Collaboration could prove to be fruitful if the firms engage with partners that have resources and knowledge that complement their own and are relevant to the innovation being sought (Nieto and Santamaria 2007). One example provided by Boschma (2005) is how to avoid "spatial lock-in", which may occur when you do not get an element of newness, but are solely based on common practices and regimes. Boschma (2005, 70) argues that, "Spatial lock-in may be solved or avoided by establishing non-local linkages, providing access to the outside world. Some argue that knowledge creation requires a balance or mixture of local and non-local relations". This in turn, highlights how networks and establishing "non-local" linkages are important for firm innovation and how diversity and space affect innovation and innovation activity.

2.1.4 Innovation as Organizational Learning

Innovation is new combination of existing resources (Schumpeter 1934), based on trial and error within firms and on routines. This relates to organizational learning in different ways. Levitt and March (1988, 320) argue that organizational learning could be divided into three aspects: firstly, routines (with trial-and-error as a key aspect of routinization), secondly, that firms make decisions based on its history, and thirdly, that organizations are target-oriented. Innovation is both the process and the outcome, and it is a process of trial-and-error, as well as it is history-dependent and target-oriented.

Levitt and March (1988, 320) argue that the first distinction in organizational learning, is that it is based on routines, and it involves matching procedures and solutions to situations and dilemmas more than it is concerned with calculating choices. "An organization is filled with choices looking for problems and solutions looking for issues to which they might be the answer" (Cohen, March,

and Olsen 1972, 2). Routines can be understood as organizational skills (Nelson and Winter 1982), or as Levitt and March (1988, 320) argue, "The generic term 'routines' includes the forms, rules, procedures, conventions, strategies, and technologies around which organizations are constructed and through which they operate". Levitt and March (1988) further argue that routines are also informal issues such as culture and knowledge that contradict formal routines. It is so embedded in an organization, for example, that it survives considerable turnover in individual actors (Levitt and March 1988).

Firms, or the actors within firms, learn from their mistakes and challenges that they have encountered through processes of trial and error. "When routines do not work well, this failure induces active search for other routines; for example, by investing in R&D. The successful replacement of routines by fitter routines can be considered an innovation" (Boschma and Frenken 2006, 6). This is also partly why the linear model has been criticized (Kline and Rosenberg 1986), because both innovation and organizational learning depend on processes involving trial and error, which is something disregarded by the linear model. When people differ in their expertise, they might differ in their perception of what the problems are or what solutions would be best fitted to that situation. On the other hand, people that are more similar are expected to perceive problems and find adequate solutions in ways that are more similar. One is shaped by one's environment and hence learns ways to address a challenge or ways of going about solving a problem (DiMaggio and Powell 1983).

The second observation put forward by Levitt and March (1988, 320) is that organizational actions are history-dependent. "Routines are based on interpretations of the past more than anticipations of the future". Time is an essential factor here. Firms learn and change, as they get older. However, at the same time, changing firms' climate, culture or routines is not something that happens overnight. This entails important aspects of organizational persistence or of path-dependency in firms. One example is how firms adjust their worker skill mix in directions that would match the profile of more mature industries (Haltiwanger, Lane, and Spletzer 2000). Firms observe and monitor other industries in order to learn how to structure and organize themselves and to become better performers. Moreover, Haltiwanger, Lane, and Spletzer (2000) find that younger businesses exhibit greater heterogeneity in earnings and productivity than mature businesses do. Hence, these routines are "transformed

at the same time as the organization learns which of them to pursue, and discrimination among alternative routines is affected by their transformations" (Levitt and March 1988, 322). There is, hence, more observed heterogeneity at the early stage in an organization's life cycle than at later stages where there is increased variety (Miles 2012).

The third observation is that organizations are oriented to targets and that their behavior "depends on the relation between the outcomes they observe and the aspirations they have for those outcomes" (Levitt and March 1988, 320). This third observation holds many similarities to innovation, as one of the driving forces behind innovation is to gain a competitive advantage over competitors (Schumpeter 1943, Dosi and Nelson 2010), hence it is target oriented. Restructuring and allocation of resources to meet these targets is thus essential.

Organizational learning can be divided into four subcategories that specify the level in which the learning takes place. First, is the individual learning level that emphasizes that an individual represents distinct skills and ideas. It builds on the construction that individuals offer new contributions, heuristics, and worldviews. The second level of organizational learning is group learning, which occurs when individuals share knowledge through interaction. Here the individual characteristics are at play again, and the discussion of the creation of in-groups/out-groups (Tajfel and Turner 1979, Turner, Brown, and Tajfel 1979) becomes relevant since the division of whether members are part of a group or not, has implications for whether individuals within these groups believe the knowledge presented to them or not. The formation of in/out-groups has implications for how actors subsequently act upon knowledge received. People are most likely to believe information from people they perceive as similar to themselves (belonging to the in-group) or with whom they share a set of characteristics. They are less likely to believe the information coming from someone that is perceived to be different (belonging to the out-group) (see in-group/out-group discussion in 3.3.2).

The concept of proximity becomes important, as there needs to be some level of complementarity in order for knowledge to be shared and communication to take place. This relates to the third level of organizational learning and is the way that an organization creates and organizes knowledge. Innovation is systemic by nature and relates to this third level of organizational learning in

the way that how an organization organizes knowledge is important for the innovation output achieved. The fourth level is interorganizational learning and is concerned with how different organizations in an alliance collaborate and interact and share knowledge and learn from one another. This relates to what was mentioned previously, with innovation occurring through interaction and collaboration. These four levels may be understood through the fact that they all highlight distinct aspects of firms' ability to recombine and structure their innovation activity that is internal and external to the firm.

This PhD thesis departs from the understanding that organizational learning take place at different levels of the organization and is concerned with observing some of the results of patterns of such constructions.

2.2 Space

Firm-level innovation cannot be conceived and implemented in isolation; hence innovation cannot be considered in isolation from its environment. Economic activity arises, grows, and develops in space (Capello 2009), and economic activity is unevenly spread out across the globe (Asheim and Gertler 2005, Florida 1995, Maskell et al. 1998). This has led to a substantial amount of empirical and theoretical contributions focusing on industrial agglomeration (Marshall, 1920) and clusters (Porter, 1990, 2000) and how space affects innovation and performance in firms, regions, and nations.

2.2.1 Agglomeration Economies

It is within agglomeration economies, highlighted that economic benefits are gained through location in a cluster. A cluster is a "geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter 1998, 199). The externalities and knowledge spillovers that are facilitated through geographical co-location are based on that firms have fluid boundaries (Coase 1937) and that geographical proximity facilitates collaboration. This is amongst other dimensions, based on social capital amongst the actors involved (Morgan 1997).

The agglomeration economies literature has classically been divided into two. The first distinction draws on the influential insights provided by Marshall and underscores the benefits gained from thick and specialized labor markets, regional knowledge spillovers, specialization of suppliers, input and information sharing and the exchange and flow of capabilities (Paci and Usai 1999). These benefits are to be gained from interactions within single industries, stressing the benefits of specialization. It has been emphasized that regions with a specialized industrial structure are more conducive to innovation and growth as compared to the regions that contain more diversified industrial structures (Glaeser, Scheinkman, and Shleifer 1992).

Secondly, it is argued that economic benefits can be gained by geographically locating near other industries irrespective of field/type of industry, so-called urbanization economies. This aligns with the work of Jacobs (1969), that holds that firms benefit from a variety of sources and underlines the positive externalities associated with new ideas that cross different sectors. Moreover, this diversified regional structure triggers new ideas because of this diversity and variety of aspects. Jacobs externalities emphasize how economic benefits may be gained through cross-pollination of ideas and diversified industrial structure.

The beneficial role of relatedness has been highlighted as important for firms and regions (Boschma, Eriksson, and Lindgren 2014, Neffke, Henning, and Boschma 2011) and is concerned with the benefits of the co-location of firms within related industries and how they can benefit from knowledge spillovers from these related industries (and are able to absorb this knowledge due to the cognitive complementarity of the industry), as opposed to the co-location of unrelated industries where there is little to no overlapping in the skill needed to perform the different tasks.

2.2.2 Geographical Proximity

Geographical proximity has traditionally been one of the dimensions of proximity that has been emphasized and used across a wide range of studies in different disciplines. The key dimension within geographical proximity has been distance (Boschma 2005), and geographical proximity can influence innovation rates (Lundvall 1988, Saxenian 1990, Glaeser 1999, Audretsch and

Feldman 1996). This is particularly the case when the information being shared is of "tacit knowledge" (Polanyi 1966) and "being there" (Gertler 1995) is important in order to capture this knowledge that is not easily transmittable. If the knowledge is tacit, the main argument is that interaction and exchange are dependent on social interaction and proximity. Just by being located near, in spatial proximity to one another, and meeting face - to - face will allow for such transmission of knowledge (Storper and Venables 2013).

There are different ways on which the innovation activity, are influenced by the surrounding environment of firms and spatial proximity. The term t*erroir* (as mentioned in the introduction) has been used to capture the total effect that the local environment has on the product (Feldman and Kogler 2010). This in turn, relates to people and places constituting each other (Massey 1994) and that space does not simply exist (Halfacree, 2006, p. 44), but that it is dynamic and symbiotic between people, places and institutions.

2.2.3 Path-dependency

Organizations and their surrounding environment co-evolve over time (Boschma and Frenken 2006). Metcalfe (1994), as cited by Boschma and Frenken (2006, 20), argues that "territory specific assets are constantly transformed, upgraded, or they get locked-in by the actions and repeated interactions of local agents. That is, organizations continually adapt and transform, intentionally or not, their environment". From this we understand that people and places produce path dependence (Martin 1999, 80) in that they are in a form of symbiotic relation and are constantly coloring and shaping each other. "Industries` and firms` location decisions respond to geographical unevenness in the labour landscape and incorporate spatial inequality in order to maximize profits; their decisions, in turn, affect workers` future skill levels and shape the future of regional economies" (Aoyama, Murphy, and Hanson 2011, 17). Massey (1984) argued that regional disparities not only came from economic factors, such as labor or capital, but also increasingly from social interactions.

2.3 Diversity

"It is hardly possible to overrate the value . . . of
placing human beings in contact with persons dissimilar
to themselves, and with modes of thought
and action unlike those with which they are familiar.
. . . Such communication has always been, and
is particularly in the present age, one of the primary
sources of progress."

(Mill 1848)

The quote above by Mill is easily applicable today. Diversity in the workforce is something that is held in high regard by many managers, policy makers, politicians, and so on. Furthermore, in many of today's organizations, employees are more likely than before to work with people who have different demographic and functional backgrounds (Guillaume et al. 2014). Apple's former Vice President of Human Resources, Kevin Sullivan, once said, "When you are surrounded by sameness, you only get variations of the same" and henceforth underlined the importance of bringing in people with different outlooks in order to achieve distinct outcomes. This holds the essence of innovation and innovative processes, in which different outlooks are needed in order to create something new.

Diversity in the workforce could bring in an element of new by mixing together people who are diverse and have different ideas, perspectives, and worldviews. This becomes important in innovation, since it is an interactive process (Lundvall 1992) that involves communication among "employees in a firm and draws on their different qualities from all levels of the organization" (Østergaard, Timmermans, and Kristinsson 2011, 500).

The article, "The Stranger: An Essay in Social Psychology" (Schuetz 1944), suggests why diversity could affect firm performance, trigger creativity, and

affect innovation. Schuetz (1944, 501-502) writes, "This 'thinking as usual', as we may call it, corresponds to Maz Scheler`s idea of the 'relatively natural conception of the world' (…), it includes the 'of-course' assumptions relevant to a particular social group". Hence, someone who is coming in from the "outside" might provide a new view or challenge the "of-course" assumptions that rest in social groups and in organizations. This could be challenged by bringing in people with different heuristics, with different work experiences and educational backgrounds, or from different birthplaces.

We are shaped by our environments, and the development of individual identity or the consciousness of such happens over several steps where the individual first learns how to copy other people's behavior, then to consciously acknowledge others, and then take the "generalized other" view on the world and itself (become conscious of oneself). Hence, through this interaction with others, the "self" or perception of the self becomes, and is consequently a social product. We observe other people's reactions to ourselves and are able to envision how others envision us (Mead 1934). Hence, an important aspect here is that "people perceive, interpret and evaluate the world according to mental categories (or forms of thought, frames or mental models) which they have developed in interaction with their physical and their social/institutional environment. This entails that "perception, interpretation and evaluation are contingent upon the institutional environment, and path-dependent and idiosyncratic to a greater or lesser extent" (Nooteboom 2000a, 71). Hence, "people with different backgrounds see, interpret and evaluate the world differently to the extent that they have developed in different social and physical surroundings and have not interacted with each other" (Nooteboom 2000a, 71).

There is a connection between this, the work by Mead (1934), and the work by Vygotsky (1962), who claimed that learning takes place through internal cognitive processes that are shaped by extensive contextual interactions. The "Zone of Proximal Development" (ZPD) is what Vygotsky called the development of learning in others. He believed that a person can only learn so much by themselves, and that through interaction with others, this knowledge can be stretched. For this to happen, there must be some shared knowledge or some sort of mutual starting points for this interaction to take place. When you then place dissimilar people together (that have distinctive worldviews,

interpretations, and evaluations of the world), they need to share some set of mutual characteristics from which to depart in order to communicate and create something together.

Bringing together different views could be one way of creating "kaleidoscope thinking" (Kanter 1968). Just like twisting the kaleidoscope and making new images appear, diversity can twist reality into new patterns and rearrange the pieces to create a new reality (Kanter 1968, 11). Challenging the "of-course" assumptions (Schuetz 1944) and "established thinking" could be reached by involving diversity across the organization and integrating it to the decision processes is vital for competitive advantage. To "shake things up" and create a new picture, it is important to work more diversely and thinking and acting in a more multi-disciplinary manner; i.e. by arranging regular visits to other parts of the organization, exchanging ideas, visiting other organizations and observing how they work, discussing with critics or "outsiders" or people who hold a different worldview (within and outside the firm), attending conferences within fields that unfamiliar, and seeking knowledge previously unknown to the firm. The latter could be facilitated through increased diversity in the organization, as it will broaden the search scope (Laursen and Salter 2006). Bringing in diversity to the firm mirrors Schumpeter's definition of innovation as a recombination of knowledge and resources, and broader internal competence and expertise will give a broader platform on which to carry out search activities which in turn will be reflected in the possibilities of acquiring a greater variety in knowledge.

Thus, when diversity in the workforce increases, the different heuristics available to solve a problem can also increase. Hong and Page (2004) demonstrate that groups that are diverse are better problem solvers than groups that are more homogenous (even if the latter has higher educational achievements). Basset-Jones (2005) argues that diversity could also lead to higher communication costs and misunderstanding, suspicion and conflict, which in turn, hamper innovation through low morale, loss of competitiveness and absenteeism. Basset-Jones (2005, 169) argues that firms "seeking competitive advantage therefore face a paradoxical situation. If they embrace diversity, they risk workplace conflict, and if they avoid diversity, they risk loss of competiveness". Implicitly, this underscores an important aspect – management. Diversity is often referred to as something that needs to be

managed (Basset-Jones 2005, Guillaume et al. 2014, Eckel and Grossman 2005, Holvino and Kamp 2009, Lauring 2009, Kreitz 2008, Podsiadlowski et al. 2013, Harrison and Klein 2007). One example of this paradoxical situation and the need for management is put forward by Guillaume et al. (2014, 785) by declaring "when mismanaged, such diversity can undermine employee social integration and effectiveness and lead to lower work group performance; when managed effectively, however, as well as facilitating social integration and effectiveness, diversity can also promote creativity and innovation". Thus, diversity can have good or bad effects on performance, or both, depending on how it is measured, managed, and what the goal is.

2.3.1 Diversity and Relatedness

The diversity literature is by itself very diverse. There is, however, a tendency in the contributions to place arguments along two perspectives: one emphasizes how people prefer to work with people who are similar to them and that communication flows easier when interacting with people who have similar heuristics, worldviews, and outlooks. The second perspective emphasizes how working together with people who are different triggers creativity and could lead to something completely new. Horwitz (2005) refers to these two different mechanisms as paradigms and names them "similarity attraction" and the "cognitive resource diversity". Horwitz (2005) argues that the two competing theories derive from social psychology (similarity-attraction paradigm) and management (cognitive resource diversity paradigm).

The cognitive resource diversity perspective[11] holds that diverse teams should ideally outperform homogenous teams "because they possess a broader range of task-relevant knowledge, skills and abilities, giving the group a larger pool of resources that when combined may generate new insights" (Van Engen and Van Woerkom 2010, 133). Van Engen and Van Woerkom (2010) further argue that when people have different experiences and expertise, they might have different perceptions of what the problem is, and what the solution to that problem might be. This in turn has implications for behavior, strategy, and

[11] This PhD thesis uses the word "perspective" as oppose to "paradigm", as the author considers perspective more suitable, especially when it comes to the issues of cognitive complementarities and dimensions of proximities bridging these divides.

innovation. The underlying assumption of the cognitive resource diversity perspective is "that teams consisting of heterogeneous members promote creativity, innovation, and problem solving, hence generating more informed decisions" (Horwitz 2005, 224-225). Horwitz (2005) draws attention to whether variety of human resources in terms of i) educational backgrounds and ii) work-life experiences provide the firm with more diverse knowledge pools on which to draw. Hong and Page (2004) argue that their results demonstrate that an ideal group would contain high-ability problem solvers who are diverse (Hong and Page 2004).

Firms that employ individuals with different pools of resources gained through their functional background or through a range of external social ties (Argote and Ingram 2000) will make more effective decisions based on that they would have a broader base on which to make these decisions. It has also been argued by Jackson, May, and Whitney (1995) that diverse teams will deliver more creative solutions than more similar teams would, due to these meeting and boundary-crossing interactions. Diversity of this kind has been referred to as "socio-cognitive horsepower" (Carpenter 2002, 280) and holds that individuals with different backgrounds will have different "frames" and ways of analyzing the world and can access different sources of resources.

This follows up on the seminal work by Penrose (1959) and others, e.g. Barney (1991) and Wernerfelt (1984) of the resource-based view of the firm, and highlighting that firms are heterogeneous because they have diverse individuals with diverse cognitions and heuristics (internal) and the resources that can be reached (external) through these internal individuals. Hence, a more diverse internal workforce could potentially reach an equally diverse marketplace (Cox 2001). These individuals "collectively serve as a team´s lens, each filtering unique environmental cues and interpreting them for the rest of the unit´s members. Similarly, units whose members have nonredundant (i.e., nonoverlapping) external network ties have access to information that other units, lacking in such variety, cannot easily obtain" (Harrison and Klein 2007, 1205), hence leading to a self-reinforcing process of diversity.

This stands in sharp contrast to the similarity attraction perspective, which holds that "homogeneous teams are likely to be more productive than heterogeneous teams because of mutual attraction of team members with

similar characteristics. Heterogeneous groups, in contrast, are hypothesized to be less productive and have lower team cohesion because of inherent tensions and relational conflicts arising from member differences" (Horwitz 2005, 224). The similarity attraction perspective emphasizes social homophily and assumes that people prefer to engage in relationships with other people that are similar to themselves (McPherson 2001) and that this similarity eases communication and could enable a more efficient execution of tasks. Similarity breeds connection (McPherson 2001, 415) following the principle behind homophily that birds of a feather flock together. "Similar people tend to interact with each other. Similarity is thought to ease communication, increase the predictability of behaviour, and foster trust and reciprocity" (Brass et al. 2004, 796). Many contributions from e.g. social psychology emphasize how people are more likely to believe information when it comes from similar others (O`Reilly 1983) than from people that are perceived to be dissimilar. This has important implications for knowledge transfer, as "knowledge transfer is more likely between individuals who display similar attitudes as well as firms having encountered similar problems in the past" (Darr and Kurtzberg 2000, 30).

"Relatedness" or "proximity" represents an in-between position in this debate of the similarity attraction perspective and the cognitive resource diversity perspective. Boschma (2005) draws attention to five forms of proximity (see discussion in 2.1.3): cognitive, organizational, social, institutional and geographical, and draws attention to the menace of having too much proximity. It is clear that each of the five types of proximity facilitate interaction, but it is also a danger that too much of this proximity could lead to situations of "lock-in" due to a lack of openness and novelty. This is what has been referred to as "the proximity paradox" by Boschma and Frenken (2010), and it has a clear link to the cognitive resource diversity perspective and the similarity attraction perspective. On the one hand, it argues that proximity, "being near", can be essential for enabling effective communication and interaction between actors, but too much proximity can be harmful because it may reduce the novelty brought in to the firm. Antecedent to this paradox are studies from developmental psychology, i.e. work by Vygotsky (1962) and the "Zone of Proximal Development", "cognitive complementarity" (Nooteboom 2000a) and "cognitive distance" based on a constructivist, interactionist view of knowledge (Mead 1934, Nooteboom 2000a, Weick 1979, Hendriks-Jansen

1996, Berger and Luckmann 1967, Wuyts 2005). One strand of literature that is highly relevant is that concerning "related variety" (cognitive complementarity) and "unrelated variety" (cognitive distance) that is for example used to analyze the conditions under which people cross-fertilize through interactions within firms and mobility flows between them (Timmermans 2014, Boschma, Eriksson, and Lindgren 2009). This in turn emphasizes the goldilocks principle (Fitjar, Huber, and Rodríguez-Pose 2016) and the importance of engaging with partners at "the right distance".

2.3.2 The In-group and the Out-group

Thus, it is now established that people gain a certain amount of knowledge through internal cognitive processes, but also through interaction with the environment, e.g. through taking advantage of the help of others, thus further advancements may be achieved (Vygotsky 1962). Relatedness needs to be put in place for such learning to occur. An important aspect within this perspective is the creation of in-groups and out-groups (Turner, Brown, and Tajfel 1979). The in-group is a social group of which an individual psychologically identifies him- or herself as being a member. Contrastingly, the out-group is an entity with which one does not identify. People organize themselves into groups all the time, and individuals do so in a very short time depending on different characteristics.

Underlying the social attraction perspective and the cognitive resource diversity perspective is this sorting into groups.[12] In fact, some, e.g. Traavik (2006), argue that the diversity literature could be divided into three: similarity attraction theory, information-processing and problem solving theory (which relates to the cognitive resource diversity perspective), and a third theory that rests on social identity and self-conceptualization. This social identity is concerned with how people define themselves into groups (Turner, Brown, and Tajfel 1979). An important observation is that people are not diverse by themselves. Groups can be diverse because they are made up by individuals that hold different set of characteristics that together make the group diverse or

[12] There are several linkages between this and the work by, e.g., Putnam, who draws on the distinction commonly made in the field of social capital, "that is, the distinction between 'bonding' social capital (ties to people who are like you in some important way) and 'bridging' social capital (ties to people who are unlike you in some important way" (Putnam 2007, 143).

not. Similarity is as such a relational concept, and an individual may only be similar with respect to another individual and based on certain attributes to dissimilar others (Brass et al. 2004, 796).

The concepts of similarity attraction and cognitive resource diversity relate to the seminal work of Granovetter (1973) regarding strong and weak ties. The similarity attraction perspective could be tied to strong ties, and weak ties could represent the cognitive resource diversity perspective. Granovetter (1973, 1361) argued that the strength of a tie is a combination of the amount of time, emotional intensity, intimacy (mutual confidentiality), and the mutual exchange that characterize the tie. This is dynamic and changes over time; hence a weak tie could over time become a strong tie, and vice versa, as it depends on the knowledge exchange and perception of the strength of the relationship. A more general idea is that strong ties consist of, for example, family or former colleagues and such, where it is expected that communication would flow easily due to shared knowledge base and the trust-based nature of the relationship. This relates well to the similarity attraction perspective, which holds that we prefer to engage in relationships with people whom we perceive as similar to us. The weak ties, similarly to the cognitive resource diversity perspective, is perceived to bring in something new which could increase the variety of knowledge within a firm and extend their search scope (Laursen and Salter 2006).

Departing from that innovation is based on routines, and by looking at the strong and weak ties from a more systemic perspective, firms may, through routines, "lock-in" to some patterns, e.g. use of the same partners. A combination of the strong and the weak ties could ensure that firms gain an optimal mix of novelty as well as access to socially embedded knowledge (Uzzi 1996, Gilsing, Lemmens, and Duijsters 2007).

2.3.3 Dimensions of Diversity

Just as there are dimensions of proximity, there are several dimensions within the diversity literature; e.g. cognitive, cultural, and demographic. A common distinction in the diversity literature is between primary and secondary diversity characteristics; the primary characteristics are those that are given at birth and that one cannot change, such as where one is born, and the secondary diversity

includes elements that one may change, such as experience and education. This has been referred to as "surface-level diversity" versus "deep-level diversity".[13] Surface-level diversity is concerned with immediately observed characteristics such as sex, gender, and race/ethnicity (Horwitz and Horwitz 2007), whilst deep-level diversity includes differences related to attitudes, beliefs, and values that are not instantly detectable (Horwitz and Horwitz 2007). When Horwitz (2005) makes the division between the "similarity attraction paradigm" and the "cognitive resource diversity paradigm", they are built on the divide of surface-level versus deep-level diversity where the "similarity attraction paradigm" rests on the basis of similarity in demographic attributes and "cognitive resource diversity paradigm" builds on deep-level diversity.

2.3.4 Birthplace Diversity

Birthplace can be a one dimension along which groups can be diverse. Birthplace diversity could be included in the abovementioned similarity attraction perspective and cognitive resource diversity perspective, because the literature concerning birthplace diversity, upholds, not unlike the cognitive resource diversity perspective, that diversity and variety trigger creativity and new knowledge, but that too much diversity could hamper innovation (Basset-Jones 2005). The birthplace diversity literature also builds on the similarity attraction perspective and stresses how birds of a feather flock together (McPherson 2001), and that people prefer to relate themselves to other people similar to them.

Even so, birthplace diversity is often treated as a separate construct in the literature. A common theme in this literature is that "surface-level" diversity in country background is hypothesized to reflect deeper-level differences (Kemeny 2014), such as "cognitive processes/schemas, differential knowledge base, different sets of experiences, and different views of the world" (Shore et al. 2009, 118). Following Kemeny (2014), "it is assumed that one's birthplace indicates in some meaningful way one's manner of approaching the world" (Kemeny 2014, 32). This could include valuable assets in a firm's innovation work, as it could function as "a breath of fresh air" and challenge this "thinking as usual", stir up the "organizational memory" and routines that firms have

[13] This is also referred to as ascribed and acquired characteristics.

(Nelson and Winter 1982), and "stir up" the "kaleidoscope" (Kanter 1968) by offering a new perspective. Foreign workers might therefore bring in different perspectives from natives, as they would have a different background and potentially distinct outlook on how to solve problems. When individuals with different knowledge and backgrounds interact, they may stimulate and help each other to stretch their knowledge for the purpose of bridging and connecting diverse knowledge (Nooteboom et al. 2007, Vygotsky 1962).

Similarly to the diversity literature in general, the literature on birthplace diversity is also very assorted. The term "cultural diversity" is often used instead of "birthplace diversity". These concepts are often used interchangeably. Some studies, e.g. Alesina, Harnoss, and Rapoport (2016), prefer the use of the term "birthplace diversity" over cultural diversity due to the fact that culture is a fuzzier concept which is hard to grasp and that birthplace diversity is "more likely to capture skill complementarity effects than alternative dimension of diversity (e.g., ethnic or linguistic fractionalization) (Alesina, Harnoss, and Rapoport 2016, 104). Others, e.g. Putnam (2007), refer to birthplace diversity as "ethnic diversity". The use of these various concepts make it increasingly hard to compare various studies, as they are based on varied and different constructs. Nevertheless, a common thought across these contributions is that birthplace diversity is a double-edged sword. On the one hand, it brings new perspectives and ideas (Nathan and Lee 2013, Ottaviano and Peri 2006), and on the other it could potentially reduce trust amongst actors and increase conflict (Basset-Jones 2005, Jehn, Northcraft, and Neale 1999, Putnam 2007, Bandiera, Barankay, and Rasul 2005).[14] Reduced trust and increased conflict have been pointed out by e.g. Putnam (2007), who asserts that ethnic diversity will in the short run reduce social capital and trust among individuals due to a fear of the unknown.

Putnam (2007) refers to studies by i.e. Gordon Allport, who during the 1950s made the "optimistic hypothesis that if we have more contact with people of other ethnic and racial backgrounds (or at least more contact in the right circumstances), we will all begin to trust one another more" (Putnam 2007, 141). So this rise in conflict level could be based on the "fear of the unknown"

[14] A more detailed discussion of findings related to birthplace diversity is found in Østergaard, Timmermans, and Kristinsson (2011), Kemeny (2014) or Solheim and Fitjar (2016).

as well as the increase in communication costs, because when working together with dissimilar others and it is thought that boundaries have to be crossed, there could be the use of different languages and so on.

One could roughly divide the literature concerning foreign workers and innovation into two: studies dealing with immigration (Maré, Fabling, and Stillman 2011, Ozgen 2015) and studies dealing with birthplace/cultural diversity (Alesina, Harnoss, and Rapoport 2016, Kemeny 2012). According to Nijkamp and Poot (2015), this is not a fixed divide, as they (immigration and cultural diversity) may be understood as an intertwined phenomenon, since they are used interchangeably in theoretical and empirical contributions, i.e. as the title "Migration and innovation: Does cultural diversity matter for regional R&D activity? by Niebuhr (2010) suggests. The birthplace diversity literature deals mostly with diversity at the firm level and at the regional (and national) level, but seldom both at the same time (with some exceptions e.g. Trax, Brunow, and Suedekum (2015) and Kemeny and Cooke (2015)).

Firm-level studies often discuss the benefits of birthplace diversity (e.g. increase in wages, firm performance or innovation), or the downsides (e.g. increase in conflict and misunderstandings). Ozgen, Nijkamp, and Poot (2013), for example, find that firms that employ relatively more migrants are less innovative (immigration). They also find that firms that employ a more diverse foreign workforce (cultural diversity) are more innovative, particularly so for product innovations (Ozgen et al., 2014). Using Danish data, Østergaard, Timmermans, and Kristinsson (2011) find no significant effect of ethnic diversity on innovation in Danish firms, whilst Parrotta, Pozzoli, and Pytlikova (2014) find that ethnic diversity is an important driving force for innovation in firms. Similar conclusions as those of Parrotta, Pozzoli, and Pytlikova (2014) are found in other European countries as those by Ozgen, Nijkamp, and Poot (2011), Ozgen et al. (2014) for the Netherlands and Germany, and Nathan and Lee (2013) for the United Kingdom. Some studies (e.g. Ozgen, Nijkamp, and Poot (2011)) based on Dutch firm level data, find that it is not the presence of foreign workers per se that matters, but the diversity amongst them. Regional-level studies are concerned with how birthplace diversity could affect housing prices, GDP per capita, crime rates, and so on. At the regional level, Ottaviano and Peri (2006) conclude that there is a significant positive effect of cultural diversity on the productivity of the native born, and Suedekum, Wolf, and Blien

(2014) find a positive association with GDP per capita for German regions.[15] Kemeny and Cooke (2015) find growing diversity in both American workplaces and cities to be associated with rising wages and henceforth, productivity.

2.3.5 Birthplace Diversity and Networks

Open innovation refers to that firms can and should take advantage of internal as well as external ideas (Chesbrough 2003) in innovation. Birthplace diversity may relate to this, as foreign workers bring with them their own personal and professional networks, which might be very different from the networks of domestic workers in terms of geographical scale and scope. Kemeny (2014, 33) argues that, "rather than some inbuilt culture-specific characteristics, foreign-born individuals enjoy international social connections to which natives lack access".

Hence, firms with a greater internal diversity of employees could in theory be able to reach out to a broader set of external partners, as each of the employees seek out partners that are similar to them. This also extends to the geographical scale, where firms with only domestic workers might be expected to seek out similar – domestic – partners, while firms with foreign workers would be more likely to have international partners. "Partners need a long-term perspective to see the real value of collaboration materialize" (de Man et al. 2008, 3) and there is a challenge to motivate partners to share knowledge. If foreign workers bring with them their own personal and professional networks, which could mean new information for the firm as well as shortening of the "long-term perspective" needed for partners to engage in collaboration, as the ties are already present. Foreign workers also could be expected to speak the language of their country of origin that could facilitate communication with actors in these countries (Lee and Nathan 2010).

This follows the idea behind homophily and that it "limits people`s social worlds in a way that has powerful implications for the information they receive, the attitudes they form, and the interactions they experience" (McPherson 2001,

[15] See also Nijkamp and Poot (2015) for a more extensive overview of theoretical and empirical contributions.

415). Firms with limited internal diversity might therefore also be expected to rely on a narrow set of information sources. This is also supported by previous research showing that the most central element to homophily is geographical space. We tend to communicate with people close to us geographically (McPherson 2001) and as noted in "Human behavior and the principle of least effort: An introduction to human ecology" by Zipf (1949), communication it is often a matter of effort. The main argument is that it takes far more energy to communicate with someone far away than someone who is geographically close (McPherson 2001).[16]

2.3.6 Birthplace Diversity and Education

Education may matter for the relationship between foreign workers and innovation for two main reasons: Firstly, foreign workers that are highly educated may have more to contribute in innovation processes. The role of workers as the primary vehicle for knowledge spillovers and innovation is often linked to a more educated workforce, "as innovation is a relatively more skill-intensive activity than imitation" (Vandenbussche, Aghion, and Meghir 2006, 97). Foreign workers could create a competitive advantage through the new skills, new solutions, and different perspectives and outlooks that they bring with them. Cultural diversity and education is considered an important asset which could serve as a source of "sustained competitive advantage because it creates value that is both difficult to imitate and rare" (Richard 2000, 165). It should be noted, however, that the transferability of human capital, is complex, and "when immigrants arrive in a country they may find that the human capital they brought with them are not relevant to their adopted labor market" (Chiswick and Miller 2009, 162). Chiswick and Miller (2009) argue that there is a less-than-perfect international transferability of skills either acquired through formal schooling or through work experience in the immigrants country of origin. It is also important to distinguish between the immigrants` country of origin as Mattoo, Neagu, and Özden (2008, 255) find "striking

[16] Some argue that the use of telecommunications and globalization have made the world "flat" (Friedman 2006) and hence "distance is dead". Many oppose this view e.g. Florida (2008) and argue that the world is not flat, but spiky. Moreover, Florida argues that place is more relevant than ever before, and that the decision of where to live is one of the most important decisions that a person make in their life as it determines career possibilities, who you might meet and work with, the ability to live happy lives etc.

differences among highly educated immigrants from different countries, even after we control for individuals' age, experience and level of education". One example is how they find that "educated immigrants from Latin American and Eastern European countries are more likely to end up in unskilled jobs than immigrants from Asia and industrial countries" (Mattoo, Neagu, and Özden 2008, 255). Hence, it is important to keep these studies by Mattoo, Neagu, and Özden (2008) and Chiswick and Miller (2009) (amongst others), in mind when investigating the effects of education on innovation and in relation to birthplace diversity.

2.4 Short Summary Theory

The theoretical part of this PhD thesis has emphasized the key topics across three dimensions: *innovation*, *space,* and *diversity*. Firstly, it distinguished between invention and innovation and emphasized that they are both dependent on structuring of resources and cooperation of actors within and across organizations. Innovation is an interactive learning process depending on different human resources. It discussed how there are different modes of innovation and that knowledge, learning, and innovation are interconnected phenomena that depend on different dimensions of proximity. Secondly, economic activity is unevenly distributed across space, and places and people constitute each other and, hence, places are increasingly path-dependent and organizations are shaped by the place and *terroir*. The benefits of being located geographically close to others (agglomeration economies) were also discussed. Thirdly, the theoretic part concerning diversity discussed the similarity attraction perspective and the cognitive resource diversity perspective. The concept of proximity and cognitive complementarity perspective and the importance of being "not too close" or "not too far" was discussed. Throughout the theoretical discussions, *innovation* was discussed in relation to space*,* and *diversity.*

2.5 Open Issues between Innovation and Diversity

Part of the complication of diversity is that the literature concerning diversity is quite varied in itself. It has been argued that the reason why there exist so many different definitions, is that the studies stem from various theoretical

backgrounds, from ecology, sociology, economics, urban planning, and so on (see Nijkamp and Poot (2015)), and also because those studies were undertaken at geographically different places. Nijkamp and Poot (2015) argue that these differences depend inter alia on the selected definition of diversity (some focus more on (im)migration, others on the cultural/ethnic diversity), the geography and spatial scale of analysis in the countries concerned, time scale, classification of the groups considered, socio-economic conditions, and institutions (Nijkamp and Poot 2015).

Moreover, research on diversity has had a tendency to depart from an orientation of studying diversity on smaller fragments of organizations. These studies have focused on work groups (Horwitz and Horwitz 2007), top management teams (Bantel and Jackson 1989, Finkelstein and Hambrick 1990, Pitcher and Smith 2001, Knight et al. 1999, Murray 1989, Smith et al. 1994, Van Der Vegt and Bunderson 2005, Wiersema and Bantel 1992), and boards (Miller and del Carmen Triana 2009). This could give a very narrow understanding of the relationship between diversity and innovation, and it needs to be widened in order to highlight and reflect the relationship between innovation and the various capabilities of workers in different hierarchical levels of the organization. Østergaard, Timmermans, and Kristinsson (2011, 501) have extended the work of past contributions aiming to investigate the relation between diversity and innovation, and have included all the employees within the firm "because the composition of the top management team does not necessarily reflect the composition of the larger pool of human capital in the firm". Østergaard, Timmermans, and Kristinsson (2011) further argue that the literature could benefit from contributions that address larger parts of organizations, and that this echoes that innovation does not only take place at top level in firms (Lundvall 1992), but increasingly depend on broader parts from the whole organization.

The diversity literature has also focused on either the context "within the firm", i.e. diversity at the top level, or teams within the organizations, or on diversity "within the region" or city-level diversity, but rarely on both at the same time. Examples from previous studies on birthplace diversity have addressed this issue of foreign workers affecting firm performance at work groups (Chatman and Flynn 2001, Joshi and Roh 2009), firms (Lee and Nathan 2010, Østergaard, Timmermans, and Kristinsson 2011), regions and cities (Audretsch, Dohse, and

Niebuhr 2010, Buch et al. 2014, Niebuhr 2010, Niebuhr et al. 2012, Kemeny 2012, Ottaviano and Peri 2006), and countries (Easterly and Levine 1997, Hart 2007), and in some rare cases there has also been some attempts at addressing this issue on multiple scales (Trax, Brunow, and Suedekum 2015, Lee 2014, Cooke and Kemeny 2016).

There have also been some contributions linking birthplace diversity to networks, such as work by Saxenian, e.g. Saxenian (2006) that discusses how migrants in Silicon Valley built up social networks that proved important when they returned home. There is, however, still a need for continued research on the underlying mechanisms of foreign workers and networks in relation to innovation. This echoes Kemeny (2014, 34): ‘‘[t]he appeal of demonstrating positive effects of immigration in cities is clear. But as social scientists, the primary goal must be to improve our understanding of the underlying mechanisms”. Natural questions to ask, is therefore: Do foreign workers affect firm innovation and the collaborative patterns of firms? These issues become increasingly central in the current age of globalization.

Another open issue between diversity and innovation, is noted in the quote above by Kemeny, that the appeal of demonstrating positive effects of immigration is clear. There is a lot of stigma tied to the relation between some aspects of diversity, especially birthplace diversity and economic performance, innovation and so on. Moreover, there is strong acceptance that the benefits of diversity and globalization operate at the metropolitan scale (Kemeny and Cooke 2015), hence that these issues mainly take place in cities. Kemeny and Cooke (2015) refer to studies investigating these ideas in cities in the U.S, in countries within the EU15, where more diversity is associated with higher levels of wages and employment. There has been substantial amount of work emphasizing the role of the world cities/global cities in relation to these issues, building on the work of e.g. Hall (1966), Friedman and Wolff (1982) and Sassen (1991). Moreover, also tied to the notion of metropolitan cities being able to tap into global city networks (Taylor and Derudder 2004, Castells 1996, Beaverstock, Smith, and Taylor 2000). Furthermore, firms located in the periphery are not only thought to be less diverse, but also to have less access to knowledge spillovers from other firms and fewer possible local and international collaboration partners. This focus has led to an augmented need to understand the underlying mechanisms of how peripheral regions are able to

connect to the global economy, and if this might be reached through diversity (foreign workers and collaboration with international partners).

The literature on diversity and innovation often holds that diversity has either good or bad effects on innovation (Axtell et al. 2000), (i.e. benefits from variety in the cognitive resource diversity perspective and benefits from similarities in the similiarity attraction perspective), hence it calls for researchers to be more nuanced and specific. The innovation literature also tends to have an either/or focus on how some types of input, e.g. education or R&D expenditure affects innovation, and would benefit from engaging in a broader measure of how different aspects of "input" affect a broader measure of innovation output. Correspondingly, there is a need to use more direct measures of innovation, i.e. such as by Østergaard, Timmermans, and Kristinsson (2011) that directly adress innovations, and not proxies of innovation.

What seems to be lacking are contributions that can provide an understanding of some of the underlying mechanisms that affect the relation between diversity and innovation. Moreover, understanding of different forms of diversity affecting different forms of innovations, and how, are lacking. The diversity literature needs contributions that can shed light on how different types of diversity (i.e. surface level diversity vs. deep level diversity, or cognitive resource diversity perspective and the similarity attraction perspective) affect different types of innovations (i.e. new products, processes, markets, patents) differently. This will provide the field with a more nuanced picture of some of the mechanisms of how and in which contexts diversity could lead to different types of innovations. In the diversity literature, there has also been substantial focus on some types of diversity issues, such as *primary* diversity (age, gender, ethnicity) (Bell et al. 2011), instead of the *secondary* diversity measures, i.e. experience and educational diversity. An example of open issues is the underlying mechanisms of birthplace diversity and the various dimensions of proximity (cognitive or social proximity potentially bridging geographical proximity) conducive to innovation and innovation performance.

In sum, there are several open issues between innovation and diversity and in particular concerning how the interactive process of innovation is organized and what role diversity has in this interactive process. How are distinct dimensions of diversity related to innovation, and how does space in the form

of geographical proximity and external knowledge linkages correspondingly affect innovation?

2.6 PhD Thesis in Response to Open Issues

As a response to the myriad of differences in the diversity literature, this PhD aims at measuring diversity by using more nuanced measures of diversity, such as in Paper I, by investigating how different human resources (diversity in functional and educational background) affect different measures of innovation (underlining the importance of not only studying the good or bad effects of diversity on innovation). This addresses the open issues concerned with the lack of focus on secondary diversity constructs in the diversity literature. Moreover, the paper considers various aspects of diversity in relation to various aspects of innovation. The measures used for innovation are varied and provide a broad understanding of some of the mechanisms that affect innovation in firms. Following up on another open issue highlighted, all of the individual papers in the PhD thesis investigates these issues by looking at the whole organizations (all employees), and not on fragments of the organization.

Papers II and III, aim at investigating some of the *underlying mechanisms* of how foreign workers might affect innovation. Hence, it does not only focus on the good or bad effects of a variable on innovation, but also aim at providing a more nuanced perspective of how birthplace diversity affects innovation. Paper III specifically looks at international ties, in the form of foreign workers and collaboration with international partners in relation to firms launching goods and/or services in international markets in core, intermediate, and peripheral regions. This is also a response to the open issue of diversity being studied in teams, work groups, at the regional level, or irrespective of where the study has been carried out. Many contributions have studied birthplace diversity issues in the core regions/at the metropolitan scale, and the empirical focus of paper III is extended to include diversity in intermediate and peripheral regions. It is concerned with investigating whether firms in these smaller, more peripheral regions uses the same channels as firms in core regions do, in order to tap into the global economy. Underlying is that firms benefit from the diversity and variety brought into the firm by foreign workers and international partners, and

that these ties might facilitate exports. Nevertheless, these issues have not undergone the same empirical scrutiny for firms in more peripheral regions.

This PhD thesis has, in Paper II and III, examined the relationship between external knowledge linkages to its internal diversity, which contributes to the diversity literature within organizational theory that has had a tendency to focus on either the within-firm diversity or the regional diversity, but rarely empirically connecting internal diversity to the external knowledge linkages. This is demonstrated in Paper II by establishing that foreign workers facilitate collaboration with international partners and paper III that international partners is positively associated with firms exporting goods and/or services to international markets.

The papers also underline the importance of studying different dimensions of proximity, such as the geographical proximity (Paper IV). Paper IV connects firms' environment to its performance by the agglomeration literature. Hence, it connects space, diversity, and innovation. This paper also provides a new and different perspective from the other papers herein, by focusing on one particular industry, the upstream oil and gas industry.

Moreover, and more generally, this PhD thesis responds to the open issues between diversity and innovation by looking at a broad range of innovations (e.g. product, process, patent, market, collaboration) and broader measures of diversity (e.g. birthplace diversity, related/unrelated educational/experience background).

3 Research Design – Methodological Comments

Methods are employed to say something about the social world. In this PhD thesis, the scientific methods that are engaged are shaped by critical realism (Bhaskar 1975). In the view of critical realism, there is a world that exists independent from the human awareness (Sayer 1981). This section is concerned with the ontological and epistemological assumptions and will discuss these in light of the research question and design of the thesis. Hence, it addresses the specific and practical perspectives on the methods used in the various papers in light of a post-positivist perspective of how we may measure the main objects studied in this PhD thesis.

There is a world existing independent of our knowledge of it and that the knowledge we do have about the world is to some extent theory-laden and fallible (Bhaskar 1975, Collier 1994, Sayer 1981). Moreover, it is in the critical realism paradigm argued that the existence of "the world" is understood through three domains: the real, the actual, and the empirical (Collier 1994). The real domain consists of all physical objects as well as the mechanisms associated with the objects and the combinations of these objects. Hence, this domain recognizes the existence of non-physical objects in the world (Collier 1994). In the actual domains, it is argued that events occur regardless of whether human beings register them or not. Lastly, the empirical domain contains the events that are experienced by human beings.

According to the ontology within the critical realist perspective, the reality is complex and differentiated, and it is a dynamic and open system, characterized by a lot of uncertainty (Sayer 2000). Linking this discussion of critical realism and the domains to the overall goal of social science, which is to be able to say something meaningful about the world "out there", critical realism holds the understanding that we are not capable of saying anything about the world and hold it as the absolute truth. The reality "out there" exists independently of our knowledge of it, but it may be inspected by scientific research (Sayer 1992, 2000). The objective in social science is to apprehend and explain reality, but critical realism comprehends that this definitive goal cannot be reached with

complete certainty. That does not mean that we should not try. Continual examination of the research design for error and building on the past are some of the crucial building blocks in order to corroborate some of the theoretical claims put forward concerning objects, structures, and mechanisms in the real world. Hence, we are able to learn something about fragments of this reality, which in turn could provide us with a useful base for understanding "the world". Just like a puzzle, by capturing fragments of this world and building on fragments of the past, we are able to build a larger picture putting the different pieces together.

Therefore, the main issues addressed in this research design section are, how we may measure innovation. How has innovation been measured in the past?

3.1.1 Measuring Innovation

The individual papers of this PhD aim at measuring innovation by using a variety of different measures. What is innovation and how can it be measured? Smith (2005) argues that there is a need to distinguish between what can and what cannot be measured in innovation: "innovation is a multidimensional process, with nothing clearly measureable about many aspects of the underlying process. (…) Innovative learning can be seen as change in the knowledge bases on which capabilities rest. Neither learning, nor the capabilities which result, seem to be measureable in any direct way" (Smith 2005, 151). Hence, we need to try to measure these learning activities and innovation by using various measures such as R&D, education, product and process innovation, increase in value added, and so on, as proxies of innovation.

Innovation has in the past been measured in various ways, typically by using R&D expenditures, expenditures on personnel working on innovation related activities such as R&D, or patents as proxies for innovation and learning. The linear model of innovation has been criticized for being overly focused on the role of R&D in innovative processes, and for modeling innovation as a process which goes through chronological and systematic stages (Kline and Rosenberg 1986). Arguably, the underlying reasoning behind the arguments put forward by Kline and Rosenberg (1986) is that innovation is best studied as a historical process (Fagerberg, Mowery, and Verspagen 2009).

All of the individual papers in the PhD thesis focus on different types or stages of innovation based on Schumpeter's different types of innovation. Hence, the thesis shed light on broader aspects of innovation. Schumpeter distinguished between five types of innovation: new products, new methods of productions, new sources of supply, the exploitation of new markets, and new ways to organize business. It has been argued that innovation is inherently impossible to measure (Smith 2005). One issue is that "measurement implies commensurability: that there is at least some level on which entities are qualitatively similar, so that comparisons can be made in quantitative terms" (Smith 2005, 149). And since innovation is by its mere definition introducing something new, hence, what is new becomes a definitional question. Therefore, the PhD thesis, aims at observing innovation at its different steps of the innovation process, from patenting and product innovation, market entry and effects on the bottom line. Hence, this PhD thesis aims at analyzing different parts of the innovation process. Furthermore, this relates to the view of critical realism mentioned above, aiming at capturing fragments of "the real world" by investigating the mechanisms between diversity, space, and innovation, we consequently aim at improving our understanding of some pieces of the real world.

Paper I uses three proxies for measuring innovation: the first captures firms' decision to engage in development work, the second uses patents and the third uses product and process innovations. This provides a broad basis on which to study innovation. Paper II measures innovation by new ways of organizing business (through using international partners) as well as product innovation, new-to-market product innovation, process innovation, and new-to-industry process innovation. In Paper III, looks at international markets (innovation captured as exploitation of markets). It is measured by whether firms have sold any goods and/or services in international markets (European and other international markets). In Paper IV, innovation is measured by value added.

3.1.2 The Data

At the start of the PhD project, a report from the Norwegian research council (NRC) was released, which argued that what appeared to be lacking in the study of geography in Norway is "research that makes use of more comprehensive

empirical data covering a wider range of regions and localities in Norway and that may be able to generate input for the more general debate on regional and urban development and policy" (NRC, 2011, p. 67). Based on this, the general research design that was chosen was to take advantage of comprehensive empirical data that cover a wide range of regions and localities in Norway. The four different papers take advantage of four distinct sources of data. This provides a platform for studying innovation, space, and diversity from different angles and at the same time holds the benefits of using different and unique data. It also generates input on the more general debate on regional development and policy in Norway. This provided an important backdrop for designing the study and important design consideration in this study of innovation, space, and diversity. It furthermore strengthens the thesis as it offers a broader platform on which to draw conclusions. All of the individual papers are based on data within the period 2000-2013. Thus, the data are relatively new and shed "up-to-date" light on these important aspects of innovation in Norwegian firms.

This thesis is concerned with innovation in private firms. In Norway, like in many other advanced economies in the developed world, it is most common that private firms undertake the role of commercialization of innovation (Fagerberg, Mowery, and Verspagen 2009).

Papers I and III use Linked Employer Employee Data (LEED) that encompasses information on all employees and all employers in Norwegian private firms. These are gathered annually by Statistics Norway and it is a unique and large database that provides many interesting opportunities to study the individual characteristics (LEED tracks individuals' career paths) in relation to firm performance. The benefits of using these large datasets besides its reliability are many, one being that we may generalize from the results to a larger degree than with smaller samples. Since these data are gathered annually for all firms, we do not have to deal with sample selection bias to the same degree as in more narrow designs.

The LEED is then merged with the Community Innovation Survey (CIS).[17] This merge was made by Statistics Norway by using unique identifiers for firms and

[17] The Norwegian Innovation Survey is conducted biannually in combination with the business enterprise Research & Development (R&D) survey. It is carried out as part of the pan-European

employees ensuring individual and firm anonymity. The CIS gives important information about the Norwegian business enterprise sector and "provides core indicators on Norwegian enterprises' ability to face transitions, introduce new products and processes, and create growth" (Wilhelmsen 2012, 3). Smith (2005, 148) argues that the CIS has taken up the challenge pointed out by e.g. Arrow (1984, 51) and Griliches (1987, 824) that "far too little fresh economic data is collected" and that "too much juice" has been made based on old data that were collected for different purposes than those they are then used for. Smith refers to the CIS as the most important development within new survey-based indicators.

It is mandatory for Norwegian firms to participate in this survey, and prior CIS surveys in Norway have not shown any indication of non-response bias. Wilhelmsen (2012, 9) demonstrates that the response rate has been very high for the CIS survey in Norway, "~95 percent or more, and there does not seem to be any clear pattern amongst non-respondents". A methodological issue related to this CIS dataset is that innovation activity is self-reported. This could lead to measurement bias, and to give an example, firms that do not wish to spend a lot of time answering the questionnaire could under-report their innovation activity, which in turn corresponds to them having to answer fewer questions. On the other hand, people could overestimate their own innovation activity, which could lead to a higher number of innovations being reported than what is actually the case.

Paper II builds on firm-level data from a survey of 533 Norwegian firms, gathered in 2013. The survey was developed by the authors, drawing on indicators from the Community Innovation Survey (CIS), in particular for the dependent variables. The data have been combined with firm-level register data on firm size and industry classification.[18] The survey was conducted in two stages: first, through a telephone interview, in which 2002 firms participated. These firms were sampled from a larger population of all firms with more than ten employees registered in the Norwegian Register of Business Enterprises

Community Innovation Survey (CIS) that is coordinated by Eurostat (the EU statistics agency). The survey is based on Guidelines for collecting and interpreting innovation data, colloquially called the Oslo Manual (Wilhelmsen 2012, 3).

[18] Nomenclature generale des Activites economoniques dans les Communautes europeennes (NACE).

according to quotas for five different regions: Oslo (500 firms), Stavanger (350), Bergen (300), Trondheim (250), and the rest of Norway (600). The "rest of Norway" category responds to peripheral regions in Norway. Referring back to the gap identified by the Norwegian Research Council of few quantitative studies of the geography and development in Norway, this was part of the backdrop in forming this study aiming at involving firms in both core and peripheral regions. The overall response rate for the telephone survey was 20 percent. During the telephone interview, respondents were invited to fill in a follow-up web questionnaire containing further questions, which 533 managers did. The dependent variables on innovation, collaboration, and the organization of innovation processes are all drawn from the telephone interviews, as are several of the control variables, while the data on foreign workers are based on the web questionnaire. Consequently, we limited the study to the firms that participated in both stages of the survey for the models concerned with foreign workers, while the association between international networking and innovation is analyzed on the full sample of 2002 firms. There could be a potential bias of the ones answering the web survey as being more innovative, and that is a trend that we also observed. This could then be considered somewhat of a sample selection bias, and that is also why we ran models following Heckman (1979).

Paper IV uses data that have been gathered by Brønnøysundregistrene, which develops and operates many of Norway's most important registers for companies and organizations. Firms are obliged by law to provide audited balance sheet and profit/loss statements to the Brønnøysund Register Centre (Sasson and Blomgren 2011). In addition to the balance sheets and the financial declarations (including profit and loss statements), the data set comprises information e.g. year of establishment, geographical location, and industrial affiliation (Sasson and Blomgren 2011, 127). The data used were from 2000-2009. There are many benefits from using these data; firstly, they are based on "hard facts" and "real" numbers, such as profit, loss statements, revenue, and number of employees. With these data, one does not have the same issues as with self-reported data as mentioned above. The source and the data are highly reliable, and it holds the benefit of using large sample data.

The research design set out to take advantage of different types of data (see table 3 for overall view). This has several benefits; firstly, the data used are

reliable by themselves, but also the weaknesses of one type of data are alleviated by the use of other data sources. Together, they provide a broader perspective on how different types of diversity and space affect different measures of innovation.

Paper	*Data Source*	*Additional information*	*Project/Source of data*
Paper I	Linked Employer - Employee data (LEED) + Community Innovation Survey (CIS).	Individuals from LEED in 2008. Innovation output information CIS 2010. 2942 enterprises.	Statistics Norway. DEMOSREG project. NIFU.
Paper II	Survey + register.	Firm-level data of 533 Norwegian firms, gathered in 2013 + firm-level register data on NACE.	UiS/IRIS under the DEMOSREG-project.
Paper III	Linked Employer - Employee data (LEED) + Community Innovation Survey (CIS).	Individuals from LEED in 2007. Collaboration CIS 2008. International markets from CIS 2010. 5996 enterprises.	Statistics Norway. DEMOSREG project. Centre for Innovation Research, University of Stavanger.
Paper IV	Panel Data.	1500 firms within the Norwegian oil and gas industry (2000-2009).	Statistics Norway/Brønnøysund Register Centre. IRIS (c/o Atle Blomgren).

Table 3: Data sources used in the various paper.

3.1.3 Norway – The Contextual Frame

As innovation is socially and *territorially* embedded, and to fully understand these processes, the institutional and cultural context needs to be taken into account (Lundvall and Johnson 1994, Asheim 2012). In this section, some aspects of the Norwegian economy and innovation will be highlighted.[19] This PhD is carried out using data on Norwegian firms, and all the papers use data within the time period of 2000-2013. This section will briefly discuss some issues related to the contextual frame that could have an impact on the interpretation of the data as well as the generalization of the results.

3.1.3.1 Norway and the Geographical Dimension

Norway is a country with 19 administrative counties and several small and peripheral regions. In April 2016, Norway had 5,223,300 inhabitants (Statistics-Norway 2016c) in a total areal of 385,186 km^2 (Statistics-Norway 2016a). This makes 13.52 inhabitants per km^2. The research design of this PhD has emphasized the importance of including both core and peripheral regions in the study, aimed at covering a wide array of regions. This is to avoid overrepresentation of some regions over others and to make the generalization of the results not specifically tied to one specific region. This also ensures that Papers I and III are estimated on all regions in Norway, and in Paper III a distinction is made between firms in core, intermediate and peripheral regions. Paper II, five different regions were used: Oslo (500 firms), Stavanger (350), Bergen (300), Trondheim (250), and the rest of Norway (600). Paper IV uses all counties in Norway but with a higher representation of the West coast of Norway (counties of Rogaland and Hordaland), due to the agglomeration of firms in the upstream oil and gas industry in these regions.

[19] This thesis does not directly incorporate elements or concepts related to National Innovation Systems (NIS), Technological Innovation Systems (TIS), Sectoral Innovation Systems (SIS), Regional Innovation Systems (RIS), or Local Innovation Systems (LIS). The author does, however, acknowledge that some of these systems indirectly could have had an impact on the results of some of the papers. A national innovation system, for example, is one way of organizing the interactive learning processes that innovation depend on.

3.1.3.2 Innovation in Norway

On the European Innovation Union Scoreboard (EIS), Norway together with, e.g., Serbia, rank as "moderate innovators", below the EU average, whilst the other Nordic countries are ranked as "leading innovators" (meaning that they are at a 20% above EU average) (Hollanders, Es-Sadki, and Kanerva 2015). The report argues that Norway is performing below the EU average for "most dimensions and most indicators, particularly for License and patent revenues from abroad, Community designs and Exports in medium and high-tech products" (Hollanders, Es-Sadki, and Kanerva 2015, 74). This could arise from the fact that it has not been a strong tradition for Norwegian firms to patent. There has, however, been an overall increase in terms of patenting activity in Europe over the last 15-20 years, and perhaps this pattern observed will change over time. Whether this increased patenting comes from strategic decisions or due to reduced costs tied to patenting is not confirmed (Smith 2005). Patent is more related to invention than to innovation, as patenting "mark[s] the emergence of a new technical principle, not a commercial innovation" (Smith 2005, 160). Another critique against the EIS is that it does not focus on process innovation and that constitutes an important aspect of the innovation activity in Norway (The Norwegian Ministry of Trade 2009), and this could also be part of why Norway comes out quite poorly in this scoreboard, as much more emphasis is placed on R&D-based types of indicators.

Despite being ranked very low on the EIS in many respects, Norway is doing well when it comes to economic indicators such as comparatively high GDP per capita and GDP per capita growth and low unemployment. Norway has strong performance in tertiary-level education, international scientific co-publications, non-domestic doctoral students, and public-private scientific co-publications (Hollanders, Es-Sadki, and Kanerva 2015). According to the report, "the Norwegian innovation performance has been increasing since 2007, with a small decline in 2014. Norway`s performance, as compared to the EU, increased until 2012, peaking at 89%, but relative performance has since then been in decline and is at 86% of the EU average for 2014" (Hollanders, Es-Sadki, and Kanerva 2015, 74). There seems to be a mismatch between innovation development and the little spending on Research and Development (R&D) in Norway (compared to other advanced economies). This has been discussed in several reports previously, and the OECD (2007) termed the

phenomenon "the Norwegian puzzle". This premise assumes "a linear model" of innovation that was criticized by Kline and Rosenberg (1986). Wilhelmsen (2012) argues that, while parts of "the Norwegian puzzle" is understood, some of the results still seem reasonably lower than they should be when compared to other European countries. This underlines the importance of studying these aspects further in detail as well as trying to measure different types of innovation.

There are many plausible explanations to this puzzle, one being that the innovation activities are not identified by the common innovation indicators and that the special structure of the Norwegian industry is not captured in the innovation surveys. According to Castellacci (2007), this has to do with the sectoral composition of the Norwegian economy, and not the innovative activities. One reason for this is the assumption that innovation activities in one of Norway's most important industries, the upstream oil and gas industry, is underreported. The Norwegian Ministry of Trade (2009) seems to agree with Castellacci (2007), as they state, "Industry by industry, R&D spending in Norway is at or above the OECD average. If all OECD countries had the same industry structure, the Norwegian industry would be the fourth most R&D-intensive country in the OECD".

3.1.4 Dimensions of a Diverse Workforce in Norway

The Norwegian work force has, like most parts of the Western world, become increasingly diverse. More women have entered the work market, more people are entering universities, and people also tend to change jobs a lot more often, which in turn have implications for their skills and knowledge base. Since two of the papers within this PhD thesis are concerned with foreign workers, some dimensions of a diverse workforce in terms of foreign workers will be discussed.

Human migration may have an impact on economic growth through different channels. For instance, immigrants from other countries may have skills that are scarce in that place and thus enhance productivity and innovation (substituting or complementing the existing skill platform); hence, the impact depends on the characteristics of those migrating (Kangasniemi et al. 2009). Bratsberg, Raaum, and Røed (2014) confirm this in a study carried out on

Norwegian data. They use longitudinal data from the date of arrival, and they find differences between immigrants from high-income countries and low-income source countries both in terms of employment rates and disability program participation. Seip (2007) found that a majority of firms sought foreign expertise due to problems finding the competence they need in Norway. That finding underpins the importance of bringing in foreign workers because of their skills and competence.

By January 2016, immigrants and Norwegians born of immigrants added up to 16.3% of the total population (Statistics-Norway 2015b). Of the total population (by January 2016) of 5.2 million, 698,500 are immigrants (13.4%) and 2.9% are immigrants born to immigrant parents. It is natural to compare the numbers to other countries in Scandinavia and Europe. Norway comes between Sweden and Denmark with its 16.3% immigrants of total populations compared to Sweden's 22.2% and Denmark's 12.3%.

Norway houses immigrants from 223 countries, of which the largest groups are Poles, Lithuanians, and Swedes. Most of the immigrants come for family (36%) and work-related (33%) reasons (Statistics-Norway 2015a).[20] Norway has 428 municipalities, and there are immigrants in all of these municipalities (Statistics-Norway 2016b). However, there are regional differences in terms of the density of immigrants. There is a tendency of foreign workers clustering in the urban regions of Norway. This is visualized in figure number 1 where first-generation immigration in relation to geographical location is depicted (see Appendices for the exact numbers of first generation immigrants in relation to county).

In the capital, Oslo, 33 per cent of the population are immigrants.[21] This is followed by Drammen, which is situated next to Oslo, and then Båtsfjord, which is a small municipality in the north of Norway (situated at the "light-yellow-colored" top in the map. Båtsfjord has just over 2000 inhabitants).

[20] These numbers exclude Nordic citizens, and one could expect the numbers of work-related immigrants to increase by including these, since one of the largest groups of immigrants to Norway are Nordic citizens (Swedes).

[21] This number is based on a classification made by Statistics-Norway on who should be considered immigrants, which is based on 163,000 immigrants and 50,900 Norwegians with immigrant parents in Oslo at the start of 2016 (Statistics-Norway 2016b).

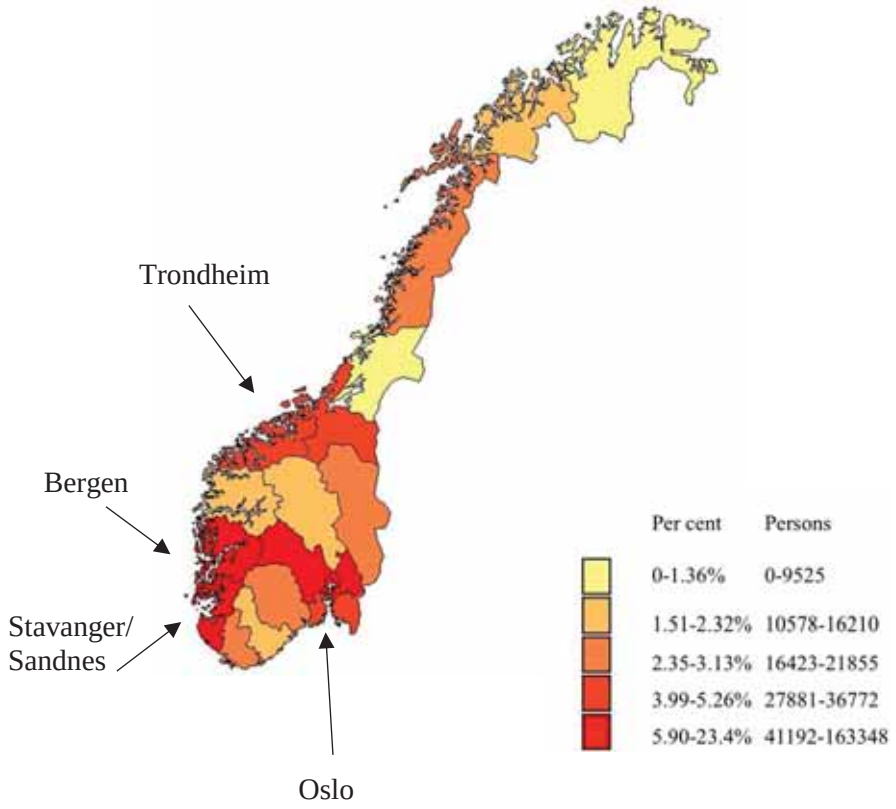

Figure 1: Map of Norway with the four core regions: Trondheim, Bergen, Stavanger/Sandnes and the capital, Oslo indicated on the map, as well as an indication of where the foreign workers are living. Data source: Statistics Norway.

The employment amongst immigrants is very high in Norway, compared to other countries in Europe. Norway has actually the lowest unemployment rate among immigrants in the whole of Europe. One example is that 66% of the female immigrant population in Norway are employed, as opposed to 54% for

the rest of Europe (Tronstad 2016). Norway is also the European country with the lowest overall unemployment rate for non-immigrants.

Immigration to Scandinavia has increased substantially over the past ten years, and since 2007 the rate of immigration has been higher to Scandinavia than to the rest of Europe (Tronstad 2016). Tronstad (2016) demonstrates that Norway has had the highest immigration rate in Scandinavia and amongst the highest in Europe. This is caused by the large work-related immigration and especially from countries such as Poland, the Baltic States, and Sweden. This could also be an explanation for why participation in the labor market is higher in Norway for employees with lower levels of education (Tronstad 2016).

Norway, and the surrounding Nordic countries, have been cautious and have tried to protect the labor market from immigration that could lead to an increase in unemployment (Seip 2014). According to Seip (2014, 165), Norway, much like other European countries, face three main political challenges in relation to migration. Firstly, is the management of the open European labor market, and secondly is being able to attract highly skilled workers from outside the European labor market. Thirdly, is inhibiting immigration of unskilled labor from e.g. outside the European labor market. Seip (2014) argues that these abovementioned challenges make legislative regulation an act of balance. In recent years, high labor demand and Norway's participation in the European Single Market has also led to immigration of unskilled workers, in particular in the construction and hospitality sectors. As in other European countries, refugees and asylum seekers have also made up a sizeable share of the immigrant population since the late 1970s.

3.1.5 Short Summary of Birthplace Diversity in Norway

In terms of what this all means for the research question and topics raised in this PhD, one of the most important issues is to note that employment (even for low educated foreign workers) among immigrants in Norway is generally significantly higher in Norway compared to the rest of the Scandinavian countries and Europe. This is based, among other things; on the low unemployment rate in Norway and on the migration regulatory policies and that more immigrants come for work-related reasons to Norway than in the neighboring countries. It is important to keep this in mind when interpreting the

results, i.e. from Paper II demonstrating how foreign workers are positively associated with innovation, at least in part because foreign workers facilitate international collaboration. Many Norwegian firms hire foreign workers because they cannot find the competence they need in Norway (Seip 2007) and employment is generally higher amongst immigrants than in the rest of Europe (Tronstad 2016). Hence, central lessons can be learned on how foreign workers can contribute to the Norwegian economy as demonstrated in Papers II and III in which foreign workers facilitate international collaboration and is positively associated with presence on international markets. These results also carry significant lessons for the importance of foreign workers within the globalized world and carry important implications of smaller, peripheral economies being able to tap into larger, global economies through international networks and foreign workers.

3.1.6 Short Summary Research Design

The data sources and the methodological issues related to them have been debated above. First, the issue related to how innovation can be measured and how the four individual papers attempt to measure innovation was discussed. Then the data sources and methodological issues related to the data were discussed prior to reflecting over Norway as the contextual frame for the studies. Critical realism underlines that all observations are theory laden and that all researchers are shaped and colored by their prior experiences and cultural background and so on, which in turn has an impact on their findings. Hence, the only way to come closer to so-called "objectivity" is by seeking data more broadly, by e.g. studying these aspects more broadly or by seeking out other individuals and hence, open up the research for different views and opinions. This relates well to the theoretical contributions of this PhD thesis, which, through the cognitive resource diversity perspective, underlines the importance of variety in the creation of new. Methodologically, this PhD has aimed at using a variety of distinct measures of diversity, space, and innovation in order to paint a broader picture of the research conducted within various different fields.

4 Concluding Discussion

This PhD thesis intents highlighting how *space* and *diversity* affect *innovation*. Through four individual papers that measure different dimensions of innovation and different aspects of diversity and space, the thesis demonstrate some of the mechanisms underlying innovation.

Drawing on different strands of literature, mainly from the literature on organizational theory, innovation, and economic geography, the thesis aims at bridging contributions from these strands of literature and addresses how firms communicate and connect with their contexts in innovative processes. The thesis departs from the idea that innovation depends on different input, and has particularly studied how diversity (and concordantly similarity) affects innovation. Moreover, there has been a tendency in contributions from the innovation literature to consider either the good or the bad effects of diversity on innovation (Axtell et al. 2000) and not using more nuanced approaches in order to capture the underlying mechanisms of how diversity might affect different aspects of innovation.

This thesis is targeted at meeting some of the open issues that lie between innovation and diversity and improve our understanding of some of the underlying forces of innovation. The thesis aims to do so by analyzing these issues regarding the whole organization (and not only fragments of the organization), using more nuanced and broader measures of both innovation and diversity in the analysis and hence, provide a fuller picture of some of the underlying mechanisms of innovation.

The four individual papers all demonstrate different aspects of the interdependencies between firms and its context while at the same time highlighting the role of diversity. The papers demonstrate how diversity amongst actors is contributing to some types of innovation (e.g. in paper I and exploration or paper II with foreign workers and international partners and innovation), whilst other types of innovation are facilitated through similarity between actors (e.g. in paper I and exploitation). This underlines the importance of distinguishing between different types of measures of innovation and different measures of diversity related to space and context. The results suggest

that different aspects of diversity can function as substitutes or complementarities, depending on different aspects of innovation activity.

Examples from Paper I demonstrate how different human resources (related and unrelated experience and educational background), conducive to the cognitive resource diversity perspective and the similarity attraction perspective, affect different aspects of innovation differently. Hence, the results from paper I demonstrate how exploration is dependent on diversity in firms human resource base, and exploitation is more dependent on similarity in firms human resource base. Paper II emphasize how foreign workers, conducive to the cognitive resource diversity perspective affect firms' collaborative patterns, hence collaborate more with international partners that in turn affects firm innovation. Paper III investigates how firms in core, intermediate, and peripheral regions tap into international markets (sell goods and/or services in European and in other international markets) by investigating the role of international ties (foreign workers and international collaboration). This paper underlines the importance of studying these issues in peripheral regions (as past research has had a tendency to focus on global cities/world cities, following up on work by e.g. Sassen (1991) and Hall (1966) amongst others) and global city networks (Castells 1996, Beaverstock, Smith, and Taylor 2000). Both paper II and III underlines the importance of variety, brought in by foreign workers and international partners (mirroring the cognitive resource diversity perspective), whilst at the same time bridging cultural divides through the similarity attraction perspective (e.g. foreign workers knowledge of international markets, customs, culture, languages etc. and their social and professional networks in their country of origin). Paper IV underlines the importance of geographical proximity as well as the close connection between suppliers and buyers that have infiltrated the industry. This paper underlines the importance of tacit knowledge and the DUI mode of innovation that has permeated the nature of the industry.

Hence, the results from the individual papers add to the understanding of the interconnectedness of knowledge and innovation, of proximity and innovation, and how different kinds of innovations are dependent on different types of knowledge and diversity.

The results have several important implications for policy and practice. For practice, they reinforce the importance of recognizing how different measures of diversity affect different measures of innovation output differently. This has an impact on the coordination and allocation of internal resources in combination with the external potential resources and the innovation-target at hand. For policy, aiming at addressing issues in relation to diversity and innovation, the results adds to the vital importance of distinction between various sources of diversity and various sources of innovation. Moreover, it addresses some of the underlying mechanisms of matching them.

However, the results from this PhD thesis also stresses the impossibility of giving "one size fits all" recommendations, but instead calls for a more nuanced understanding of the potential effects of space, and diversity, on innovation.

4.1.1 Directions for Future Research

The final comments in this kappe will contain some reflections on future research questions that would be fruitful to address in relation to the topics discussed and reflected upon in this PhD thesis.

Firstly, the PhD thesis has been concerned with studying some of the underlying mechanisms of space, diversity, and innovation. A fruitful "next step" on this path would be to use different types of methods to continue studying these aspects, with an obvious point of departure being the use of more qualitative methods. Employing, e.g., case study or field study approaches presents opportunities to further address the dimensions and nuances of diversity, space, and innovation, which are needed within this line of research.

Following up on the open issues between diversity, and innovation, an interesting point of departure would be to continue using more nuanced measures of innovation, as well as more nuanced measures of diversity and by integrating spatial aspects into these research objectives. Other interesting points of departure, continuing along this path would be to study the complementarities of internal skills in relation to external knowledge linkages, and investigate whether there are some substitution or complementarity effects.

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Appendices

Figure A1: Map over Norway with counties

Table A2: Table demonstrating number of persons (first-generation immigrants) in the different counties in Norway in 2016. Source: Statistics Norway.

1 Østfold	36772
2 Akershus	90111
3 Oslo	163348
4 Hedmark	16423
5 Oppland	16210
6 Buskerud	41192
7 Vestfold	27881
8 Telemark	17713
9 Aust-Agder	12386
10 Vest-Agder	21855
11 Rogaland	68175
12 Hordaland	61217
14 Sogn og Fjordane	10578
15 Møre og Romsdal	28240
16 Sør-Trøndelag	31543
17 Nord-Trøndelag	9525
18 Nordland	19937
19 Troms	16019
20 Finnmark - Finnmárku	9425
Total	698550

PART II

LIST OF PAPERS

This PhD thesis is a compilation of four individual papers

I. Solheim, Marte C.W. and Sverre J. Herstad. “On the differentiated effects of human resource diversity on organizational learning and innovation”. Under review in *Industry and Innovation* (Submitted 23.06.2016).

II. Solheim, Marte C.W. and Rune Dahl Fitjar. ”Foreign workers are associated with innovation, but why? International networks as a mechanism”. Published in *International Regional Science Review* online ahead of print 21.01.2016.

III. Solheim, Marte C.W. “Foreign workers and international partners as channels to international markets in core, intermediate and peripheral regions”. Published in *Regional Studies, Regional Science* online ahead of print 07.12.2016.

IV. Solheim, Marte C.W. and Ragnar Tveterås. “Do firms in upstream oil and gas sectors benefit from co-location?”

Paper I

On the differentiated effects of human resource diversity on organizational learning and innovation

Marte C.W. Solheim[1], Sverre J. Herstad[2]

Abstract

By linking theoretical perspectives on human resource diversity to the distinction between exploration and exploitation in organizational learning, this paper contributes to the growing research literature on diversity and innovation while following up on the original argument by March (1991) that the two dimensions call upon different knowledge bases and organizational processes (March 1991, Nooteboom et al. 2007). Empirically, the paper draws on a unique dataset constructed by merging Norwegian employer-employee register data for 2001-2010 with Community Innovation Survey (CIS) data gathered in 2010. Bivariate probit regressions with controls for innovation strategy find exploration responding differently to the composition of firms' human resource bases than exploitation does, and firms' investments in innovation to be important moderators of these effects.

KEYWORDS: Innovation, Diversity, Exploration, Exploitation, Norway

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1. Introduction

Innovation is a social process (Van de Ven, Angle, and Poole 1989) in which people with different, yet complementary knowledge interact (Østergaard, Timmermans, and Kristinsson 2011, Lundvall 1992) in order to identify opportunities and solve problems (Bathelt, Malmberg, and Maskell 2004). Thus, it is closely connected to heterogeneity of individual skills and perspectives (Mattes 2012), but at the same time reliant on a certain degree of similarity to allow communication and work towards common goals (Mattes 2012).

This paper links antecedent research on the composition of firms' human resource bases to the distinction between exploration and exploitation in organizational learning, By doing so, it contributes to the research literature on diversity and innovation (Østergaard, Timmermans, and Kristinsson 2011) while following up on the original argument by March (1991) that the two dimensions call upon different organizational processes and external stimuli (March 1991, Nooteboom et al. 2007). Empirically, a unique dataset constructed by merging Norwegian employer-employee register data for 2001-2010 with Community Innovation Survey (CIS) data gathered in 2010 allow different output from firms' development work to be regressed on sophisticated diversity measures that describes the educational backgrounds and prior work-life experiences of employees. Moreover, it allows controls for innovation strategy to be implemented and absorptive capacity effects to be acknowledged through the inclusion of interaction terms involving innovation expenditures and human resources (Cohen and Levinthal 1990).

2. Theoretical framework

2.1 Dimensions of organizational learning and innovation

The competitiveness of firms depend on the capacity to innovate, i.e. to develop, access and exploit knowledge for the purpose of improving products, production processes, organizational principles and business models. Due to the complexity of modern industrial activity, it involves a broad range of interlinked tasks, and potentially conflicting viewpoints and objectives (Herstad, Sandven, and Ebersberger 2015). Still, there is a general tendency in empirical work to treat "learning" and "innovation" as clearly defined, one-dimensional constructs. In the innovation litterature, it is for instance common to either focus on the research and development phase, or on the idea implementation phase where new technologies are transformed into real-life products or processes, but rarely on both at the same time (Axtell et al. 2000, 269). As a result, research fails to capture how different aspects of organizational learning and innovation depend on different strategies, types of skills and interactions between them.

To approach this, a distinction between exploration and exploitation can be made (March 1991, Raisch et al. 2009). Exploitation involves work aimed at refining the capabilities that are valued in firms' present markets. Therefore, it can be expected to depend on the specialized knowledge and skills that employees have accumulated (Wang, He, and Mahoney 2009), and take the form of continuous improvements of product lines, production processes and business models in response to gradually evolving circumstances. Sophisticated organizational practices and distinct "codes" (March, 1991), or "routines" (Levinthal and March 1993, Cyert and March 1963), that reflect the accumulated experiences of the firm and govern interaction between individuals are involved, because this type of development work demand continuous communication between departments and hierarchical levels with complementary capabilities, responsibilities and external network contact points (Grant 1996, Herstad, Sandven, and Ebersberger 2015). Consequently, limitations to the diversity of human resources that firms can effectively make use of for the purpose of refining and exploiting their current capabilities stem from the need for coordination and integration of knowledge that has a high firm- of industry-specific content.

Exploration, by contrast, is described as "the pursuit of knowledge of things that might come to be known" (Levinthal and March 1993, 105) and refers to activities aiming at transcending the confines of current technologies, products and organizational practices. The development of new component technologies, or technological respositing at the firm level (Tzabbar 2009, Asheim 2011), are examples of explorative efforts and the success of firms in this respect is expressed e.g. as patent output (Herstad, Sandven, and Ebersberger 2015). As it involves breaking with established ways of thinking and acting, it can be assumed to depend on the presence of skills and mind-sets that are different from each other and from those that are shaped by the ongoing business processes of firms.

Consistent with this, prior research has found diversity of expertise to be positively associated with non-routine task environments (Murray 1989, Hambrick, Cho, and Chen 1996). Moreover, it has demonstrated how inflows of expertise from outside firms own' industry domains strengthen specifically the explorative efforts that are expressed by firms' patent output (Herrera, Munoz-Doyague, and Nieto 2010), without necessarily influencing exploitation because this depends on skills and organizational practices that are to a much larger extent context-dependent (Herstad, Sandven, and Ebersberger 2015). As it is commonly argued that the long-term competitiveness of firms depend on their ability to combine exploration and exploitation (Jensen et al. 2007, March 1991, Hall, Lotti, and Mairesse 2008, O'Reilly and Tushman 2008), a fundamental question that arises is whether the human resource bases that allow firms to balance exploration and exploitation (Raisch et al. 2009, He and Wong 2004) are different from those associated with either one of the two types of organizational learning (Bonesso, Gerli, and Scapolan 2014, 392).

2.2 Perspectives on human resources and organizational learning

The exploration-exploitation framework focuses on how the knowledge of individuals and the routines that govern their interactions within firms are inter-related in dynamic processes of organizational learning (March 1991, 74). By doing so, it acknowledges that knowledge resides with individuals, and reflect their learning at past and present places of employment (Vaghely and Julien

2010, Boschma, Eriksson, and Lindgren 2014, Dokko, Wilk, and Rothbard 2009). In spite of this, there has been a tendency in the diversity literature to emphasize diversity in terms of age, gender and ethnicity (Bell et al. 2011), even though focus is on innovation (Østergaard, Timmermans, and Kristinsson 2011). Therefore, scholars in this field are now calling for a clearer distinction to be made between *primary* diversity, associated with e.g. gender, age and ethnicity, and *secondary* diversity, which concerns characteristics that are more immediately task-relevant; and acquired or evolving as opposite to fixed and given at birth (Bell et al. 2011, Harrison and Sin 2006).

Education is important in this context, because it shapes the professional identities and languages of individuals, and opens doors to career paths. Still, the actual skills, behavioral characteristics and networks of individuals are distinct from their educational backgrounds, due to individuals being years of experience-based learning away from when they originally graduated (Bell et al. 2011).[3] Thus, as the complexity and knowledge-intensity of modern work-life increases, the career path of individuals must be viewed as equally if not more important than educational backgrounds in terms of capturing their cognitions.

Prior research emphasizes three ways in which work-life experiences shape human resources. First, it allows individuals to acquire skills and insights that reflect the specialized knowledge bases and organizational routines of employer firms. Second, it embeds individuals in enduring interpersonal ties, through which information is transmitted between past and present places of employment long after the mobility even itself (Agrawal, Cockburn, and McHale 2006, Oettl and Agrawal 2008, Dahl and Pedersen 2004, Bouty 2000). Third, it shapes behavioral attributes, i.e. the manners in which individuals act and communicate their knowledge (Dokko, Wilk, and Rothbard 2009, Madsen, Mosakowski, and Zaheer 2003). Consequently, the knowledge bases and routines that comprises firms' innovation capacities, and the networks through

[3] Part of the complexity of dealing with functional and demographic/educational diversity is that there has often not been a clear divide between educational diversity and experience diversity. To give an explicit example:"**experience diversity** refers to the differences in knowledge and skills among group members as a result of their work **experience** and **education**" (Engen 2009, 131).

which they search for new ideas and information (Laursen 2012), are to varying degrees collective expressions of employees' accumulated experiences.

In spite of this, work within the field of innovation studies has traditionally awarded more attention to interactions between firms (Rutten and Boekema 2012), than to the interactions of individuals within them. Moreover, to the extent that human resources have been considered explicitly, emphasis has been put on specific corporate functions or occupational groups, notably R&D departments, researchers and inventors (Herrera, Munoz-Doyague, and Nieto 2010, Maliranta, Mohnen, and Rouvinen 2009, Tzabbar 2009). Similarly, the focus of diversity research has been on smaller fragments of the organizations, such as work groups (Horwitz and Horwitz 2007), top management teams (Bantel and Jackson 1989, Finkelstein and Hambrick 1990, Pitcher and Smith 2001, Knight et al. 1999, Murray 1989, Smith et al. 1994, Van Der Vegt and Bunderson 2005, Wiersema and Bantel 1992) and boards (Miller and del Carmen Triana 2009, Bjørnåli and Gulbrandsen 2010). Consequently, innovation studies and diversity research align in a need for the focus be broadened in order to reflect the dependence of organizational learning and innovation on interactions *between* different functions, hierarchical levels and types of skills within the firm (Lazonick 2002, Grant 1996).

Doing so aligns with the view of diversity as compositional *variety* (i.e. differences in knowledge or experience among the unit members), which is by Harrison and Klein (2007) distinguished from diversity as compositional *separation* (i.e. differences in position among unit members) and *disparity* (differences in concentration of valued social assets, e.g. pay status) (Harrison and Klein 2007, 1200). Approaching 'variety' conceptually, a distinction can be made between the 'cognitive resource diversity' perspective and the 'similarity attraction' perspective (Simons and Rowland 2011, Christian, Porter, and Moffitt 2006, Horwitz 2005). The cognitive resource diversity perspective holds that that diverse teams outperform more homogenous teams (Hong and Page 2004) since more diverse teams "possess broader range of range of task-relevant knowledge, skills and abilities, giving the group a larger pool of resources that when combined may generate new insights" (Van Engen and Van Woerkom 2010, 135).

When team members differ in their expertise, they might have different perceptions of what the problem exactly is (Van Engen and Van Woerkom, 2010:133), which in turn has implications for behavior, learning and innovation. The underlying assumption of the cognitive resource diversity perspective is that groups consisting of heterogeneous members generate more informed decisions, because they have a broader range of perspectives and viewpoints to choose among (Horwitz 2005, 224-225). Accordingly, interaction between individuals holding distinct perspectives is seen as a way of creating "kaleidoscope thinking" (Kanter 1968), which entails that the presence of a variety of perspectives is important in triggering new knowledge.

However, variety of perspectives may also lead to miscommunication, uncertainty, and conflicting views which could cause firms to retain rather than adjust current practices (Madsen, Mosakowski, and Zaheer 2003). Acknowledging this, the similarity attraction perspective assume that people prefer to engage in relationships with other people that are similar to themselves (McPherson, Smith-Lovin, and Cook 2001), and that this similarity eases communication and enable a more efficient execution of tasks. It is assumed that homogenous teams outperform heterogeneous teams because of "mutual attraction of team members with similar characteristics. Heterogeneous groups, in contrast, are hypothesized to be less productive and have lower team cohesion because of inherent tensions and relational conflicts arising from member differences" (Horwitz 2005, 224).

The two perspectives have a clear parallel to the 'proximity paradox' of contemporary evolutionary theory (Boschma and Frenken 2010), which emphasizes the tension between cognitive distance, conducive to novel thinking, and cognitive proximity, conducive to effective communication, and thus to understanding. As an antecedent to this paradox, Nooteboom and colleagues introduced the concept of 'cognitive complementarity' (Nooteboom 2000, Wuyts et al. 2005) to describe the conditions under which proximity conducive to communication balances distance conducive to learning (Mattes 2012, Fitjar, Huber, and Rodríguez-Pose 2016). These distinctions are now echoed in the concepts of specialization (cognitive proximity), 'related variety' (cognitive complementarity) and 'unrelated variety' (cognitive distance) that are used to analyze the conditions under individuals and firms learn from each

other through interactions within organizations, and between organizational boundaries them (Timmermans and Boschma 2014).

In terms of the dynamics of organizational learning, what these contributions are currently doing is echoing, in their different yet complementary ways, March's (1991, p. 85) observation that convergence of individual beliefs towards the collective logic of the organization, as emphasized by the similarity attraction perspective and mirrored in the concept of 'cognitive proximity', is generally beneficial to performance because it strengthens the capacity to effectively execute specialized tasks, i.e. *exploit* the knowledge available. However, it comes at the cost of exploration, and with the risk of cognitive lock-ins, because individuals with deviating perspectives adjust to the dominant logic of the organization before the logic of the organization can respond to the new insights that individuals convey (March 1991). In these cases, as emphasized by the cognitive resource diversity perspective, the choices that organizations make concerning new products, production processes, markets and strategies may be severely restricted by choices made, and learning paths established, in the past.

2.3 The moderating role of innovation efforts

Ultimately, what firms do is transform the knowledge of individuals into collective capabilities that are expressed in the marketplace. Consequently, the compositional variety of firms' human resource bases cannot be assumed directly reflected in innovative output. Instead, it should depend on the efforts made at integrating and transforming these human resource bases into novel output i.e. on firms' investments in research, development and innovation. Over time, the size of these efforts will in themselves, through learning, influence firms' knowledge bases and routines, their capacity to coordinate internal resources and their ability to assimilate and exploit those that are at the outset external (Cohen and Levinthal 1990). This means that a stronger emphasis on innovation can be expected to be associated with more emphasis put on overcoming the communicative challenges involved in linking and integrating diverse cognitions, and, through absorptive capacity effects, a higher potential

for success in this respect. Conversely, diversity equals a broader range of internal resources for R&D departments or project groups to draw on (Grant 1996). This may increase the capacity of firms to translate the efforts of such into new technologies (exploration) or improvements of already existing products and production processes (exploitation).

While this suggests a complementary relationship between diversity and innovation efforts, substitution effects may also be at play. This is because the composition of firms' human resources bases in terms of educational backgrounds and prior work-life experiences may be more important to innovation in firms that have chosen not to engage in systematic development work, but that instead engage in continuous improvements of products, production processes and organizational as an integral part of their daily business operations (cf. the concept of "hidden" innovation, (e.g. Barge-Gil, Jesús Nieto, and Santamaría 2011)).

3. Empirical analysis

3.1 Data

The empirical analysis is based on data that cover innovation activities and outcomes in a representative sample of Norwegian firms during the three-year period 2008-2010. It was collected by Statistics Norway in 2010, as an extended version of the harmonized pan-European Community Innovation Surveys commonly abbreviated 'CIS' (Eurostat 2010). The questionnaire is based on the definitions of innovation input (R&D and non-R&D expenditures), external linkages (technology sourcing and innovation collaboration) and output laid out in the second revised edition of OECD`s Oslo Manual (OECD 2005). Additional information on individuals working in the firm in 2008, i.e. at the start of the reference period, has been gathered from Linked Employer-Employee Data (LEED).[4]

[4] CIS and LEED data are available for Statistics Norway, for research purposes only. Due to the sensitivity of information that is compulsory for sampled firms to provide, access to CIS data is subject to stricter regulations than access to LEED is. Permission to link data must be applied

The complete CIS2010 sample consists of 6595 enterprises in aquaculture, offshore oil & gas extraction, manufacturing industries, wholesale trade & transportation, hotels & restaurants, energy & infrastructure, construction and knowledge intensive business services (KIBS). To reduce sectoral heterogeneity beyond what can reasonably be accounted for by control variables, the analysis uses only observations in oil & gas, manufacturing and knowledge intensive business services industries. To allow computation of diversity measures at the beginning of the CIS reference period, it is moreover restricted to the 2942 enterprises sampled in 2010 that could be identified in the employment registers for 2008. Sample characteristics are summarized in Table 2 below.

3.2 Dependent variables

Three dependent variables are used in the analysis. The first is the binary variable ENGAGEMENT, which captures the decision to engage in systematic development work. Following the routing structure of the CIS questionnaire, it takes on the value 1 if the firm reported positive innovation expenditures (R&D or non-R&D), finalized, ongoing or abandoned innovation projects, or positive innovation outcomes during the period 2008-2010 (e.g. Ebersberger and Herstad 2012, Cassiman and Veugelers 2006).

The binary dependent variable EXPLORATION takes on the value 1 if the firm states, in the CIS, that it filed a patent application during the reference period. Thus, it builds on the assumption that patent applications express technological novelties to which the firm has actively contributed to developing, that as such can be viewed as reflecting explorative efforts. The binary dependent variable EXPLOITATION takes on the value 1 if a product innovation or a process innovation is reported, irrespective of patent applications. A product innovation occurred if the focal firm itself developed, or actively contributed to the development of, a new or significantly improved product (good or service) during the reference period (OECD 2005). Similarly, a process innovation occurred if the firm itself developed, or actively contributed to the development

for specifically. When granted, all data is delivered with identifiers that are unique to each research project and must be deleted upon completion.

of, new production processes or support functions[5] that were implemented by the firm. Thus, EXPLOITATION reflects attempts at exploiting commercially new combinations of knowledge, irrespective of technological novelty content but contingent on the active contribution of the firm.

3.3 The diversity construct

According to van Knippenberg and Schippers (2007, 534): "Diversity research needs to move beyond conceptualizations and operationalizations of diversity simply as dispersion on single dimension of diversity. Rather, it should conceptualize diversity as a combination of different dimensions of differentiation". In the context herein, this is reflected in a distinction between variety within (education or experience domains) and variety between (education and experience domains) based on the use of entropy measures (Jacquemin and Berry 1979).

Each individual working in the firm has been assigned a five-digit code that expresses their educational background, i.e. the type and level of education obtained. If each firm has n educational types present, represented by the categories (cf. Fevolden, Herstad, and Sandven 2015), then the total entropy for each firm is given by:

$$E_T = \sum_{i=1}^{n} P_i \ln \frac{1}{P_i}$$

were Pi is each category's proportion of the total number of individuals present within the firm. These categories are structured hierarchically as specialized sub-fields within main aggregate fields. If we have s main fields, and Ps is the proportion of employees in each main field, then the entropy across main fields is given by:

[5] At least one of the following types of innovations, as stated in the CIS questionnaire: i) new or significantly improved method of production, ii) new or improved method for storing and distributing goods and services, iii) new or significantly improved support function.

$$E_A = \sum_{i=1}^{s} P_s \ln \frac{1}{P_s}$$

Entropy within each main field is likewise given by:

$$E_w = \sum_{i \in s} \frac{P_i}{P_s} \ln \frac{P_s}{P_i}$$

The total entropy may be expressed in the following way (cf. Jacquemin and Berry pp. 361-362):

$$E_T = \sum_{i=1}^{n} P_i \ln \frac{1}{P_i} = \sum_{s=1}^{s} P_s \left(\sum_{i \in s} \frac{P_i}{P_s} \ln \frac{P_s}{P_i} \right) + \left(\sum_{s=1}^{s} P_s \ln \frac{1}{P_s} \right)$$

or

$$E_t = \sum_{s=1}^{s} P_s \, (E_w) + E_A$$

E_w is a weighted average of the entropy within each main educational field, were the weights are the proportion of employees in each of the educational classes present within the firm (i.e. the Ps defined previously). This is hereafter referred to as *related educational variety* (EDUVAR_REL). It expresses variety within clearly delineated educational fields, in which a certain overlap of cognitions, languages and identifies can be expected present. E_A is the entropy across main fields, and is in the following referred to as *unrelated educational variety* (EDUVAR_UNREL) because it expresses variety across fields that cannot be assumed to be characterized by common professional

identifies and overlapping languages. E_t equals the sum of the two, and thus the total educational variety of the focal firm (EDUVAR_TOT).

(Table 1 about here)

To capture experience diversity, matrixes describing the career paths of individuals during the five-year period ending in 2008, i.e. at the start of the CIS2010 reference period, have been generated, for each individual firm in the dataset. The firm in the example given in Table 1 had of 20 employees in 2008 and was engaged in the production of engines and turbines (NACE 28.110). Including 2008 and the four years prior to it gives 20 x 5 = 100 experience-years, of which 74 were associated with employment in the focal firms' sector (NACE 28.110). Due to unemployment, five person-years do not count as experience-years. The remaining 21 experience-years were generated in NACE 09.101 (oil & gas sector drilling services), NACE 24.421 (primary production of aluminum), NACE 24.422 (aluminum half-fabrics), NACE 26.110 (electronic components), NACE 26.200 (computers and equipment), NACE 26.300 (communication equipment) and NACE 62.101 (programming services). As the NACE codes are hierarchically ordered and consists of two-digit main groups with three-digit sub-groups, variety in terms of accumulated work-life experiences is expressed by entropy measures capturing the total (EXPVAR_TOT), related (EXPVAR_REL) and unrelated (EXPVAR_UNREL) experience variety of firms' workforces as described above.

(Table 2 about here)

3.4 Control variables

From the example in Table 1, it is evident that high employee turnover may lead to high experience diversity. High turnover rates, and thus low average organizational tenure (Bell et al. 2011), may work against innovation because it weakens the capacity of firms to accumulate knowledge and develop knowledge integration routines (Kleinknecht, van Schaik, and Zhou 2014, Zhou, Dekker, and Kleinknecht 2011, Herstad and Ebersberger 2014, DiMaggio and Powell 1983). Moreover, it reduces the probability that

individuals come to understand the social knowledge, values and expected behaviors necessary to assume an organizational role (Sturman 2003, DiMaggio and Powell 1983). As these effects may draw in different directions than experience diversity per se, the control variable REPLACEMENT is included. It captures the number of employees replaced during the 2008-2010 period as a proportion of employees present at the start of the period.

Organizations with higher overall education levels can be expected to outperform those with lower educational levels (Bell 2007, Herstad, Sandven, and Solberg 2013) as "innovation is a relatively more skill-intensive activity than imitation" (Vandenbussche, Aghion, and Meghir 2006, 97). Although education levels have also been investigated as a diversity variable in its own right (e.g. Amason, Shrader, and Tompson 2006), the distribution of employees across different education levels is not likely to increase the breadth of perspectives available for the firm to draw on beyond what is associated with educational variety (Bell et al. 2011). Thus, the variable EDULEVEL is included as a control that captures the mean educational level of the firms' workforce based on the 8-level scale used in the public registers.

The more employees that firms have, the larger can the entropy of experience and education be. As size increases, so does the probability of output from innovation processes, the paper follows conventions and include the logarithm of employment in 2008, i.e. the year for which diversity is observed, as a control (Grimpe and Kaiser 2010). Different industrial sectors are characterized by different incentives to engage in innovation activities, different output propensities and differences in the composition of human resource bases (cf. Table 2). Based on the NACE industry codes provided in the CIS and reflecting the technology intensity classes of OECD (Hatzichronoglou 1997), manufacturing firms are divided into 4 sector groups that are distinguished from the 6 main types of services provision covered by the CIS. Last, petroleum extraction industries are idiosyncratic to the Norwegian economy and classified as such. This gives 11 industries in total, which are represented by 10 industry dummies in the regressions (cf. Table 2). Market presence determines potential market size and diversity of market information exposure, and may therefore influence innovation (Crepon, Duguet, and Mairesse 1998, Ebersberger and Herstad 2011). Moreover, it provides the reference for when a product introduction is also a market novelty. MARBREADTH captures the share of

world regions specified in the CIS questionnaire on which the firm indicates a market presence.[6]

Innovation outcomes are strongly determined by the overall emphasis put by the firm on development work, which in turn may influence the capacity of firms to exploit diverse cognitions. To control for this, innovation expenditures are controlled for using the binary variable INNOVINT that takes on the value 1 if reported innovation expenditures per employee were above the sample median. The use of a binary measure is chosen over the option of a continuous measure to allow straightforward interpretation of interaction effects between INNOVINT and diversity (see Ebersberger and Herstad 2011 for a more elaborate discussion of this point).

Innovation output is also influenced by the extent to firms strategically uses knowledge and technology from collaboration partners (Grimpe and Kaiser 2010). Because different types of collaboration partners provide different yet potentially complementary types of knowledge (Ebersberger and Herstad 2011, Roper, Du, and Love 2008, Nieto and Santamarıa 2007), we follow prior studies (Laursen and Salter 2006, Grimpe and Kaiser 2010) in including a control included for the number of different collaboration partners used by the firm (COBREADTH) during the reference period.[7] Both innovation strategy controls are constructed from CIS data.

[6] The options included in CIS: Local/regional in Norway, elsewhere in Norway, Other EU, EFTA or EU candidate countries, and other countries.

[7] The options given are: Other units within parent enterprise group, clients, suppliers, competitors, consultancy firms, universities and other higher education institutions, commercial R&D laboratories, private and public R&D institutes.

3.5 Econometric approach

In the first stage of the analysis, probit regression models are used to estimate the dependent variable ENGAGEMENT using only information available for all firms (N = 2942). The estimations are first conducted with the measures for total diversity included (Model 1), and then with diversity split into related and unrelated (Model 2). In the second stage, bivariate probit regression models are used to estimate EXPLORATION and EXPLOITATION simultaneously (cf. Herstad, Sandven, and Ebersberger 2015), thus allowing conditional marginal effects to be estimated. This stage of the analysis include only the engaged firms (N=1450). Technically, this restriction is necessary because only engaged firms provide information on innovation expenditures and collaboration.[8] More substantially, implementing it acknowledges that human resource diversity may influence the decision to engage in development work, the types of innovation capacities built and outcomes form this work in fundamentally different ways.

For the sake of transparency, estimations in Table 5 and Table 6 are first conducted using only background information on the firm and total diversity measures (Model 3). Innovation strategy controls are then included (Model 4), before interactions between INNOVINT and the two measures of total diversity are included (Model 5). Diversity is then divided into related and unrelated educational and experience variety (Model 6). In the last set of estimations (Model 7), it is assumed that the capacity of firms to translate diverse human resources into support for knowledge exploration and exploitation activities depend on the emphasis put on development work, i.e. on INNOVINT. The size of effects are difficult to determine from probit coefficients (Hoetker 2007), in particular when interaction terms are involved (Ebersberger and Herstad 2011, Ai and Norton 2003). Therefore, average marginal effects of diversity contingent on innovation intensity are reported in Table 7 and interpreted

[8] This translates into a risk that estimates are biased by unobserved determinants of sample selection, i.e. of the decision to engage. To acknowledge this, supplementary regressions have been estimated using the two-step procedure of Heckman (1979). In these estimations, the results remain structurally consistent with those reported and discussed below. Due to the absence of the instrumental variable needed to ensure that the procedure does not build serious multicollinearity into the models, it is not implemented in the reported regressions (cf. Puhani 2000).

against the background of predicted innovation outcome probabilities at different levels of diversity.

4. Results

Model 1 reported in Table 3 finds ENGAGEMENT positively associated with the size and average educational level of the firm, and with the breadth of its market presence. It is found to be negatively associated with the replacement rate. This suggests either that high replacement rates reduces the *need* to engage in development work, due to learning-by-recruitment effects, or reduces the incentives of firms to engage due to appropriability problems associated with high outflows of knowledge (cf. Herstad and Ebersberger 2014, Suarez-Villa and Walrod 1997). (Table 3 about here)

Generally, ENGAGEMENT is positively associated with human resource diversity, and most consistently so with educational variety. When the distinction between related and unrelated variety is implemented in Model 2, positive and significant estimates are obtained for related educational variety and unrelated experience variety. Not only does this underline the importance of making this distinction, it also suggests that innovation active firms tend to employ individuals with diverse work-life experiences and related educational backgrounds.

Table 4 describes the distribution of innovation outcomes, for engaged firms only. The most common outcome observed is the introduction of a product or process innovation during the period (EXPLOITATION = 1), without any patent applications filed (EXPLORATION = 0). This highlights the need for caution when patent data is used to describe the innovation capacities of firms (e.g. Herrera, Munoz-Doyague, and Nieto 2010), and substantiate the relevance of distinguishing between the two fundamentally different outcomes (e.g. Herstad, Sandven, and Ebersberger 2015).

(Table 4 about here)

Table 5 reports the estimations of EXPLORATION (Equations A). The base Model 3 finds exploration positively and significantly associated with total

experience variety within the firm. The inclusion of controls for innovation strategy in Model 4 (Equation A) does not structurally alter this, beyond underscoring the importance of commitment to innovation and partner contributions to development work. When interaction effects are included in Model 5, base and interaction estimates for innovation expenditures are all insignificant. This suggests that the impact of such expenditures on knowledge exploration efforts are dependent on human resource characteristics that are not captured consistently by the two overall diversity measures.

(Table 5 about here)

This, in turn, underscores the importance of distinguishing between related and unrelated variety. When implemented in Models 6 and 7, the results find the probability of patent application increasing with unrelated experience variety. A positive and weakly significant base effect of unrelated educational variety is also obtained; yet, the interaction with innovation expenditures is negative and strongly significant. Thus, individuals with diverse educational backgrounds strengthen the knowledge exploration capacities of firms that are not strongly committed to innovation. By contrast, committed firms are able to explore human resources that are diverse in terms of work-life experiences, but should not be excessively diverse in terms of the professional identities and background knowledge that individuals have gained through education.

(Table 6 about here)

Estimations of EXPLOITATION capacity (Equation B) are reported in Table 6. The base Model 3 finds this aspect of innovation capacity associated foremost with the breadth of market presence, and not influenced by total educational or experience variety. The importance of investments in innovation and the active contribution of collaboration partners is evident from Model 4, and a strongly significant interaction effect is obtained between INNOVINT and EDUVAR_TOT in Model 5. Model 6 finds innovation output positively associated with related experience variety only, while Model 7 suggests that the positive effects of INNOVINT on the probability of innovation is conditional on unrelated educational variety.

The strong and positive sign of the interaction is highly notable, because it is contrary to the negative and significant interaction effect obtained in the mirroring estimation of inventive output (Model 7 Equation A). These results align with prior recent research linking labor market mobility to performance dynamics at the firm level (Timmermans and Boschma 2014, Boschma, Eriksson, and Lindgren 2009, Herstad and Ebersberger 2015) and growth dynamics at the regional level (Boschma, Eriksson, and Lindgren 2014, Neffke, Henning, and Boschma 2011). Another striking contrast between Equations A (EXPLORATION) and Equations B (EXPLOITATION) is the absence of significant estimates for average educational levels in the latter set, compared to the highly significant estimate obtained in the former. Consequently, EXPLORATION is more dependent on formal qualifications than EXPLOITATION is.

4.1 Detailed predicted probability and marginal effects analysis

As stated above, the size and substantial relevance of effects are difficult to determine directly from probit coefficient estimates (Hoetker 2007), in particular when base and interaction effects must be evaluated jointly (Ai and Norton 2003, Ebersberger and Herstad 2011). To circumvent this problem, average marginal effects of educational and experience variety have been computed conditional on innovation intensity. Consider first knowledge exploration capacity. As was evident from the absence of a significant interaction effect in Model 7, it is positively associated with unrelated experience variety in both sub-samples. For the sample as a whole, the estimated increase in the probability of inventive output is from 14 per cent at zero experience variety, through 23 per cent at the mean and up to 39 per cent at the cut-point for the 99^{th} percentile. This equals a factor of 1.64, or a 64 per cent increase in the probability.

The negative interaction between unrelated educational variety and innovation expenditures translate into a significantly positive average marginal effect of variety amongst firms with a low commitment to innovation, and a zero average marginal effect among the more committed firms. Thus, it does not weaken the knowledge exploration capacity of firms that are financially committed to

innovation, but strengthens this capacity among firms that are not. In the latter group, the probability of inventive output increases from an estimated 12 per cent at zero educational variety, through 20 per cent at the sub-sample mean and up to 26 per cent at the cut-point for the 99th percentile. Thus, the probability more than doubles.

(Table 7 about here)

Consider then the probability of innovation, i.e. EXPLOITATION = 1. In the sub-sample of firms with a weak financial commitment to innovation, the actual probability increases from an estimated 54 per cent at zero related experience variety, to 57 per cent at the sample mean and up to 70 per cent at the 99th percentile cut point. Thus, in this range, it increases by a factor of 1.3 and translate into a significant average marginal effect of related experience variety only. This effect is absent among firms that exhibit higher levels of commitment to innovation. This commitment, however, instead allow firms to translate educational variety into an increase in the probability of innovation from 55 per cent at zero variety, through 67 per cent at the sub-sample mean to 73 per cent at the cut-point for the 99th percentile, i.e. by a factor of 1.33.

The last set of average marginal effect estimates displayed in Table 7 show that the probability of co-occurring EXPLORATION and EXPLOITATION, approximating the concept of 'ambidexterity', is positively and significantly associated with unrelated experience variety, and that this effect is independent of firms' financial commitments to innovation. When this conditional probability is predicted for the sample as a whole, the estimated increase is from 9 per cent at zero unrelated experience variety, through 14 per cent at the sample mean to 23 per cent at the cut-point value for the 99th percentile. This equals an increase by an impressive factor of 2.67, and means that 'ambidextrous' organizations are those that have accumulated a broad range of experience-based knowledge.

5. Discussion and concluding remarks

Reflecting the cumulative, collective and multi-faceted nature of organizational learning, this paper has investigated how the overall composition of firms' human resource bases in terms of education and experiences is reflected in their performances as innovators. The baseline selection Models 1 and 2 found firms that are engaged in innovation activities to be characterized by more diverse human resources, than firms that are not. From the subsequent outcome regressions, a first and overarching conclusion is that knowledge "exploitation" (operationalized as the capacity to introduce new products and production processes) depends on different human resources and organizational processes than knowledge "exploration" (operationalized as technological development expressed through patent output) does. Consequently, neither innovation capacities per se, nor the resources on which they depend, can be conceptualized and captured empirically as one-dimensional constructs.

The results obtained are clearly consistent with the view that exploration benefits from diversity of human resources, as emphasized by the cognitive resource diversity perspective (Horwitz 2005) and in Marchs' (1991) original contribution. Both unrelated educational variety and unrelated experience variety yield positive average marginal effect estimates for exploration among firms that are not strongly committed to innovation. Further underscoring the importance of knowledge gained through prior employment, the exploration capacities of firms with a higher commitment to innovation is strengthened only by the unrelated experience variety of their employees. In essence, this suggests that variety in terms of education serve as a functional substitute for R&D efforts in the explorative efforts of firms that have not engaged in such.

Exploitation, on the other hand, depends on efforts aiming at adapting technology to specific contexts of applications, and refining highly specialized skill bases, organizational practices and business strategies. This can be understood through the lenses of the similarity attraction perspective (Horwitz 2005), which emphasizes that common languages and similarity of knowledge serve to smooth the complex interactions on which ongoing work processes in advanced industrial organizations depend, and align with the recent focus of evolutionary economic geography on 'related variety'. Consistent with this, the

estimate for related experience diversity was positive and highly significant for firms with a low financial commitment to innovation. Still, among more committed firms, only a weakly significant estimate is obtained for unrelated educational variety. This suggests that the actual efforts of these firms reduces their sensitivity to human resources.

Finally, it is evident that ambidexterity, i.e. the ability to combine exploration and exploitation, depend strongly on unrelated *experience* variety. To research and innovation policy, this has three important implications. First, it underscores the relevance of moving beyond the common focus of innovation studies on the interactions of firms, towards a supplementary focus on the interactions of individuals within and between them (Rutten and Boekema 2012), and thus on the knowledge dynamics of on-the-job learning and labor market mobility. By doing so, and second, it contributes to research on the path-dependent nature of industrial development new micro-level insights into how different aspects' of firms learning and innovation processes are influenced by the human resources that they have access to, in their locations, as externalities of surrounding industrial configurations and the education choices that individual make. Following from this, and finally, it demonstrates that empirical analyses treating organizational learning and innovation as one-dimensional constructs are at risk of severely underestimating the complexity of the interplay between human resources and corporate strategies that shape the commercial performances of firms, and, ultimately, the human resource bases of territorial economies.

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Table 1: Example of experience diversity matrix. Firm with 20 employees.

Year of observation		Sector of employment in prior years			
Employee no	**2008**	**2007**	**2006**	**2005**	**2004**
1	28.110	09.101	09.101	09.101	09.101
2	28.110	28.110	28.110	28.110	28.110
3	28.110	28.110	62.020	62.020	62.020
4	28.110	28.110	28.110	28.110	28.110
5	28.110	28.110	28.110	28.110	28.110
6	28.110	28.110	*unemployed*	*unemployed*	*unemployed*
7	28.110	28.110	28.110	28.110	28.110
8	28.110	28.110	28.110	62.020	62.020
9	28.110	28.110	28.110	28.110	28.110
10	28.110	28.110	28.110	28.110	28.110
11	28.110	28.110	28.110	28.110	28.110
12	28.110	28.110	28.110	*unemployed*	*unemployed*
13	28.110	28.110	28.110	28.110	28.110
14	28.110	28.110	28.110	28.110	28.110
15	28.110	28.110	24.421	24.421	24.421
16	28.110	24.422	24.422	24.422	24.422
17	28.110	28.110	28.110	26.110	26.200
18	28.110	28.110	28.110	28.110	28.110
19	28.110	28.110	26.300	26.300	26.300
20	28.110	28.110	28.110	28.110	28.110

Unrelated experience diversity (Entropy of distribution between 2-digit groups)	0,830069
+ Related experience diversity (Entropy of distribution within 2-digit groups)	0,100334
= Total experience diversity (Entropy of distribution between 5-digit groups	0,930403

Table 2: Description of sample.

	All observations					ENGAGED firms only		
	Sample	EDUVAR_REL	EDUVAR_UNREL	EXPVAR_REL	EXPVAR_UNREL	Sample	EXPLORATION	EXPLOITATION
Oil & gas. Mining	0.052	**0.632**	1.083	**0.167**	**1.189**	0.033	**0.521**	0.521
HT manufacturing	0.034	**0.552**	1.090	0.138	**0.915**	0.055	**0.450**	**0.725**
MHT manufacturing	0.105	0.411	1.032	0.109	0.912	0.149	**0.389**	**0.681**
MLT manufacturing	0.213	0.389	1.031	0.105	0.818	0.182	**0.258**	**0.686**
LT manufacturing	0.181	0.344	**1.135**	0.132	0.663	0.161	0.116	0.622
Publishing & printing	0.087	**0.570**	**1.392**	**0.147**	**0.992**	0.087	0.119	**0.675**
Telecom & ICTs	0.109	**0.552**	**1.184**	**0.195**	**1.134**	0.135	0.112	0.587
Finance & real-estate	0.071	**0.569**	**1.172**	**0.170**	0.906	0.044	0.016	0.469
Professional services	0.028	**0.574**	1.072	0.135	**1.352**	0.032	0.239	**0.630**
Scientific & technical serv.	0.093	0.591	0.893	0.145	1.050	0.110	**0.358**	0.547
Other business services	0.028	**0.493**	**1.198**	0.121	**0.965**	0.012	0.111	0.389
All	1	0.474	1.105	0.138	0.919	1	0.240	0.626
	(N=2942)					(N=1450)		

Note: Above country averages in bold.

Table 3: The probability of ENGAGEMENT = 1.

	Model 1		**Model 2**	
	Coeff	*SE*	*Coeff*	*SE*
SIZE	0,112	0,025***	0,109	0,026***
MARBREADTH	0,337	0,025***	0,336	0,025***
EDULEVEL	0,220	0,035***	0,201	0,038***
REPLACEMENT	-0,571	0,191***	-0,562	0,191***
EDUVAR_TOTAL	0,211	0,067***		
EXPVAR_TOTAL	0,094	0,052*		
EDUVAR_REL			0,360	0,119***
EDUVAR_UNREL			0,124	0,088
EXPVAR_REL			-0,233	0,190
EXPVAR_UNREL			0,165	0,064***
LR Chi2 (df)	621.40(16)***		626.93(18)***	
Pseudo R2	0.1524		0.1537	

Note: Coefficient estimates and robust standard errors from probit regression models. ***. ** and * indicate significance at 1 per cent. 5 per cent and 10 per cent levels respectively. 10 jointly significant sector controls are included but not reported.
N= 2942

Table 4: Distribution of inventive and innovative outcomes.

	EXPLORATION = 0	EXPLORATION = 1	Sum
EXPLOITATION = 0	456	85	541
EXPLOITATION = 1	646	263	909
Sum	1102	348	1450

Table 5: The probability of EXPLORATION = 1.

	Model 3 Equation A		Model 4 Equation A		Model 5 Equation A		Model 6 Equation A		Model 7 Equation A	
	Coeff	*SE*	*Coeff*	*SE*	*Coeff*	*SE*	*Coeff*	*SE*	*Coeff*	*SE*
Equation A: EXPLORATION										
SIZE	0.167	0.036***	0.144	0.037***	0.144	0.037***	0.161	0.039***	0.164	0.039***
MARBREADTH	0.134	0.039***	0.118	0.039***	0.118	0.039***	0.117	0.039***	0.117	0.039***
EDLEVEL	0.253	0.056***	0.217	0.057***	0.220	0.056***	0.233	0.062***	0.241	0.061***
REPLACEMENT	-0.469	0.320	-0.409	0.320	-0.410	0.325	-0.460	0.321	-0.442	0.328
INNOVINT			0.182	0.079**	0.561	0.342	0.181	0.079**	0.773	0.362**
COBREADTH			0.069	0.019***	0.068	0.019***	0.069	0.019***	0.068	0.019***
EDUVAR_TOT	-0.049	0.116	-0.052	0.116	0.124	0.160				
EXPVAR_TOT	0.351	0.082***	0.357	0.082***	0.291	0.111***				
INNOVINT*EDUVAR_TOT					-0.328	0.203				
INNOVINT*EXPVAR_TOT					0.138	0.159				
EDUVAR_REL							-0.146	0.182	-0.153	0.252
EDUVAR_UNREL							0.008	0.149	0.362	0.212*
EXPVAR_REL							-0.103	0.344	-0.433	0.417
EXPVAR_UNREL							0.434	0.102***	0.429	0.138***
INNOVINT*EDUVAR_REL									0.006	0.300
INNOVINT*EDUVAR_UNREL									-0.647	0.273**
INNOVINT*EXPVAR_REL									0.621	0.627
INNOVINT*EXPVAR_UNREL									0.030	0.192
Walds Chi2(df)	238.96(32)***		311.18(36)***		318.20(40)***		319.71(40)***		333.16(48)***	

Note: Coefficient estimates from bivariate probit regressions, equation A. Model statistics are for the full models.
***. ** and * indicate significance at 1 per cent. 5 per cent and 10 per cent levels respectively. 10 jointly significant sector controls are included but not reported.
N= 1450

Table 6: The probability of EXPLOITATION = 1.

	Model 3 Equation B		Model 4 Equation B		Model 5 Equation B		Model 6 Equation B		Model 7 Equation B	
	Coeff	*SE*	*Coeff*	*SE*	*Coeff*	*SE*	*Coeff*	*SE*	*Coeff*	*SE*
SIZE	0.007	0.033	-0.036	0.035	-0.034	0.035	-0.040	0.036	-0.039	0.036
MARBREADTH	0.081	0.033**	0.058	0.033*	0.059	0.033*	0.062	0.034*	0.062	0.033*
EDLEVEL	0.059	0.048	0.004	0.049	0.003	0.049	0.017	0.054	0.015	0.054
REPLACEMENT	0.232	0.277	0.279	0.283	0.266	0.284	0.284	0.282	0.269	0.284
INNOVINT			0.181	0.070***	-0.380	0.293	0.184	0.070***	-0.473	0.307
COBREADTH			0.130	0.020***	0.130	0.020***	0.131	0.020***	0.132	0.020***
EDUVAR_TOT	-0.010	0.097	-0.017	0.099	-0.191	0.126				
EXPVAR_TOT	0.078	0.071	0.080	0.072	0.096	0.095				
INNOVINT*EDUVAR_TOT					0.367	0.169**				
INNOVINT*EXPVAR_TOT					-0.040	0.138				
EDUVAR_REL							-0.111	0.167	-0.218	0.206
EDUVAR_UNREL							0.038	0.124	-0.197	0.165
EXPVAR_REL							0.541	0.269**	0.696	0.343**
EXPVAR_UNREL							-0.011	0.088	-0.032	0.117
INNOVINT*EDUVAR_REL									0.227	0.256
INNOVINT*EDUVAR_UNREL									0.492	0.226**
INNOVINT*EXPVAR_REL									-0.367	0.523
INNOVINT*EXPVAR_UNREL									0.038	0.164

Note: Coefficient estimates from bivariate probit regressions, equations B. Model statistics are given in Table 4.

***. ** and * indicate significance at 1 per cent. 5 per cent and 10 per cent levels respectively. 10 jointly significant sector controls are included but not reported.

N= 1450

Table 7: Average marginal effects of cognitive diversity.

	Subsamples			
	INNOVINT = 0		INNOVINT = 1	
Mode 7 Equation A: EXPLORATION				
	Marg. Eff	*SE*	*Marg. Eff*	*SE*
EDUVAR_REL	-0.035	0.058	-0.041	0.063
EDUVAR_UNREL	0.084	0.049*	-0.080	0.054
EXPVAR_REL	-0.100	0.097	0.053	0.139
EXPVAR_UNREL	0.099	0.032***	0.130	0.039***
Mode 7 Equation B: EXPLOITATION				
	Marg. Eff	*SE*	*Marg. Eff*	*SE*
EDUVAR_REL	-0.081	0.076	0.003	0.073
EDUVAR_UNREL	-0.073	0.061	0.100	0.058*
EXPVAR_REL	0.258	0.126**	0.112	0.138
EXPVAR_UNREL	-0.012	0.043	0.002	0.042
Model 7: EXPLORATION & EXPLOITATION				
	Marg. Eff	*SE*	*Marg. Eff*	*SE*
EDUVAR_REL	-0.038	0.042	-0.029	0.051
EDUVAR_UNREL	0.043	0.036	-0.034	0.042
EXPVAR_REL	-0.022	0.069	0.066	0.116
EXPVAR_UNREL	0.064	0.024***	0.095	0.032***

Table A1: Descriptive statistics & correlations. Engaged enterprises only.

		Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13
1	EXPLORATION	0,240	0,427	0	1	1												
2	EXPLOITATION	0,627	0,484	0	1	0,150	1											
3	SIZE	3,968	1,183	2,303	9,771	0,147	0,004	1										
4	MARBREADTH	2,671	1,072	1,000	4	0,180	0,085	-0,001	1									
5	EDULEVEL	4,492	1,089	2,429	7,5	0,102	-0,024	-0,181	0,097	1								
6	REPLACEMENT	0,184	0,128	0	1	-0,081	0,025	0,190	-0,045	-0,147	1							
7	INNOVINT	0,492	0,500	0	1	0,100	0,100	-0,003	0,092	0,055	-0,031	1						
8	COBREADTH	1,229	2,011	0	7	0,212	0,185	0,001	0,148	0,062	-0,056	0,107	1					
9	EDUVAR_TOT	1,648	0,421	0	2,864	0,022	-0,003	0,115	0,030	0,220	0,052	0,045	0,044	1				
10	EXPVAR_TOT	0,527	0,274	0	1,523	0,107	-0,015	0,037	0,094	0,500	-0,091	0,051	0,145	0,679	1			
11	EDUVAR_REL	1,122	0,309	0	1,886	-0,066	0,010	0,124	-0,042	-0,145	0,151	0,015	-0,069	0,759	0,036	1		
12	EDUVAR_UNREL	1,106	0,517	0	2,791	0,128	0,015	-0,284	0,042	0,268	0,087	0,012	0,019	0,209	0,184	0,121	1	
13	EXPVAR_REL	0,143	0,142	0	1,172	0,022	0,030	-0,154	-0,028	0,104	0,044	-0,028	0,013	0,190	0,150	0,125	0,565	1
14	EXPVAR_UNREL	0,963	0,453	0	2,535	0,139	0,008	-0,277	0,057	0,273	0,085	0,022	0,018	0,179	0,164	0,099	0,966	0,332

Note: N = 1450

Paper II

FOREIGN WORKERS ARE ASSOCIATED WITH INNOVATION, BUT WHY? INTERNATIONAL NETWORKS AS A MECHANISM

Marte C.W. Solheim
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Abstract

While there is a wealth of empirical research examining the potential relations and effects of foreign workers, immigration and cultural diversity on wages, employment, economic growth and – in recent years – innovation, very little of this research has provided a convincing empirical demonstration of the mechanisms through which foreign workers would affect innovation. Most accounts hypothesise that foreign workers provide a different perspective that contributes to a diversity of ideas in the firm, while some also add the idea that foreign workers might help a firm build international networks. Nonetheless, these mechanisms have for the most part remained entirely theoretical, with few attempts being made at uncovering the intermediary relationships. This paper contributes to filling this gap by focusing on the second of these mechanisms, asking whether firms that employ foreign workers also have broader international networks and whether this may, in turn, promote innovation through access to new knowledge. The paper builds on survey data from approximately 500 firms in Norway with more than ten employees, covering all sectors and regions. We find evidence that firms with highly educated foreign workers collaborate more frequently with international partners, and that there is a positive relation between having a variety of international partners and the probability of product innovation and new-to-market product innovation.

Keywords: Foreign workers, innovation, networks, diversity, Norway.

Introduction

The relationship between foreign workers and innovation has been a hot topic in the literature in recent years, as growing international mobility is making firms and regions more diverse. The literature concerning foreign workers is partly concerned with migration/immigration and partly with diversity. One common focus across the varied literature is that immigration produces cultural diversity, which is thought to promote new ideas and perspectives (Ottaviano and Peri 2006, Nathan and Lee 2013), but also potentially to increase conflicts and reduce trust (Jehn, Northcraft and Neale 1999, Bandiera, Barankay and Rasul 2005, Putnam 2007). Previous studies have addressed this issue at various scales, from work groups (Chatman and Flynn 2001, Joshi and Roh 2009) via firms (Lee and Nathan 2010, Østergaard Timmermans, and Kristinsson 2011) to regions (Niebuhr 2010, Kemeny 2012) and countries (Easterly and Levine 1997, Hart 2007), and in some cases at multiple scales (Trax, Brunow and Suedekum 2013, Lee 2014). Although the majority of contributions tend to find support for the idea that foreign workers and/or the diversity being produced as a consequence are conducive to innovation (e.g. Shore et al, 2009, Ozgen, Nijkamp and Poot 2013), the bag of evidence is still somewhat mixed. Other studies suggest that the effects might depend on characteristics of the immigrants, such as their skill levels (Borjas 1990, Suedekum, Wolf and Blien 2014).

While many studies can show a positive empirical association between cultural/immigrant diversity and innovation, the theoretical understanding of this relationship is based on a number of hypotheses about potential mechanisms through which the causal effect might work. These mechanisms have, however, not been subjected to the same level of empirical scrutiny. As Kemeny (2014, 34) notes in an extensive review of the literature on this topic, "[t]he appeal of demonstrating positive effects of immigration in cities is clear. But as social scientists, the primary goal must be to improve our understanding of the underlying mechanism". Until research in this area can demonstrate the mechanisms at play in the relationship between immigration and innovation, the hypothesis will remain a nice, but perhaps somewhat naïve idea, based on potentially spurious empirical associations.

The literature on the relationship between immigration and innovation focuses on two main mechanisms. The first, and by far the most prevalent, is that foreign workers bring cultural diversity, which is thought to provide a new and different view to the company and the region (Shore et al, 2009). Foreign workers add skills and perspectives that are new to the firm, providing a variety of perspectives that are important in triggering new knowledge, or what

Kanter (1968) has termed kaleidoscope thinking. This is related to Schumpeter's classical definition of innovation as new combinations of new and existing knowledge and resources.

However, a major issue with this line of thinking is that "it is assumed that one's birthplace indicates in some meaningful way one's manner of approaching the world" (Kemeny 2014, 32). This is an assumption that has never been convincingly tested, and none of the literature on this has empirically demonstrated either the relationship between birthplace and a different way of thinking, or between within-group differences in ways of thinking and innovation[1]. An equally probable mechanism might be that "rather than some inbuilt culture-specific characteristics, foreign-born individuals enjoy international social connections to which natives lack access" (Kemeny 2014, 33). Indeed, other contributions have also shown that a more diverse workforce can help the firm to exploit and make use of external knowledge and extract it from more diverse source bases (Østergaard, Timmermans and Kristinsson 2011). For instance, Saxenian (2006) discusses how migrants in Silicon Valley built up social networks that proved vital in their continued work when returning home. This ability of migrants to access networks in different parts of the world could significantly expand the firm's search scope.

This paper continues this line of reasoning by examining international networks as a potential mechanism in the relationship between immigration and innovation. We examine whether firms that employ foreign workers connect with a more diversified set of international partners in their innovation processes, and whether this is, in turn, associated with higher probability of innovation in these firms. Addressing this question might provide one building block in empirically establishing the mechanisms that can account for the observed relationship between immigration and innovation.

The paper is structured into four sections: The first section presents the theoretical framework and hypotheses. This theoretical framework focuses on three dimensions: The relationship between foreign workers and innovation; the relationship between foreign workers and international networking; and the relationship between international networking and innovation. Second, we introduce the empirical framework, and thirdly, the data, descriptive statistics and models. The final section presents the results of a series of regression analyses

[1] A recent exception is Desmet, Ortuño-Ortín and Wacziarg (2015), who examine the first part of this relationship, finding that while ethnicity is significantly related to cultural attitudes, it account for only a very small share of the variation.

of the relationship between foreign workers and international collaboration, and between international collaboration and innovation, leading up to the concluding remarks.

Establishing a mechanism for the relationship between foreign workers and innovation

This paper aims to fill a gap in the literature by empirically demonstrating a mechanism by which immigration and the resulting presence of foreign workers might affect innovation at the firm level. While the dominant interpretation in the literature is that the presence of foreign workers promotes a diversity of perspectives and ideas, this paper focuses on a different mechanism, which has hitherto received relatively little attention in the literature: The idea that foreign workers have international connections and/or a set of intercultural and language skills that help them make such connections, and that these connections may in turn promote the firm's potential for innovation (Rauch 1999, Rauch and Trindade 2002, Saxenian 1999). In order to explain why we expect these mechanisms to hold, this section reviews the literature and existing empirical evidence on the relationships between each set of the variables: Firstly, between immigration and innovation; secondly, between immigration and international networks; and thirdly, between international networks and innovation.

Why would foreign workers affect innovation?

There is by now a considerable literature examining the relationship between immigration and innovation both at the firm and the regional level (see e.g. Nijkamp and Poot 2015 for a recent review). A common theme in this literature is that "surface-level" diversity in country background is hypothesised to reflect deeper-level differences, such as "cognitive processes/schemas, differential knowledge base, different sets of experiences, and different views of the world" (Shore et al, 2009, 118). Foreign workers might therefore bring in different perspectives from natives, as they would have a different background and possibly outlook on how to solve problems. When individuals with different knowledge and backgrounds interact, they may stimulate and help each other to stretch their knowledge for the purpose of bridging and connecting diverse knowledge (Nooteboom et al, 2007). This is a purpose not only useful, but also vital for innovation.

To what extent do foreign workers contribute with a different view? This relationship has remained mainly in the theoretical realm and has been the subject of little direct empirical scrutiny. Desmet, Ortuño-Ortín and Wacziarg (2015) find that there is a significant relationship between ethnic background and cultural attitudes, but the within-group differences are much larger than those between groups. Previous contributions on the effects

of foreign workers on economic outcomes have mostly examined this association directly, leaving the establishment of the causal mechanisms mainly to theoretical speculation. Empirical studies of the relationship have mostly focused on wages and employment, for instance how foreign workers affect the unemployment rate of natives (Foged and Peri 2015). Studies of the relationship with innovation outcomes directly are a relatively recent phenomenon, but contributions by Niebuhr (2010), Ozgen, Nijkamp and Poot (2011), Nathan and Lee (2013), among others, have helped to fill in this gap. For the most part, these studies find a positive association between the two phenomena, although several studies find no significant effects or significant effects only for some groups (e.g. Østergaard, Timmermans and Kristinsson 2011, Parrotta, Pozzoli, and Pytlikova, 2014, Ozgen et al, 2014).

The impact of foreign workers should also not be viewed through rose-tinted spectacles. Too much internal heterogeneity also has potential costs, for instance in terms of language barriers, conflicts, internal clashes and distrust. These issues could harm collaboration within the firm and consequently lead to less innovation (Basset-Jones 2005, Parrotta, Pozzoli and Pytlikova 2014). In some cases, foreign and domestic workers self-organize into two different groups within the firm, with little bridging across the groups. This could impede their opportunities for contributing in the various processes leading up to innovation. Foreign workers might also experience discrimination and non-transferability of their skills, as well as a lack of recognition of their qualifications, which "can be barriers to free exchange of ideas and the accumulation of new knowledge" (Ozgen, Nijkamp and Poot 2013, 1) and may increase conflict levels (Williams and O'Reilly 1998, Jehn, Northcraft and Neale 1999). Some conflict might be good for innovation, but too much conflict is almost certainly harmful.

Why would foreign workers affect international networking?

While the mechanisms discussed above are certainly plausible as an explanation for the relationship between immigration and innovation, they remain fraught with controversy. It is hard to demonstrate empirically that foreign workers really have different cognitive schemes and perspectives in ways that would matter for innovation. Arguably, different educational backgrounds or employment histories might be at least as important as country of origin in shaping work-related perspectives. A perhaps less controversial assumption, which has nonetheless received very scant attention in the literature so far, is that foreign workers might help the firm to establish international connections and networks. This could be the result either of their own personal or professional networks, which almost by definition span

multiple countries, or because they provide a set of skills that are useful in connecting to and collaborating with international partners, whether in terms of foreign language command, knowledge of foreign cultures or experience from working in a different cultural environment.

Ultimately, the relationship between foreign workers and international networking is an empirical question. However, to the best of our knowledge, little research has been carried out on this relationship. Nonetheless, some studies have pointed to the role of employee diversity in broadening the search scope of the firm (Østergaard and Timmermans 2012, Østergaard, Timmermans and Kristinsson 2011, Parrotta, Pozzoli and Pytlikova 2014). There are two reasons for expecting such a relationship. Firstly, foreign workers bring with them their own personal and professional networks, which might be very different from the networks of domestic workers in terms of geographical scale and scope. Secondly, foreign workers also possess cultural and linguistic skills that may enable firms to collaborate with partners outside the individual network of the employee. Certainly, all foreign workers will have knowledge and understanding of the language and culture of their country of origin, which might be valuable to the firm in creating effective partnerships there. By definition, foreign workers also have experience from working in a different cultural context, which provide a level of understanding of intercultural issues that could prove helpful in connecting with partners also from different cultural contexts.

Foreign workers might be able to compensate for the geographical distance inherent to international networks with a greater sense of social and institutional proximity to international partners (Saxenian 2006, Usai, Marrocu and Paci 2015). If they perceive their personal network as close in a social sense, this might make up for the geographical distance, and similarly, increased social and institutional distance to local partners might reduce collaboration at the local scale. Thus, in a social sense, international partners may seem closer than regional ones, as is arguably the case for Saxenian's (2006) New Argonauts in Silicon Valley. There are many challenges linked to finding a successful partner in relation to enhancing innovation. One important element is mutual understanding, which is important for successful collaboration. However, too much familiarity may hamper innovation, and the challenge is rather to find partners "at sufficient cognitive distance to tell something new, but not so distant as to preclude mutual understanding" (Nooteboom et al, 2007, 1017). In sum, more diversity might lead to more cooperation, as foreign workers bring with them new perspectives, resources and potential and existing networks.

However, the benefits of foreign workers might not hold for all types of workers. Several studies find that the impact of foreign workers on economic outcomes depends on the characteristics of those migrating, in particular their skill levels (Kangasniemi et al, 2009, Bratsberg, Raaum and Røed 2014). Human capital might matter for the relationship between foreign workers and international networking for two main reasons: Firstly, foreign workers that are highly educated may have more to contribute in networking processes. The role of workers as the primary vehicle for knowledge generation and innovation networking is often linked to a more educated workforce "as innovation is a relatively more skill-intensive activity than imitation" (Vandenbussche, Aghion and Meghir 2006). Secondly, highly educated workers typically have positions of more responsibility, in which they are more able to participate in innovative processes, whereas less educated workers may conduct more manual labour, which may be more or less detached from innovation processes. This might particularly be the case for foreign workers, who more frequently hold positions below their qualification levels (Chiswick and Miller 2008, Nielsen 2011), and who may therefore need higher levels of formal education than natives do to reach positions of influence in the firm.

Furthermore, foreign workers might be particularly important for firms that lack other channels for connecting to international partners. Multinational enterprises that have operations in many countries may employ many expatriate workers at each location, but their presence at different locations could still prove more important in connecting to partners at each site. Conversely, firms that have operations in only one country will have more difficulties in discovering and connecting to partners abroad. In this context, foreign workers with a set of social contacts and intercultural communication skills can prove pivotal in developing international networks.

Based on the above discussion, we can formulate the following hypotheses:

H1: Firms which employ foreign workers, tend to cooperate with a wider range of partners at the international scale.
H2: The relationship between foreign workers and international cooperation is stronger for more educated foreign workers.
H3: The relationship between foreign workers and international cooperation is stronger for firms without employees abroad.

Why would international networking affect innovation?

The final piece of the puzzle is to establish whether and why international networks that foreign workers help to facilitate, would be associated with innovation. In general, collaboration can enhance innovation due to the increased amount and variety of knowledge available to be shared, as well as the possible compatibilities of knowledge in an alliance (Nieto and Santamaria 2007). There has been an increased focus on the role that networking plays in innovative processes across the literature on innovation in various disciplines (e.g. Powell et al, 1996, Etzkowitz and Leydesdorff 2000, Chesbrough 2006, Huggins and Thompson 2014). Previous research (Amara and Landry 2005) also show that firms that introduce more radical innovations are more likely to use a wider range of information sources. Similarly, Laursen and Salter (2006) find that firms with a broader search scope tend to be more innovative.

The regional science literature has traditionally been more preoccupied with the local and regional networks that firms develop. However, there is an increasing recognition that international networks may be at least as important for innovation in the contemporary economy (e.g. Bunnell and Coe 2001, Freel 2003, Shearmur 2011, Huggins and Thompson 2014). International networks allow access to a wider set of potential partners and a greater likelihood of encountering new ideas (Oinas 2002, van Geenhuizen 2007, Moodysson 2008, Lorenzen and Mudambi 2013). Meanwhile, conceptual work on proximity has emphasized that the problems associated with geographical distance can to some extent be bridged by proximity in other, non-geographical, dimensions (Rallet and Torre 1999, Boschma 2005) or by temporary proximity through business travel (Maskell et al, 2006, Torre 2008). Consequently, the literature on global innovation networks emphasises connections at the international scale as crucial in boosting the innovativeness of regions or firms, especially in lagging regions (Zander 1999, Ernst and Kim 2002, Kafouros, Buckley and Clegg 2012, Chaminade and Plechero 2015).

In recent years, an abundance of studies in the regional science or economic geography literature from various geographical contexts have concluded that firms with a greater variety or density of international contacts tend to be more likely to introduce new products or processes. This includes studies from Norway (Fitjar and Rodriguez-Pose 2011), Sweden (Moodysson 2008), Denmark (Lorentzen 2008), Austria (Trippl, Todtling and Lengauer 2009), Canada (Doloreux and Dionne 2008), India (Lorenzen and Mudambi 2013) and China (Leung 2013), among others. Starting from a conceptual perspective, Morrison, Rabellotti,

and Zirulia (2013) have demonstrated using a simulation model the need for external connections to import new knowledge into regional networks in order to ensure the continuous renewal of knowledge and ideas within the cluster and avoid the risks of lock-in. In a similar sense, Rodriguez-Pose and Fitjar (2013) talk of archipelago economies in which distant regions are connected by pipelines to bypass traditional hinterlands and interact directly with each other.

Based on this, we might formulate the following hypothesis:

H4: Firms that collaborate with wider range of international partners, tend to be more innovative.

Data and case description

This paper builds on firm-level data from a survey of 533 Norwegian firms, gathered in 2013. The survey was developed by the authors, drawing on indicators from the Community Innovation Survey (CIS), in particular for the dependent variables. The data has been combined with firm-level register data on firm size and NACE-classification. The survey was conducted in two stages: First, through a telephone interview, in which 2002 firms participated. These firms were sampled from a larger population of all firms with more than ten employees registered in the Norwegian Register of Business Enterprises according to quotas for five different regions: Oslo (500 firms), Stavanger (350), Bergen (300), Trondheim (250), and the rest of Norway (600). The overall response rate for the telephone survey was 20 per cent, and the response rates for each sector and region are shown in Table 1. During the telephone interview, respondents were invited to fill in a follow-up web questionnaire containing further questions, which 533 managers did. The dependent variables on innovation, collaboration, and the organization of innovation processes are all drawn from the telephone interviews, as are several of the control variables, while the data on foreign workers are based on the web questionnaire. Consequently, we limit the study to the firms that participated in both stages of the survey for the models concerned with foreign workers, while the association between international networking and innovation is analysed on the full sample of 2002 firms.

Table 1 shows descriptive statistics for both the full sample and for the 533 firms that participated in both parts of the survey. The share of innovative firms and of firms reporting collaboration activities at all scales are somewhat higher in the latter group, suggesting that

there is potentially some overrepresentation of more innovation-active firms in the sample. This represents a limitation that should be considered in the interpretation of results.

---------- Table 1 about here ----------

The study is conducted in the context of Norway, a historically ethnically homogeneous country that has over the past four decades had a growing immigrant population. By January 2015, immigrants and Norwegians born of immigrants added up to 15.6 per cent of the total population (Bratsberg et al, 2014, Statistics Norway 2015), the largest groups being Poles, Swedes and Lithuanians. Norway is a small, open and mixed economy that is strongly based on natural resources and engineering competence. The Norwegian economy has a substantial maritime sector (i.e. oil & gas, maritime & marine operations, aquaculture and shipping) with a largely international customer base. Many leading technological milieus in these sectors are also located abroad and are vital to reach out to and tap into. From the 1970s onwards, immigration of skilled foreign workers was important in the development of the Norwegian petroleum industry, which is now the largest export industry. Even though the oil and gas industry accounts for a small share of employment, it has opened up a large market for Norwegian manufacturing and services (Fagerberg, Mowery and Verspagen, 2009, 7), and this has had and still has a huge impact on the Norwegian economy. In terms of contributions to GDP, primary industries account for less than 2 per cent, secondary industries for 28 per cent and tertiary industries accounting for 70 per cent.

In recent years, high labour demand and Norway's participation in the European Single Market has also led to immigration of unskilled workers, in particular in the construction and hospitality sectors. As in other European countries, refugees and asylum seekers have also made up a sizeable share of the immigrant population since the late 1970s. Despite the growing number of immigrants in Norway, no research has previously addressed the impact of foreign workers on innovation in Norwegian firms, although there has been some work on firm perceptions of the need for foreign workers' skills. For instance, Seip (2007) found that a majority of firms sought foreign expertise due to problems finding the competence they need in Norway. That finding underpins the importance of bringing in foreign workers because of their skills and competence. This paper goes beyond firm perceptions in examining the relationship between employing foreign workers and the innovation behaviour of the firm.

Variables and model

In order to examine the relationship between having foreign workers in the firm and international networking, we examine whether firms have or have not cooperated during the last three years with any of seven different types of partners located abroad: other firms in the conglomerate, suppliers, customers, competitors, consultants, universities, and research institutes. Based on this, we construct an index counting the number of different types of partners used at the international scale[2]. We further examine the relationship between this variable and the presence of foreign workers, using a poisson regression model, specified as follows:

$$\log(E(\text{Partners}_i)) = \alpha + \beta_1 \text{ Foreign workers}_i + \beta_2 \text{ Controls}_i + \varepsilon \quad (1)$$

The main independent variable of interest is *Foreign workers*, which measures the presence of foreign workers in the firm, as well as the highest level of education among these workers. The variable is specified as a categorical variable with four possible values: (1) The firm has no foreign workers; (2) The firm has foreign workers, but no university educated foreign workers (*low educated foreign workers*); (3) The firm has foreign workers, and some of the foreign workers have university education (*medium educated foreign workers*); (4) The firm has foreign workers, and some of the foreign workers have postgraduate university education (*highly educated foreign workers*). In the models, we include dummy variables for categories 2-4, comparing with the baseline of having no foreign workers. An additional model controls for whether the firm has operations in different countries through asking whether or not they have any employees abroad. In order to test H3, we further run the model separately for these two subsets of firms.

The data does not allow us to identify how many foreign workers are employed in the firm(s) nor country of origin and immigrant status. The data provides information on the highest skill level of the foreign workers in the firm, but not linked directly to a specific worker.

In order to isolate the effect of foreign workers on international networking and avoid spurious associations, we employ two further robustness checks: Firstly, the model itself

[2] The index captures the diversity of the firm's network in terms of the number of different types of international partners. This does not translate directly into the number of partners, as firms may have one or many partners of each type. It also does not say anything about the intensity of the relationships. Furthermore, it does not measure the number of different countries in which the firm has partners, only whether or not it has any partners abroad of each type. However, it may serve as an indicator of the scope of the firm's network at the international scale in terms of the number of different types of partners used.

controls for several confounding variables, including firm size (measured by the natural log of the number of employees), the overall educational level in the firm (log percentage share of employees with university-level education), research & development intensity (measured by log of R&D expenditure), and foreign ownership (measured by percentage share of foreign ownership), the sector of the firm (applying ten different dummy variables for different industries) and the location of the firm in different regions of Norway (including dummy variables for the four largest city regions - Oslo, Bergen, Stavanger and Trondheim and one category for "the rest of Norway"). Secondly, to control for any remaining unobserved heterogeneity that may cause firms with foreign workers to network more in general, we run the model also for counts of different types of regional and national partners as outcomes. If foreign workers are indeed associated with larger international networks, we would expect to find an effect only for this dependent variable and not for regional and national partners as dependent variables.

Second, we examine the relationship between international networks and innovation, testing H4. In this model, the count of different types of international partners serves as the main independent variable of interest, while the dependent variables are four measures of innovation, derived from Community Innovation Survey indicators for product innovation, new-to-market product innovation, process innovation and new-to-industry process innovation. We control for the same variables as in Model (1) above, as well as for counts of different types of partners used at the regional and national scales. In this analysis, we exploit the full sample of 2002 firms participating in the telephone interviews, as all the indicators are derived from this part of the survey. The model is specified as follows:

$$\text{logit}(\Pr(\text{Innovation}_i=1)) = \alpha + \beta_1 \text{ International partners}_i + \beta_2 \text{ Controls}_i + \varepsilon \qquad (2)$$

Table 2 shows the correlation matrix of all the variables included in the analysis. The presence of highly educated foreign workers in the firm has a positive, but weak, association with all four innovation outcomes (medium foreign workers with two of the innovation outcomes). The presence of less educated foreign workers is not significantly correlated with any of four innovation outcomes.

---------- Table 2 about here ----------

Results

Table 3 shows the results of the estimation of model (1), examining the relationship between foreign workers and the use of international partners, in order to test H1, H2 and H3. The analysis shows, in line with expectations, that firms with foreign workers cooperate with a wider range of international partners (H1). These findings lend support to earlier claims in the literature that foreign workers possess international social connections to which natives lack access (Kemeny 2014,33), and that a more diverse workforce can thus help firms exploit and make use of external knowledge and extract it from more diverse source bases (Østergaard, Timmermans and Kristinsson, 2011). While it is impossible to rule out self-selection processes, by which foreign workers may be attracted to firms that are more internationally focused in the first place, these findings nonetheless indicate the presence of an association that has previously mostly been assumed, rather than tested.

However, the findings further suggest that the above association might only hold for foreign workers of a certain educational level, supporting H2. Firms with highly educated foreign workers cooperate with a significantly higher number of international partners, whereas for firms with medium or low educated foreign workers there are no significant differences in the levels of international cooperation compared to firms without any foreign workers. For firms with no highly educated foreign workers, the model predicts an average of 0.92 international partner types, while the predicted value for firms with highly educated foreign workers was 1.20 international partner types. The results suggest that highly educated foreign workers might be more involved in their firms' partner search and collaboration procedures, and are thus able to influence the collaboration patterns of the firm. Medium and low educated foreign workers tend to hold positions of less responsibility in which they may not be able to utilize their cultural and language skills to increase the search scope of the firm. Thus, these findings support earlier literature showing that the presence of highly educated foreign workers in particular is associated with beneficial economic outcomes (Kangasniemi et al, 2009).

Furthermore, the results also suggest that the association only holds for firms without alternative channels to foreign contacts, i.e. through employing workers abroad directly. In column 2, we control for whether firms have any employment abroad. This has a large and highly significant effect on international networking. When controlling for employment abroad, the presence of highly educated foreign workers is also no longer significantly associated with international networking. A separate analysis of firms with and without employment abroad, respectively (columns 3 and 4), explains this pattern: For firms with employment abroad, the presence of foreign workers in their Norwegian operation has no

additional effect on their propensity to build international networks. These firms are capable of connecting with international partners through their direct presence abroad. Conversely, for firms without any employees abroad, the effect of highly educated foreign workers is stronger than that observed for the full sample, supporting H3. For firms with no highly educated foreign workers, the model predicts an average of 0.63 international partner types, while the predicted value for firms with highly educated foreign workers was 1.04 international partner types (for firms with no employees abroad).

For regional and national partners as outcomes (columns 5 and 6), none of the variables related to foreign workers have any significant effect. This suggests that the presence of foreign workers is not related to the firm's general collaboration pattern, but is specific to collaboration with international partners. Thus, there does not seem to be anything different about the general collaboration pattern of firms employing foreign workers, apart from their higher propensity to participate in international networks. Among the control variables, we note that the firms with foreign ownership tend to collaborate with a wider range of international partners, as well as national partners. This is also the case for larger firms, for more R&D intensive firms, and for firms with a higher share of educated workers. These variables are also significantly associated with national and (except for education) regional collaboration. However, the effect of R&D intensity is stronger for international networking.

---------- Table 3 about here ----------

Table 4 shows the results of the estimation of model (2) examining the relationship between international networking and innovation, in order to examine the second step of the proposed mechanism in the relationship. For product innovation, we find a significant positive effect of interacting with international partners. This holds both for product innovation in general and for new-to-market product innovation. Interaction with international partners also has a significant positive effect on new-to-industry process innovation, while it is not significantly related to process innovation in general. For each added type of international partner, the odds of launching new product innovation increases by 6.2%, and 5.8 % for the odds of launching new-to-market product innovations, and 6.4% for launching new-to-industry process innovations.

These results lend support to H4 and to previous studies showing how international networks allow access to a wider set of potential partners, and thus a greater likelihood of encountering new ideas (Oinas 2002, van Geenhuizen 2007, Moodysson 2008, Fitjar and Rodríguez-Pose

2011, Lorenzen and Mudambi 2013). International networks might be particularly important in the Norwegian case, given its limited population size and peripheral location, as well as an industry structure oriented towards export markets.

Engaging in relationships with regional partners or national partners has no significant effects on product or new-to-market product innovation. However, national collaboration has a significant positive effect for both process and new-to-industry process innovation, while regional collaboration has a positive effect on process innovation. The effect of international partners is robust controlling for the industry and region, as well as for its R&D expenditure, size, human capital stock (log of education) and international orientation (foreign ownership and employees abroad). Both of the latter variables are furthermore positively related to product and new-to-market-product innovation, providing additional support for the notion that more internationally oriented firms tend to innovate to a greater extent.

---------- **Table 4 about here** ----------

In the appendix (Table A.1), the direct effect of foreign workers on innovation is also included in model (2). This reduces the sample size to the 496 firms for which we have data on foreign workers, and hence weakens the power of the analysis. Controlling for foreign workers, international partners is still positively and significantly related to new-to-market product innovation, while the associations with product innovation and new-to-industry process innovation are still positive, but no longer significant. However, for both these variables, the coefficients are higher than in Table 4, which did not control for foreign workers. Highly educated foreign workers have a significant positive effect on process innovation, while medium educated foreign workers have a significant positive effect on product innovation and new-to-market product innovation. Hence, there is still a residual effect of foreign workers beyond their relationship to firms' international networking.

Conclusion

The relationship between foreign workers and innovation has been frequently discussed in the literature, but few contributions have so far looked in detail at the mechanisms involved in this relationship. While most previous research has focused on the diversity of ideas and perspectives that foreign workers might bring, this analysis provides tentative evidence on another potential mechanism: Firms with foreign workers engage in a wider set of international relationships, which is in turn associated with higher levels of innovation. However, this association only emerges for certain types of foreign workers and for certain

types of firms. Specifically, firms with highly educated foreign workers have broader international networks, while those with only low or medium educated foreign workers have no significantly different networks than those without any foreign workers. Considering that foreign workers are often overqualified for their positions (Chiswick and Miller 2008, Nielsen 2011), this may suggest that medium and low educated foreign workers could contribute more if they are involved to a greater extent in their firms' international networking processes.

Furthermore, the association with foreign workers holds only for firms without operations abroad, while those with employees abroad gain no additional benefit from employing foreign workers in their international networking. Hence, foreign workers are particularly important for firms that operate only in one country and lack other channels through which they can connect to international partners. Highly educated foreign workers are frequently employed by multinational enterprises, but they may be even more important for the majority of firms which are not multinational.

The results further indicate that firms that collaborate with a broader set of international partners are more likely to introduce product innovation, new-to-market product innovation, and new-to-industry process innovation. This suggests that the presence of highly educated foreign workers might be related to innovation output through the relationship of international collaboration with these variables. The main contribution of this paper is hence in empirically studying one of the mechanisms by which foreign workers can influence innovation at the firm level. This is a necessary step in going beyond establishing an empirical association between foreign workers and innovation, which has been done by numerous recent contributions, and towards unbundling the various mechanisms that make up a potential causal chain accounting for this relationship.

However, this study represents only one of the hypothesised mechanisms. Further research is required in order to demonstrate whether foreign workers can also affect innovation through producing a diversity of perspectives and ideas within the firm. Secondly, while this paper has highlighted differences in the impact of foreign workers with different skill levels, the expected impact of foreign workers may be increasingly complex as immigrants are progressively more heterogeneous in terms of their ethnic background, skills, abilities and education (Ozgen 2015). Additional layers may therefore be needed in these analyses. Thirdly, the present contribution is limited to the level of the firm, and further research is needed to examine whether similar mechanisms hold also at lower or higher scales, such as

work groups, regions or nations. Fourthly, the study is based on survey data, and innovation active firms are somewhat overrepresented among respondents. Further research using register data may provide insights into whether this has any implications for the results. Finally, this study is conducted in the context of Norway, a historically ethnically homogeneous peripheral country. Even though immigration has been growing over the past four decades, Norway`s geographic location and its many peripheral regions, could make these international networks even more important than they would be in an ethnically more diverse and larger country. Nonetheless, the present study represents a necessary start in probing more deeply a relationship that has been heavily theorised, but only quite crudely examined with empirical data.

TABLES

Table 1: Summary statistics

	Telephone survey			Web survey	
Company size					
Median	23			24	
Interquartile range	32			30	
Mean	71.8			68.7	
Industry	*Response rate, %*	*N*	*Percent*	*N*	*Percent*
Mining and quarrying	25.4	32	1.6	16	3.0
Manufacturing	23.2	339	16.9	119	22.3
El., gas and water supply	39.0	56	2.8	16	3.0
Construction	16.9	341	17.0	59	11.1
Trade	20.3	402	20.1	98	18.4
Transport and storage	18.2	115	5.7	29	5.4
Hotels and restaurants	15.5	153	7.6	29	5.4
Information and communications	20.1	122	6.1	28	5.3
Financial services	24.2	130	6.5	32	6.0
Other services	22.6	312	15.6	107	20.1
Total	20.1	2002	100.0	533	100.0
Region	*Response rate, %*	*N*	*Percent*	*N*	*Percent*
Oslo	14.9	501	25.0	127	23.8
Bergen	24.5	308	15.4	74	13.9
Stavanger	30.3	351	17.5	115	21.6
Trondheim	27.0	234	11.7	60	11.3
Rest of Norway	18.4	608	30.4	157	29.5
Total	20.1	2002	100.0	533	100.0
Innovation		*Percent*	*N*	*N*	*Percent*
Product innovation		52.2	1044	319	59.9
New-to-market product innovation		28.2	565	172	32.3
Process innovation		43.5	871	250	46.9
New-to-market process innovation		15.1	303	85	15.9
Partners		*M*	*SE*	*M*	*SE*
Regional partners		2.4	0.04	2.6	0.07
National partners		1.4	0.03	1.5	0.06
International partners		0.8	0.03	1.0	0.07
Foreign workers				*N*	*Percent*
All				286	53.6
Highly educated				79	14.8
Medium educated				86	16.1
Low educated				121	22.7

Table 2: Correlation matrix of the variables used in the estimation models

	Product innovation	New-to-market product innovation	Process innovation	New-to-industry process innovation	Highly educated foreign workers	Medium educated foreign workers	Low educated foreign workers	Log of education	Regional partner	National partner	International partner	Log of R&D	Log no. of employees	Foreign ownership	Employees abroad
Product innovation	1.0000														
New-to-market product innovation	0.5654***	1.0000													
Process innovation	0.2560***	0.2921***	1.0000												
New-to-industry process innovation	0.1581***	0.2474***	0.4634***	1.0000											
Highly educated foreign workers	0.0831**	0.1187***	0.1370***	0.1067***	1.0000										
Medium educated foreign workers	0.1200***	0.1009**	0.0374	0.0318	-0.0107	1.0000									
Low educated foreign workers	-0.0586	-0.0100	0.0471	0.0086	0.1630***	-0.0551	1.0000								
Log of education	0.1917***	0.1597***	0.0920**	0.1066***	0.3148***	0.1039**	-0.2499***	1.0000							
Regional partner	-0.0506	-0.0323	0.0664	0.0615	0.0964**	0.0655	-0.0032	0.0886**	1.0000						
National partner	0.0113	0.0498	0.1658***	0.1367***	0.1195***	0.0453	-0.0150	0.2183***	0.3158***	1.0000					
International partner	0.1893***	0.2387***	0.1458***	0.1319***	0.3169***	0.0237	-0.1051**	0.2392***	0.1074***	0.4048***	1.0000				
Log of R&D	0.2988***	0.3420***	0.2240***	0.1632***	0.2651***	0.0523	-0.0865**	0.3146***	0.1309***	0.1856***	0.2951***	1.0000			
Log no. of employees	0.0382	0.1108***	0.1359***	0.1057***	0.0895**	0.1065***	0.1047***	0.0497	0.1496***	0.1861***	0.2096***	-0.0008	1.0000		
Foreign ownership	0.1074***	0.1073***	0.0516	0.0655	0.2053***	0.0147	-0.0796*	0.1615***	-0.0770*	0.1096***	0.3899***	-0.0004	0.1633***	1.0000	
Employees abroad	0.1618***	0.1969***	0.1064***	0.0700	0.2743***	0.1573***	-0.0860**	0.1887***	0.1371***	0.2805***	0.4718***	0.2479***	0.1829***	0.2080***	1.0000

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Poisson regression model of collaboration with partners

VARIABLES	International partners	International partners	International partners (firms w/no employees abroad)	International partners (firms w/ employees abroad)	Regional partners	National partners
Highly educated foreign workers	0.26**	0.15	0.50***	-0.07	0.06	-0.02
	(0.11)	(0.12)	(0.16)	(0.18)	(0.09)	(0.11)
Medium educated foreign workers	-0.04	-0.13	-0.24	-0.21	0.05	0.01
	(0.12)	(0.12)	(0.19)	(0.20)	(0.08)	(0.10)
Low educated foreign workers	-0.12	-0.10	-0.17	-0.02	0.00	0.12
	(0.13)	(0.13)	(0.16)	(0.25)	(0.07)	(0.10)
Log of education	0.13***	0.13**	0.11*	0.04	0.03	0.17***
	(0.05)	(0.05)	(0.06)	(0.11)	(0.03)	(0.04)
Log of R&D	0.30***	0.23***	0.28***	0.17**	0.08***	0.14***
	(0.05)	(0.05)	(0.07)	(0.07)	(0.03)	(0.04)
Log no. of employees	0.14***	0.09**	0.05	0.12*	0.10***	0.15***
	(0.04)	(0.04)	(0.08)	(0.06)	(0.03)	(0.04)
Foreign ownership	0.00***	0.00***	0.00***	0.00**	-0.00	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Employees abroad		0.67***				
		(0.10)				
Sector (10)	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Region (5)	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant	-1.34***	-1.30***	-1.20***	0.02	0.35**	-1.04***
	(0.26)	(0.26)	(0.36)	(0.50)	(0.15)	(0.22)
Observations	496	496	402	94	496	496
Pseudo R^2	0.18	0.21	0.19	0.07	0.04	0.06

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Baseline: No foreign workers

Table 4: Logit regression model of innovation

VARIABLES	Product innovation	New-to-market product innovation	Process innovation	New-to-industry process innovation
International partner	0.11*	0.12**	0.06	0.11*
	(0.06)	(0.06)	(0.05)	(0.06)
Regional partner	-0.04	-0.01	0.08***	0.04
	(0.03)	(0.04)	(0.03)	(0.04)
National partner	0.06	0.06	0.17***	0.12**
	(0.04)	(0.04)	(0.04)	(0.05)
Log of education	0.11**	0.15***	0.03	0.07
	(0.04)	(0.05)	(0.04)	(0.06)
Log of R&D	0.77***	0.64***	0.33***	0.28***
	(0.07)	(0.07)	(0.06)	(0.08)
Log no.of employees	0.13**	0.14**	0.23***	0.12
	(0.07)	(0.07)	(0.06)	(0.08)
Foreign ownership	0.00*	0.00**	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Employees abroad	0.32*	0.47***	-0.03	-0.10
	(0.17)	(0.16)	(0.15)	(0.19)
Sector (10)	Controlled	Controlled	Controlled	Controlled
Region (5)	Controlled	Controlled	Controlled	Controlled
Constant	-1.35***	-2.53***	-2.09***	-2.98***
	(0.30)	(0.34)	(0.29)	(0.38)
Observations	1,852	1,852	1,852	1,852
Pseudo R^2	0.17	0.17	0.07	0.05

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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APPENDIX

Table A.1: Logit regression model of innovation and foreign workers and employees abroad

VARIABLES	Product innovation	New-to-market product innovation	Process innovation	New-to-industry process innovation
International partner	0.19	0.19*	0.06	0.13
	(0.12)	(0.10)	(0.10)	(0.12)
Regional partner	-0.05	-0.11	-0.01	-0.01
	(0.07)	(0.07)	(0.06)	(0.09)
National partner	-0.21**	-0.12	0.20**	0.16
	(0.09)	(0.09)	(0.08)	(0.10)
Log of education	0.28***	0.15	-0.02	0.11
	(0.10)	(0.11)	(0.09)	(0.14)
Log of R&D	0.65***	0.74***	0.33***	0.24*
	(0.13)	(0.13)	(0.11)	(0.14)
Log no.of employees	-0.04	0.20	0.25**	0.23
	(0.13)	(0.13)	(0.13)	(0.14)
Foreign ownership	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Employees abroad	0.44	0.20	-0.05	-0.28
	(0.34)	(0.30)	(0.29)	(0.37)
Highly educated foreign workers	-0.19	-0.04	0.55*	0.35
	(0.36)	(0.33)	(0.31)	(0.37)
Medium educated foreign workers	0.79**	0.52*	0.23	0.17
	(0.31)	(0.29)	(0.27)	(0.35)
Low educated foreign workers	-0.14	0.22	0.33	0.36
	(0.26)	(0.28)	(0.25)	(0.35)
Sector (10)	Controlled	Controlled	Controlled	Controlled
Region (5)	Controlled	Controlled	Controlled	Controlled
Constant	-1.69***	-3.13***	-2.24***	-3.26***
	(0.58)	(0.65)	(0.56)	(0.73)
Observations	496	496	496	496
Pseudo R^2	0.16	0.18	0.09	0.10

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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SHORT ARTICLE

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Foreign workers and international partners as channels to international markets in core, intermediate and peripheral regions

Marte C. W. Solheim

ABSTRACT

Past contributions stress that international ties in the form of foreign workers and international collaboration enable firms to be present in international markets by providing access to diverse knowledge, and professional and social networks. These mechanisms have, however, not undergone the same empirical scrutiny for firms in intermediate and peripheral regions. If firms in more peripheral regions are able to tap into the global economy using international channels, this has important implications, for example, for the localization decision of firms. The empirical analysis builds on linked employer–employee data (LEED) merged with community innovation survey (CIS) data. The results demonstrate that there is a positive association between international ties and international market presence for firms in core, intermediate and peripheral regions, demonstrating that peripheral regions are not detached from global processes. There are, however, slight different patterns observed, for example, indicating that different collaboration partners are used in order to reach international markets for firms in core, intermediate and peripheral regions.

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Foreign workers; international markets; export; regions; Norway

INTRODUCTION

A wealth of contributions stress the importance of personal contacts for market entry (Bonaccorsi, 1992; Ellis, 2000; Liang & Stump, 1996; Simmonds & Smith, 1968). Following up on the seminal insights of Gould (1994), Head and Ries (1998) and Rauch and Trindade (2002) scrutinizing the 'migration–trade nexus', several contributions have established a link between foreign workers and international market presence. This has been explained by foreign workers' social proximity to actors operating in international markets as well as information they hold about these markets. Their networks also induce social capital and lower transaction costs. Awareness of opportunities in international markets are furthermore facilitated through relationships with partners external to the firm (Ellis, 2000; Johanson & Mattsson, 1988). Unique competitive advantages are created by links to international partners, considered as 'exclusive or non-redundant ties to distant clusters' (Ellis, 2000, p. 447). Nevertheless, these studies have for the most part not considered the location of the firm. Sassen (2006, 50) argues that much of what is referred to as 'global' essentially

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materializes in cities, e.g., as do contributions concerning world cities (Friedmann & Wolff, 1982; Hall, 1966). Cities and core regions have greater diversity in terms of foreign workers and greater possibilities to connect to global partners, e.g., through global city networks (Beaverstock, Smith, & Taylor, 2000; Castells, 1996; Taylor & Derudder, 2004). This stands in sharp contrast to the studies of smaller, peripheral regions that have not only received less attention but also are often seen as less diverse and less capable of taking part in the global economy. A key question is therefore whether firms in peripheral regions are also able to use foreign workers and international partners to reach international markets.

This paper examines the relation between foreign workers, international collaboration and international market presence for firms in core, intermediate and peripheral regions. The results demonstrate a positive association between foreign workers, international collaboration and firms exporting to international markets. This indicates that peripheral regions are not detached from the global processes, but are able to partake in the global economy, particularly through collaboration with international partners. When subdividing the foreign workers and international partners into more detailed categories, a more fine-grained picture is painted, e.g., demonstrating that peripheral regions reach international markets through collaboration with Nordic partners, whilst core and intermediate regions benefit from collaboration with European partners.

The paper is structured as follows. The theoretical framework is introduced in the next section. The data and models are presented in the third section. The results are presented in the fourth section. Finally, the conclusions and implications discussed in the final section.

THEORETICAL FRAMEWORK

A wealth of contributions stress the importance of creating competitive advantages for sustaining a strong market presence (Pfeffer, 1994; Porter, 1990). Referring to Basile (2001), Dhanaraj and Beamish (2003) and Roper and Love (2002), Lewandowska, Szymura-Tyc, and Gołębiowski (2016, p. 3674) argue that it is 'the new products and technologies that contribute to the competitive advantage of firms in international markets'. On the operational side, Kaleka (2002) argues that part of firms' competitive advantage is the ability to make contacts in international markets. There are numerous contributions stressing the importance of collaborating with various partners in relation to exports and internationalization of firms (Lewandowska et al., 2016). A presence on international markets through exports of products is increasingly important for the survival of firms (Lim, Sharkey, & Heinrichs, 2006). Foreign workers and collaboration with international partners are two ways of accessing important information and networks that in turn might facilitate export. Therefore, the theoretical discussion starts by debating the role of foreign workers and international partners in relation to international markets. Not all regions have the same capabilities (Boehe, 2013; Ebersberger, Herstad, & Koller, 2014) of attracting foreign workers or collaboration partners, and this will be discussed below.

Foreign workers and tapping into international markets

Over the past 50 years, global flows of international migration have more than doubled (Kemeny & Cooke, 2015), and due to the globalization of the world economy, there has been an upsurge in interaction between actors at diverse locations in the world. Following up on insights made by Gould (1994), Head and Ries (1998) and Rauch and Trindade (2002), several contributions have found positive associations between migration and trade, e.g., Hatzigeorgiou and Lodefalk (2016), Aleksynska and Peri (2014) and Felbermayr and Toubal (2012), who all find that foreign workers positively affect international trade. The mechanisms through which foreign workers might affect exporting are many. Foreign workers might increase firms' search scope (Østergaard,

Timmermans, & Kristinsson, 2011) and absorptive capacity, which in turn could be important in order to be present on international markets. Lee and Nathan (2010) argue that foreign workers reduce costs tied to the sourcing of information due to their contacts in their country of origin and since they are 'more likely to speak the language of those in their origin country and will be more astute at tacit communication' (p. 58). Foreign workers do not make a sharp and definitive break with their homelands, but often sustain ties with their birthplaces (Brubaker, 2005; Herander & Saavedra, 2005; Saxenian, 2006), which could lead to augmented levels of trust towards these contacts in their native country, e.g., manifested as social proximity based on social interaction between actors (Boschma, 2005).

International partners and tapping into international markets

'Foreign market opportunities are seen to be communicated to the firm via its relationships with network partners' (Ellis, 2000, p. 447), hence partners can be a source of a firm's competitive advantage (Lavie, 2006; Lechner & Dowling, 2003). Access to essential knowledge can be facilitated through these contacts that in turn might aid international market presence (Coviello, 2006; Johanson & Mattsson, 1988; Johanson & Vahlne, 2009; Lewandowska et al., 2016; Rauch, 2001). Firstly, this could be caused by international partners connecting the firms to their local network. Market entry is not straightforward because 'to the outsider looking in, local business networks are opaque as a consequence of the general invisibility of relationships' (Ellis, 2000, p. 450). Secondly, connecting to international partners is vital because they can provide firms with information and ties that are not only new to the firm but also bridging what Burt (1992) refers to as 'structural holes' (Ellis, 2000). Bridging these could lead to information benefits acquired by communicating with people or firms with knowledge that complements what is already known to the firm (Granovetter, 1973). Transnational networks may be beneficial in several ways as they facilitate market information about potential opportunities, e.g., how consumers would respond to new products, or by helping firms find and access suitable distributors or partners for joint-venture projects (Rauch, 2001, p. 1184). International partners also have information about market regulations and laws that is vital in order for operations to run smoothly.

Regional capabilities for tapping into international markets

Developed, high-cost economies are incapable of competing on cost alone and increasingly rely on exports of knowledge-intensive-produced goods. These are often developed in core regions as the 'terrain where a multiplicity of globalization processes assume concrete, localized forms. These localized forms are, in good part, what globalization is about' (Sassen, 2005, p. 40). A presence in the global economy is facilitated by being located in world cities (Friedmann & Wolff, 1982; Hall, 1966; Sassen, 1991) and engaging in world-city networks (Castells, 1996; Taylor & Derudder, 2004). Hence, cities around the world benefit not only from regional knowledge spillovers, and 'diverse labour markets, diverse networks of firms and colleagues, concentrations of diverse types of information on the latest developments and diverse marketplaces' (Sassen, 2006, p. 37), but also from taking part in a global network. In world cities, a thick and diverse concentration of people and firms provides many opportunities for interaction as well as exchange of ideas and greater diversity in terms of foreign workers and international collaboration.

Regional characteristics influence international presence (Ebersberger et al., 2014; Herstad & Ebersberger, 2015; Laursen, Masciarelli, & Prencipe, 2012), and past contributions have demonstrated a link between firms' location in a strong regional business environment and being able to export successfully (Boehe, 2013; Yu, Gilbert, & Oviatt, 2011; Zhou, Wu, & Luo, 2007). Smaller peripheral regions often tend to operate in more narrow and specialized economic sectors (Wolfe, 2014). This could represent a threat of being locked into diminishing

industries with limited input from the outside world (Wolfe, 2014). Engaging in non-local linkages, e.g., international linkages, is one way to avoid spatial lock-in because they provide contact with the outside world (Boschma, 2005, p. 70), and new input might be reached that could prove pivotal for firms. Contributions from, for example, Fitjar and Rodríguez-Pose (2011), Doloreux and Shearmur (2012) and Grillitsch and Nilsson (2015), demonstrate that these mechanisms of knowledge spillovers and access to global pipelines are at least as important in peripheral regions. This provides a background in which it is essential to learn more about the mechanisms by which firms in intermediate and peripheral regions are tapping into international markets.

DATA AND MODELS

The empirical estimations are carried out on linked employer–employee data (LEED) that comprise information on all individuals and firms in the private sector in Norway. LEED is then merged with an extended version of the community innovation survey (CIS), which asks about firms' innovation activity.[1] The dependent variables regarding international market presence are gathered in the three years leading up to the survey in 2010. The variables concerning collaboration are from the CIS in 2008. The independent variables about foreign workers are from the LEED in 2007. Thus, the independent variables are measured in the period before the observed international market presence.[2]

The following model is considered:

$$logit\left(Pr\left(InternationalMarket_{it}=1\right)\right)=\alpha+\beta_1 ForeignWorkers_{i(t-1)}$$
$$+\beta_2 InternationalCollaboration_{i(t-1)}+\ controls_{i(t-1)}+\varepsilon$$

Two binary dependent variables are used in the estimations: European market presence and presence in other international markets.[3] This is done in order to see whether the international ties affect different markets differently.

The econometric approach is twofold. Firstly, the estimations are run using the share of foreign workers and overall international collaboration as predictors. Foreign workers is measured as the share of foreign workers in the firms. International collaboration is a binary variable where 1 equals that the firm has collaborated with partners abroad, and 0 if it has not. The controls include regional and national collaboration, industry (based on nine different industry classifications; Figure A1), size (measured by log of employees), education (measured by the share of college-educated workforce) and log of research and development (R&D) expenditure. International, national and regional collaboration refers to whether firms have collaborated with eight different types of partners: other businesses within the conglomerate, suppliers, customers, competitors, consultancies, universities, research institutions and commercial laboratories, and whether these partners are located locally/regionally, elsewhere in Norway or internationally.

The second approach is more specified. Since the dependent variables are concerned with European and other international markets, and past theoretical contributions have emphasized that foreign workers and international partners might facilitate access to international markets corresponding to their country of origin (Ellis, 2000; Rauch & Trindade, 2002), foreign workers and international collaboration are divided into categories in order to demonstrate a more fine-nested picture of the relation. The groups of foreign workers comprise the share of workers from Nordic countries (excluding Norwegians), the EU-15, other European Union, and other Western,[4] and non-Western countries.[5] International collaboration comprises collaboration with partners from Nordic, European, US, Chinese and Indian, and other countries.

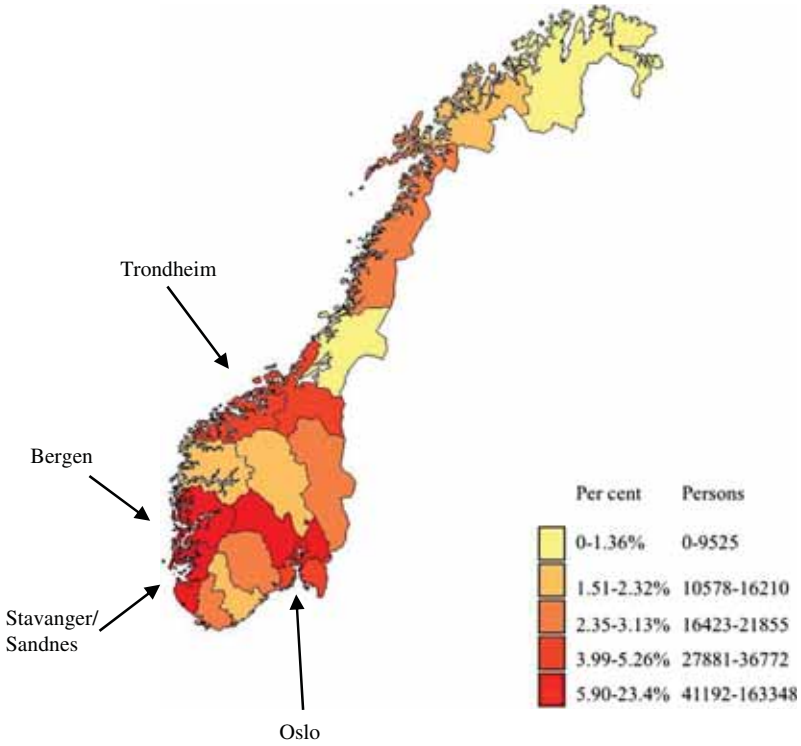


Figure 1. Map of Norway. The core regions indicated and population density of first generation immigrants in 2016 shown. Data source: Statistics Norway.

The estimations are carried out using logit regression models:

- On all firms in the dataset.
- On firms in core regions only.
- On firms in intermediate regions only.
- On firms in peripheral regions only.

Core regions consist of the largest city regions in Norway (Oslo, Bergen, Trondheim and Stavanger/Sandnes; Figure 1) with more than 200,000 inhabitants. Intermediate regions consist of regions with between 50,000 and 200,000 inhabitants. Peripheral regions are smaller regions with fewer than 50,000 inhabitants. See figure 1 demonstrating the core regions and population density of first-generation immigrants in 2016. The empirical case is Norway, a small and open economy dependent on being present in the global economy. The top five trading partners for Norwegian firms are the UK, Germany, the Netherlands, France and Sweden; export goods are produced in all regions in Norway, particularly located on the west coast.

RESULTS

There are more firms in core regions that export than firms in intermediate or peripheral regions (see figure 2). A total of 37.3% of firms in core regions have reported that they exported to

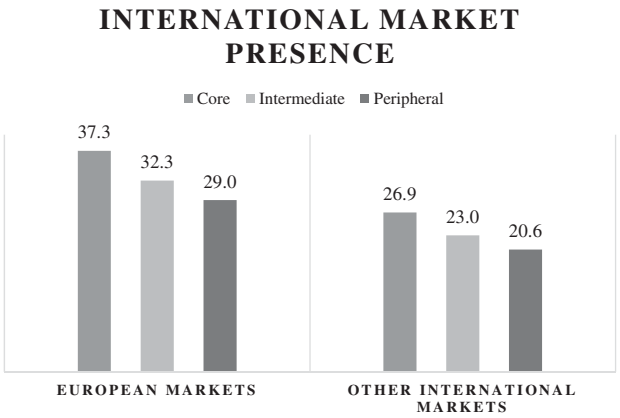
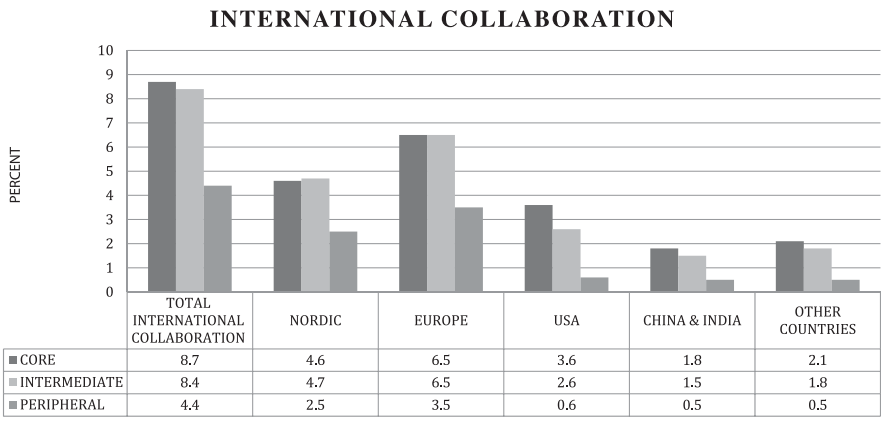


Figure 2. International market presence in core, intermediate and peripheral regions (%).



	TOTAL INTERNATIONAL COLLABORATION	NORDIC	EUROPE	USA	CHINA & INDIA	OTHER COUNTRIES
CORE	8.7	4.6	6.5	3.6	1.8	2.1
INTERMEDIATE	8.4	4.7	6.5	2.6	1.5	1.8
PERIPHERAL	4.4	2.5	3.5	0.6	0.5	0.5

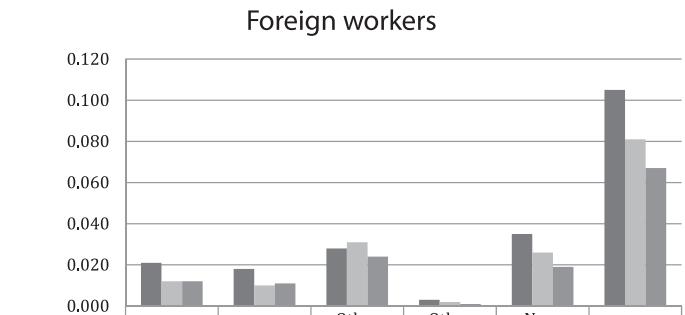
Figure 3. International collaboration in core, intermediate and peripheral regions (%). Firms may choose several partners within the different categories, therefore numbers do not add up to the total percentage of international collaboration.

European markets compared with 32.3% in intermediate regions and 29.0% in peripheral regions. For other international markets, around 26.9% of the firms in core regions report that they have exported, compared with 23.0% in intermediate regions and 20.6% in peripheral regions.

Firms in core and intermediate regions also collaborate more internationally (see figure 3). A total of 8.7% of firms in core regions report that they have collaborated with international partners. Relatively similar numbers are found for firms in intermediate regions (with 8.4%). In peripheral regions, 4.4% reported that they collaborated with international partners.

Quite similar patterns are found for firms in core and intermediate regions and in terms of the percentage of firms stating that they collaborate with international partners, e.g., in both cases, 6.5% of firms collaborate with European partners. Firms in peripheral regions collaborate substantially less.

Foreign workers tend to centralize, and there are more foreign workers in core regions than in intermediate and peripheral regions (e.g., 0.2% of all workers are Nordic and 0.2% are from



	Nordic	EU15	Other European	Other Western	Non-western	Total
Core	0.021	0.018	0.028	0.003	0.035	0.105
Intermediate	0.012	0.010	0.031	0.002	0.026	0.081
Peripheral	0.012	0.011	0.024	0.001	0.019	0.067

Figure 4. Descriptive statistics. Foreign workers in core, intermediate and peripheral regions. Values shown are means.

EU-15 countries in core regions, whilst 0.1% of all workers are Nordic and 0.1% are from EU-15 in intermediate and peripheral regions). See figure 4.

Turning to the regression results for all firms,[6] foreign workers and international collaboration are positively associated with a presence in European markets. International collaboration is also positively associated with a presence in other international markets, while the coefficient for foreign workers is in this case not statistically significant (see table 1).

Collaborating with international partners is positive for firms in all regions, apart from those in intermediate regions. Foreign workers are positively associated with European market presence, for firms in intermediate and peripheral regions, whilst none of the variables concerning foreign workers was statistically significant for other international markets.

Moving on to the second part of the analyses, the general results for all firms in the sample demonstrate that in order to export to European markets, firms benefit from having workers from EU-15 countries, as well as collaborating with Nordic and European partners (see table 2). For a presence in other international markets, firms benefit from having workers from EU-15 countries, workers from other Western countries, as well as collaboration with European, US, and Chinese and Indian partners. The results demonstrate that firms benefit from employing foreign workers (in particular from the EU-15). There are also positive associations between collaboration with partners from other countries and a presence on other international markets. This lends support to theories of international partners holding vital information about international markets.

The results subdivided by region demonstrate that firms in all types of regions benefit from employing workers from EU-15 countries when exporting to European markets. For firms in intermediate and peripheral regions, collaborating with Nordic partners is positively associated with export to European markets, whilst firms in core and intermediate regions benefit from collaborating with European partners. For non-European markets, firms in core and intermediate regions benefit from hiring workers from EU-15 countries, other Western countries, and collaborating with partners from other countries. Moreover, firms in core regions benefit from European collaboration, and collaboration with Chinese and Indian partners, whilst for firms in intermediate regions, collaborating with US partners is beneficial. Nordic collaboration is positive for firms in peripheral regions, but negative for firms in core and intermediate regions.

Table 1. International market presence for firms in core, intermediate and peripheral regions.

	European market				Other international market			
	All firms	**Core**	**Intermediate**	**Peripheral**	**All firms**	**Core**	**Intermediate**	**Peripheral**
Foreign workers	.52** (.22)	.21 (.28)	.76* (.45)	1.31** (.59)	.39 (.24)	.35 (.30)	.44 (.51)	.57 (.65)
International collaboration	1.03*** (.16)	.95*** (.22)	.96*** (.31)	1.11*** (.44)	.49*** (.15)	.44** (.21)	.27 (.28)	.84** (.43)
Norwegian collaboration	–.18 (.15)	–.15 (.22)	.06 (.29)	–.50 (.38)	–.07 (.15)	–.15 (.20)	.19 (.28)	–.05 (.38)
Regional collaboration	–.46*** (.14)	–.38** (.19)	–.66*** (.27)	–.32 (.33)	–.27** (.14)	–.01 (.18)	–.62** (.26)	–.48 (.35)
Log of employees	.16*** (.03)	.10*** (.04)	.14*** (.05)	.52*** (.08)	.15*** (.03)	.10*** (.04)	.14** (.06)	.43*** (.08)
Log of R&D	.18*** (.10)	.18*** (.14)	.20*** (.03)	.14*** (.28)	.19*** (.01)	.17*** (.01)	.23*** (.02)	.18*** (.03)
Share of college educated	1.34*** (.18)	1.31*** (.23)	1.29*** (.39)	1.46*** (.57)	1.60*** (.19)	1.55*** (.24)	1.95*** (.42)	1.60*** (.61)
Sector	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Observations	5947	3002	1727	1182	5943	3002	1724	1181
Pseudo-R^2	17.5	16.2	20.1	21.2	19	17.3	23	22.3

Notes: R&D, research and development.
*p <.1 **p <.05 ***p < .01.

Table 2. International market presence with specifications.

	European market				Other international market			
	All firms	**Core**	**Intermediate**	**Peripheral**	**All firms**	**Core**	**Intermediate**	**Peripheral**
Nordic workers	.09 (.62)	.08 (.81)	.18 (1.20)	.83 (1.68)	–1.17 (.76)	–1.34 (1.00)	–2.0 (1.88)	.03 (1.90)
EU-15 workers	4.14*** (.75)	3.89*** (.93)	4.8*** (1.84)	3.98** (1.77)	2.78*** (.74)	2.24*** (.90)	6.04*** (2.0)	2.90 (1.87)
Other EU workers	–.53 (.44)	–1.38** (.70)	–.38 (.80)	.66 (.90)	–.06 (.47)	–.11 (.68)	–.86 (.98)	.57 (.98)
Other Western countries workers	2.75 (1.80)	1.60 (1.82)	13.6** (5.94)	2.37 (8.49)	6.59*** (2.17)	6.18*** (2.40)	15.6*** (5.80)	–.13.95 (13.5)
Non-Western workers	–.07 (.39)	–.06 (.47)	1.15 (.86)	1.40 (1.21)	.03 (.43)	.012 (.51)	.68 (.96)	–.11 (1.43)
Nordic collaboration	.61*** (.22)	.36 (.30)	.73** (.38)	1.12* (.62)	–.27 (.20)	–.47* (.29)	–.68* (.36)	1.07* (.58)
European collaboration	1.04*** (.20)	1.28*** (.28)	.68* (.37)	.50 (.54)	.35* (.19)	.43* (.25)	.11 (.35)	.08 (.54)
US collaboration	.26 (.37)	.26 (.37)	1.13* (.62)	–.1.06 (1.29)	.43* (.26)	.50 (.33)	.94* (.50)	–.26 (1.28)
China and India collaboration	.38 (.37)	.37 (.47)	.37 (.70)	1.23 (1.37)	.97*** (.36)	1.48*** (.48)	–.42 (.66)	1.89 (.1.33)
Other countries collaboration	–.38 (.34)	–.50 (.44)	–.44 (.61)	–	1.28*** (.37)	.90** (.45)	2.04*** (.72)	–
Norwegian collaboration	–.30** (.16)	–.31 (.22)	–.02 (.30)	–.48 (.38)	–.13 (.15)	–.25 (.21)	.19 (.30)	–.09 (.38)
Regional collaboration	–.47*** (.14)	–.36* (.19)	–.73*** (.27)	–.37 (.35)	–.36*** (.14)	–.13 (.19)	–.73*** (.27)	–.61* (.37)
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Pseudo-R^2	18.4	17.4	21.3	21.1	20.1	18.8	25.2	22.2

Notes: R&D, research and development.
*p <.1 **p <.05 ***p < .01.

CONCLUSIONS AND IMPLICATIONS

The results support the idea that cooperation with international partners give firms access to vital information that enables them to be present in international markets. This could be explained by the knowledge or networks held by international partners. This is further underlined when introducing the variables concerned with collaboration with specific partners. Firms also seem to benefit from foreign workers in order to tap into international markets.

When subdividing the variables concerned with the international ties, a more fine-grained picture is painted, e.g., collaboration with European partners aids a European market presence, and collaboration with other international partners is associated with a presence on other international markets. The results also demonstrate a positive association between international market presence and foreign workers, particularly the share of workers from EU-15 countries. The results have implications for localization decisions, recruitment strategies and for how to organize activities related to international market presence, for example, through networking and allocation of personnel.

The results indicate that peripheral regions are not detached from global processes, but are capable of partaking in the global economy. This participation in the global economy is particularly facilitated through collaboration with international partners (and specifically through Nordic partnerships).

The results have several important implications for practice and theory/research: firstly, the paper shows that firms in peripheral and intermediate regions tap into the global economy, and that international ties act as facilitators. The results motivate that there is no 'one-size-fits-all' application. Firms in core, intermediate and peripheral regions are present in international markets, and through the help from foreign workers and international collaboration, but they do so in slightly different ways, e.g., there is a positive link between Nordic collaboration and exports for firms in peripheral regions, while firms in core and intermediate regions seem to benefit more from European collaboration. For future research, the paper shows the importance of studying diversity-related issues in peripheral and intermediate regions in addition to core regions.

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NOTES

1. It is mandatory for Norwegian firms to respond to the CIS survey, and the response rate is approximately 95% (Wilhelmsen, 2012).

2. Firms might have launched goods and/or services in these markets prior to this survey, and these variables capture whether they are still present
3. Based on the question: in which geographic markets did your enterprise sell goods and/or services during the three years 2008–10?
4. Japan, United States, Canada, Australia and New Zealand
5. The countries not included above
6. For correlation matrices for the regression results, see Tables A2 and A3 in Appendix 1. *Z*-tests were carried out in order to determine whether there are statistically significant differences in international market presence, international collaboration and foreign workers between core, intermediate and peripheral regions. The results indicate that there are statistically significant differences between these levels.

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APPENDIX 1

Table A1. Descriptive statistics sector in core, intermediate and peripheral regions.

Sector	Mean	SD	% Core	% Intermediate	% Peripheral	Total %
Seafood	.01	.12	22.50	13.75	63.75	100
Mining	.03	.17	67.05	13.87	19.08	100
Manufacturing	.32	.47	37.29	36.82	25.89	100
Supply	.04	.20	32.44	29.77	37.79	100
Construction	.10	.29	41.96	34.97	23.08	100
Trade	.12	.32	63.26	25.82	10.92	100
Transport	.06	.23	49.54	33.43	17.02	100
Information	.12	.32	68.12	21.01	10.87	100
Finance	.04	.20	64.11	20.97	14.92	100

Table A2. Correlation matrix of the data – first part of the analyses.

	1	2	3	4	5	6	7	8
1. European markets	1							
2. Other international markets	.60***	1						
3. Foreign workers	.05***	.05***	1					
4. International collaboration	.26***	.24***	−.01	1				
5. Norwegian collaboration	.19***	.19***	−.02*	.62***	1			
6. Regional collaboration	.17***	.18***	−.02*	.57***	.49***	1		
7. Log of employees	.13***	.12***	.06***	.15***	.14***	.11***	1	
8. Log of R&D	.39***	.39***	−.03**	.47***	.43***	.43***	.21***	1
9. Share of college educated	.19***	.20***	.04***	.16***	.11***	.15***	−.01	.27***

Notes: R&D, research and development.
*$p < .1$; **$p < .05$; ***$p < .01$.

Table A3. Correlation matrix of the data – second part of the analyses.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. European markets	1															
2. Other international markets	.60***	1														
3. Nordic workers	.01	– .01	1													
4. EU-15 workers	.11***	.11***	.04***	1												
5. Other EU workers	–.02*	–.01	.01	.07***	1											
6. Other Western workers	.06***	.08***	.02	.06***	–.01	1										
7. Non-Western workers	.03**	.02*	.04***	.07***	.11***	.03**	1									
8. Nordic collaboration	.20***	.16***	.00	.04***	–.03**	.03**	–.01	1								
9. European collaboration	.26***	.24***	–.00	.06***	–.03**	.03***	–.01	.59***	1							
10. US collaboration	.19***	.21***	–.00	.06***	–.03**	.05***	–.02	.43***	.57***	1						
11. China and India collaboration	.13***	.16***	–.00	.03***	–.02*	.03***	.02*	.35***	.39***	.45***	1					
12. Other countries collaboration	.13***	.20***	–.00	.05***	–.01	.05***	.00	.32***	.44***	.53***	.47***	1				
13. Norwegian collaboration	.19***	.19***	–.01	.03*	–.03**	.04***	–.03**	.51***	.56***	.39***	.31***	.34***	1			
14. Regional collaboration	.17***	.18***	–.01	.03**	–.03**	.02	–.03**	.44***	.48***	.39***	.29***	.33***	.49***	1		
15. Log of employees	.13***	.12***	.05***	–.01	.02	.01	.06***	.14***	.15***	.14***	.08***	.11***	.14***	.11***	1	
16. Log of R&D	.39***	.39***	–.02	.06***	–.05***	.04***	–.03**	.34***	.42***	.33***	.21***	.27***	.43***	.43***	.21***	1
17. Share of college educated	.19***	.20***	.07***	.15***	–.06***	.11***	–.01	.11***	.13***	.14***	.07***	.10***	.11***	.15***	–.01	.27***

Notes: R&D, research and development.

*$p < .1$; **$p < .05$; ***$p < .01$.

Paper IV

Do firms in upstream oil and gas sectors benefit from co-location?

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Abstract

Numerous contributions study firms' clustering in space and the nexus between productivity and agglomeration. This paper analyses how different sectors and firms within the Norwegian upstream oil and gas industry benefit from regional agglomeration. Since upstream oil and gas value chains develops and produces sophisticated and highly customized knowledge-intensive goods and business-to-business services, the sector is a particularly interesting candidate for studying localized external economies. Our estimated panel data models on the value added of 1,500 firms indicate that firms in the upstream oil and gas industry benefit from being co-located, particularly firms within the same subsector.

KEYWORDS: Agglomeration, Petroleum, Localized external returns to scale, Norway

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1. Introduction

Countries with domestic petroleum resources may have several policy ambitions related to generating economic benefits from their upstream oil and gas industry.[2] Frequently, policy makers are not satisfied with creating income from petroleum extraction alone, but want to increase value added and employment through development of domestically located sectors that supply technologies and services to the upstream oil and gas industry. Furthermore, governments and policy makers may even seek to stimulate regional growth and employment opportunities in particular regions by stimulating industrial competence locally. These policy ambitions are often referred to as local content development, where the objective is to build an internationally competitive industry with a domestically oriented knowledge base (Heum 2008).

Across petroleum-producing countries, very different patterns in the development and employment of the domestic supplier sectors is observed. In some countries the supplier sectors has employment that is considerably higher than in the upstream oil and gas companies alone. Given the potential for economic growth, it is natural to ask what conditions are necessary for the establishment and growth of a domestic supplier sector. We still lack understanding of the mechanisms that create and enhance innovations, productivity growth, and economic impacts from modern petroleum extraction, particularly the role of spatial proximity or distance between economic agents related to the industry. The capacity of firms to innovate or increase productivity is not only defined by the firms` boundaries, but also increasingly depends on external resources that agglomerate in different places (Lecocq et al. 2012, Lundvall 1992). The research in regional development (and others, e.g. economic geography) argues that firms may benefit from geographic clustering through localized knowledge spillovers, territorial learning, and specialization (Marshall 1920, Krugman 1991b, a, Jaffe, Trajtenberg, and

[2] The upstream oil and gas industry includes seismic exploration for underwater crude oil and natural gas resources, drilling of exploratory wells, and subsequent drilling and operating wells that bring crude oil or raw natural gas to the surface. In this paper, the upstream oil and gas industry is defined as “oil companies” and “oil and gas sector suppliers”, that is, companies that are direct or indirect suppliers of capital equipment, materials, and services to the oil companies.

Henderson 1993, Storper 1995, Audretsch and Feldman 1996, Porter 2000, Rosenthal and Strange 2003, Huber 2012).

Productivity and innovation are endogenous phenomena shaped through interaction between firms and their environments (Fagerberg, Mowery, and Verspagen 2009, 21). There is rich evidence that firms cluster in space and that there is a nexus between productivity and clustering. Regionally specialized industries also tend to grow at a faster pace induced by learning that takes place between neighboring firms. This is something isolated firms miss out on (Simonen, Svento, and Juutinen 2015). This paper goes beyond identifying the effects of clustering across a broad set of sectors, but address particular issues related to agglomeration economies or localized external returns to scale, more specifically the nexus between geographic and sectorial dimensions in terms of productivity impacts. It is argued that localized external economies of scale are related to knowledge spillovers and specialized suppliers, and these issues are examined by employing econometric models of firm value added on a panel data set of 1.500 firms. Do these localized external economies of scale have statistically significant effects on the productivity of the supplier sector?

This paper is organized as follows: In the next section, the nature of agglomeration economies in general (section 2.1), and agglomeration economies in the petroleum sector in particular (section 2.2), is discussed. In section 2.3, a historical overview of the Norwegian upstream oil and gas industry is provided. Furthermore, the subsectors in the industry (2.4) are described, and insights to the geographic distribution of the industry is presented (2.5). In section 3, the econometric models are demonstrated prior to the presentation of the empirical results and discussion in section 4. Finally, in section 5, concluding remarks are provided.

2. Background and theory

2.1 The nature of agglomeration economies

The potential benefits from co-location can be studied from various perspectives, from a focus on sector space to a focus on regional space, or the two combined. Many contributions in the literature have tried to explain why sectors and firms in some regions thrive while others struggle (Porter 1990,

Faggian and McCann 2009, Barro and Sala-i-Martin 1995, Henderson 1997). However, contributions studying the empirical impact of cluster composition on regional economic performance are lacking (Delgado, Porter, and Stern 2012). Firms may receive economic benefits in the form of increased productivity and profits due to localization in a cluster which is a geographic concentration of inter-connected companies and supporting institutions where firms receive economic benefits from localization in the cluster which are not obtained by firms residing outside the cluster (Porter 2000).

A distinction between two types of external agglomeration economies (localization and urbanization) is often depicted in the literature. The former increase returns within a single or more narrowly defined industry (industry clusters). The latter increase returns to a diversity of industries in a regional or urban economy (Rosenthal and Strange 2004). These agglomeration economies have also been referred to as intra (localization) and inter (urbanization) clustering (Melo, Graham, and Noland 2009). The first type draws from the seminal insights put forward by Marshall (1920), and argue that firms that co-locate could enjoy external economies because of exchange of inputs, expertise, and information and division of labor (Paci and Usai 1999), and these economic benefits would mostly operate within a single industry. The second type emphasizes the positive externalities associated with new ideas across different sectors, as suggested by Jacobs (1969). The results from past contributions on agglomeration effects have demonstrated mixed results, often depending on the focus of the study as well as the unit of observation, e.g. firm level or regional level (Delgado, Porter, and Stern (2012). Some contributions have demonstrated the effects of localization economies (Cingano and Schivardi 2004, Henderson 2003) as well as some contributions demonstrating the effects of urbanization economies (Jacobs 1969, Combes 2000, Glaeser, Scheinkman, and Shleifer 1992, Frenken, Van Oort, and Verburg 2007, Caragliu, de Dominicis, and Groot 2016).

Agglomeration effects or localized external returns to scale have received attention in a large number of studies[3], as documented in several literature surveys (e.g., Rosenthal and Strange (2004), Melo, Graham, and Noland (2009)

[3] "External economies", "localized external returns to scale" and "agglomeration effects" are used interchangeably throughout this paper.

and Cohen and Paul (2009)). Several of the studies investigating agglomeration effects have been based on a production function approach following Hall (1990). These studies have generally demonstrated that clustering of economic activities increases productivity because of external economies of scale.[4] The external scale economies in turn increase the competitiveness of an area, as the firms located in the area presumably have higher productivity than firms located outside the area. The literature has shifted from focusing on external economies of scale that lower transportation and transaction costs to highlighting knowledge spillovers, innovation, and learning (Malmberg, Malmberg, and Lundequist 2000). This view is supported by Capello and Nijkamp (2009) who underline reflections that might be useful for industrial economists such as collective learning and relational proximity, where "endogenous spatial development patterns of knowledge are not left to simple probabilistic contacts, but explained through territorial processes" (Capello and Nijkamp 2009, 8).

Kaldor (1970, 340) argued that agglomeration economies are the result of "the development of skills and know-how, the opportunity for easy communication of ideas and experience, the opportunity of ever-increasing differentiation of processes and specialization on human activities". Both strong ties between regional actors (Scott 1993, Storper 1995) and knowledge spillovers from science-based activities (Romer 1986, 1990, Lucas 1993, Krugman 1991b, a) can contribute to higher rates of innovation, increased entrepreneurial activity, and increased productivity within geographically bounded areas. Location and geographical proximity can influence innovation rates and technological progress (Lundvall 1988, Saxenian 1990, Glaeser, Scheinkman, and Shleifer 1992, Jaffe, Trajtenberg, and Henderson 1993, Audretsch and Feldman 1996, Glaeser 1999, Baptista 2000, 2001, Boschma 2005). This is particularly true for circumstances in which knowledge has a high degree of uncertainty, so that information is not easily conveyed using a standardized medium. This type of knowledge can be what is referred to as "tacit knowledge" and it is based on the fact that "we know more than we can tell" (Polanyi 1966, 4). Face-to-face

[4] Among the early studies following Hall (1990) using aggregated (sector) data were Caballero and Lyons (1992, 1990) and Bartelsman, Caballero, and Lyons (1994). Examples of later studies using disaggregated (firm, worker) data are Graham et al. (2010) and Martin, Mayer, and Mayneris (2011).

interaction (Storper and Venables 2004), and geographical proximity (Boschma 2005), becomes central as it facilitates the diffusion of tacit knowledge (Maskell 1998, Von Hippel 1998). Bathelt, Malmberg, and Maskell (2004) argue that buzz is communication shared through face-to-face contacts and through the co-location of firms and people within the same region or industry. This motivates studying whether firms in a specific sector or technological domain, such as the upstream oil and gas industry, benefits from co-location.

2.2 Agglomeration economies in the upstream oil and gas industry?

Since conditions for agglomeration economies may not be present in all industries, a natural question to ask is whether the upstream oil and gas industry is an interesting case for studying agglomeration economies. Much of the cluster research has focused on manufacturing and information technology sectors, which often are characterized by a high level of technological sophistication and innovation rates, specialization, and lumpiness. These characteristics are certainly present in the upstream oil and gas industry (Silvestre Dos Santos and Dalcol 2009) that develops highly customized knowledge-intensive goods and services. Offshore field development, which involves design, engineering and construction of production facilities and infrastructure, is a highly complex process where many types of knowledge and technologies are combined. Consequently, many supplier firms have specialized in different knowledge and technological domains. Thus, the industry is characterized by knowledge-intensive firms with demanding customers in several stages of the value chain. Each offshore field has unique technological solutions partly reflecting the heterogeneity of petroleum reservoirs (e.g. petroleum well pressure and temperature) and other physical field characteristics (e.g. water depth, current and wave conditions, distance from onshore facilities). Since offshore fields have entered into development at different points in time, the almost continuous technological changes in the industry have influenced the organization and technological concepts of the development phase. During its production life cycle, a petroleum field will typically be subject to several small and large investment projects related to maintenance, technological upgrading and capacity expansion. These life cycle investment projects will often be complex and unique in several respects due to the uniqueness of each field in terms of technological concepts, reservoir and

other physical characteristics. This leads to the need for involvement of many supplier firms and extensive interaction between firms in various stages of the project. It is not uncommon that cumulative investment costs during the production phase are similar or above the initial field development investment costs, which typically are in the range of one to ten billion US dollars.

The technologies within the upstream oil and gas industry are habitually developed in close cooperation directly with the purchasers or handlers of the systems through a Doing, Using, and Interacting (DUI) approach (Jensen et al. 2007) that emphasizes the importance of tacit knowledge facilitated by cognitive and physical proximity (Marshall 1920, Gertler 2003, 1995). Innovation and production processes frequently involve extensive interaction between suppliers and customers at different stages (Isaksen and Karlsen 2012). This close collaboration between producers and customers facilitates the emergence of innovative and highly specialized systems for advanced operations. Face-to-face contact is a mechanism for deliberate knowledge exchange in formal settings (Asheim, Coenen, and Vang 2007), but there is also a strong sense of "local buzz" within the regions that are heavily invested in the upstream oil and gas industry. There are typically many informal and formal meeting points for firms in the sector, e.g. events, fares, meetings, which serve to inspire and provide information to actors (Bathelt, Malmberg, and Maskell 2004). This sharing of information is facilitated by a shared technological relatedness, cognitive proximity, cultural similarities that provides the background upon which intended and unintended learning processes and discussions may depart from (Bathelt, Malmberg, and Maskell 2004). The industry is based on the joint development of routines and standards in order to solve both technological and organizational challenges. In sum, the form of interaction is dependent on cognitive proximity where the actors share a common knowledge base, fostered through trust-based relationships (social proximity) as well as the geographical proximity (being near)(Boschma 2005). Arguably, some firms in the industry may be less dependent on geographic proximity to partners as they operate in an international market, competing for international projects and global customers in many parts of the world. This does not exclude theoretical discussion of the importance of "being there" (Gertler 1995). It may in fact be a driving force behind engaging in cooperation among these international partners. Hence, partners may prefer to cooperate

with a firm in a cluster to working with a firm that does not enjoy localized external economies. Specialization and diversity of factors in a location will often increase the rate of product innovation. Rauch (1993) provided an example of workers enhancing their human capital by exchanging ideas: As the overall size of the regional industry increases, a larger number of workers and a greater diversity of human capital increase the probability that a random pair-wise interaction between any two workers will lead to the exchange of ideas and skills that improve the human capital of both workers. This enhanced interaction may lead to a more productive and higher paid workforce.

The upstream oil and gas industry has evolved over time in ways that may have influenced the mechanisms and magnitudes of localized external economies. It has faced increasing technological challenges at different stages since large-scale crude oil extraction began in the middle of the 19th century. The industry started with "low-hanging fruits," extracting oil onshore from reservoirs just below the soil. As the easily accessible onshore petroleum resources became scarcer over time, oil companies were forced to explore and develop resources in deeper onshore reservoirs and to move offshore. In recent years, the industry has dealt with the complex challenges of developing petroleum resources several hundred kilometers from land at water depths of around 2,000 meters, sometimes extreme weather conditions, in reservoirs which may be around 6,000 meters deep, and with challenging reservoir characteristics such as high temperatures and high pressure, in addition to fulfilling the strict safety and environmental standards of the industry (Osmundsen, Roll, and Tveterås 2012, 2010). To date, the industry has responded to the emerging technological challenges with a combination of radical and incremental innovations at different stages. Technological advances and the transition toward a more knowledge-based industry have changed the upstream oil and gas industry in ways also seen in other industries that have experienced similar development. The industry has become more capital intensive and the scale and complexity of offshore investment projects has increased substantially. Labor and its tasks have become more specialized, with an accompanying need for a wider range of specialized skills.

The characteristics of the petroleum industry described above provide a rationale for investigating localized external economies of scale. As petroleum exploration and development activities shift to new regions around the world,

increased knowledge of agglomeration economies will also provide a better understanding of the potential economic opportunities and requirements for developing new oil- and gas-related clusters.

2.3 The Norwegian case: Historical overview and policy measures

Nearly half a century ago, in 1969, oil was discovered in the North Sea Ekofisk field in Norway. This discovery led to the emergence of a substantial oil and gas-related industry. Prior to this discovery, the industry was essentially non-existent in Norway. However, in 2011, the industry employed approximately 140,000 people with a value added representing close to one third of the nation's gross domestic product (GDP) (Sasson and Blomgren 2011). Although the industry is unevenly spread out geographically in Norway, it is still clustered in various municipalities and regions. Most of these clusters tend to be smaller and peripheral than the leading clusters in the oil and gas-related industry throughout the world, such as Houston and Alberta. Regions in which technological activities agglomerate tend to enjoy numerous positive externalities because firms may share certain resources, which in turn may lead to increased innovation and productivity through a reduction in transaction and transportation costs, knowledge spillovers, and learning (Beaudry and Breschi 2003, Deeds, Decarolis, and Coombs 1999, Baten et al. 2007, Baptista 1998).

In the early 1970s, the development of offshore petroleum fields relied heavily on the financial capital and knowledge of multinational oil companies. Norway lacked the specific industrial capabilities and competence to operate the business on its own (Engen 2009). From the initial phase, the Norwegian government had a policy aim to develop a domestic supplier sector and oil companies that could contribute to increase value added and employment. This objective was pursued through different policy measures that forced or gave incentives to international oil companies to employ and train Norwegian labor in different stages of offshore petroleum operations and to hire Norwegian companies as suppliers. Until the early 1980s, the international oil companies were to some extent encouraged to choose technological concepts that may not have been the most efficient from their economic viewpoint, but which increased the opportunity for Norwegian labor and supplier companies to enter the sector (Engen 2009). Statoil, a Norwegian state-owned oil company established in 1972, enjoyed positive discrimination from the government in

several areas, including granting of exploration licenses and petroleum field ownership licenses. A central ambition for Statoil was to become an operator of petroleum fields in production, a role that would require considerable internal competence. In 1981, as the first Norwegian company to do so, the company acquired operator rights on the Norwegian continental shelf in the Gullfaks field. Over time, Statoil became a dominant oil company in the Norwegian upstream industry. This dominant role was made possible by the ongoing strengthening of the company through the abovementioned regulatory frameworks as well as through the technical, financial, and human resources of the firm. A large part of this picture is that Norway came relatively quickly to terms with the scale of skills, demands, and industry requirements needed and built an internally stable workforce that could expand production operations and exploration within the country (Andrews 2015). Andrews (2015) argues that the Norwegian approach to workforce development is one of the greatest examples of how a nation can efficiently grow its oil and gas sector, as well as nationalize its workforce, thereby providing ample career opportunities for the local population. Having a qualified workforce means that companies can carry out operations across Norway, including in its more peripheral regions.[5] During the 1970s and 1980s, the discovery and development of new petroleum fields together with the stimuli from government policies aimed at developing a domestic sector contributed to the growth of a Norwegian petroleum labor force and supplier companies. This supply sector has experienced significant changes over time in terms of skill and technology base, international competitiveness, and markets. Indeed, the discovery of new petroleum resources and their development from 1970 onward led to an increase in production and value added in the upstream oil and gas industry, as shown in figure 1. The industry also increased its share of Norwegian GDP from zero to more than 20%.

(Figure 1 around here)

Over time, the Norwegian upstream oil and gas industry has faced multiple challenges from the global market, domestic economy, and increasingly more demanding characteristics of the petroleum resources being developed. This has

[5] Note also that even though Norway lacked specific industrial capabilities and competence in upstream petroleum, the country had relevant industrial competence from metal production, shipping, and the mining industry (Heum 2008).

influenced the development of technologies, skills, companies, and the interactions between firms. Before the dramatic oil price decline in the mid-1980s, the sector enjoyed prices that provided high economic rates of return in oil field development projects, even with the substantially higher costs associated with inefficient technological concepts and mobilization of labor and companies that were still early in their learning curves. The significantly lower oil price levels from 1986 to 2000 reduced the economic margins of existing fields and new field development. From the 1970s, Norwegian labor costs have increased in relation to most other countries, partly fueled by the growth of the oil sector. Furthermore, new petroleum resource discoveries have been more technologically challenging in terms of their reservoir characteristics (e.g., formation type and complexity, formation pressure and well temperature, water depth, weather conditions, distance to land).

All these developments contributed to restructuring of the industry and induced innovation in several technology areas to reduce the cost of field development and production. They also contributed to the evolution of the supply sector's skill and technology base, as changes in oil prices, increased labor costs, and the changing characteristics of new fields provided new opportunities and challenges for existing companies and entrepreneurs in the supply sector. In response to the above-described developments, numerous technological innovations have been introduced in new petroleum fields over time, as described by Sasson and Blomgren (2011Ch.6.2). These manifested in new physical field installations, drilling technologies, and petroleum transportation technologies, among other innovations. The Norwegian supplier sector held a central role in many of these innovations via the development of technological components and the combination of components. Furthermore, the sector introduced innovations to the organization of development and maintenance projects. These above-mentioned developments served as a catalyst for firms, pushing them into interaction and developing solutions together.

(Figure 2 around here)

The Norwegian upstream oil and gas industry has experienced significant development from its infant stage when it relied partly on government protection from foreign competition in the domestic market. Employment in the industry was practically zero in 1970. In 2000, more than 70,000 persons

were employed, and in 2009, employment had increased to 133,000 persons, of which 22,000 were in oil companies (see figure 2). The supplier sector is now exporting globally, has subsidiaries in many countries, and is providing a broad range of petroleum-related services and capital goods. In 2009, total international sales of Norwegian oil and gas industry suppliers reached an estimated 120 billion Norwegian krone (NOK hereafter), of which around 70% was exports and 30% was foreign subsidiaries. In the same year, the export value of oil and gas was 405 billion NOK (Sasson and Blomgren 2011).

2.4 Sector structure

In this paper, the upstream oil and gas industry is defined as "oil companies" and "oil and gas sector suppliers", that is, companies that are direct or indirect suppliers of capital equipment, materials, and services to the oil companies.

Oil companies are often called "licensees" or "operators,"[6] that is, firms that hold production licenses or have been granted operatorships for oil or gas fields (e.g., BP, ConocoPhillips, Statoil, and Shell). This sector consists of 179 entities, with a combined employment of 22,000 in 2009. Statoil, the largest firm in the Norwegian sector, accounts for more than three-quarters of the total employment amongst oil companies. Oil and gas sector suppliers are a heterogeneous group of firms in terms of size, products, processes/technology, and knowledge. Standard industrial classifications of economic activities are not very fruitful for grouping firms according to their products and production processes or for understanding the supplier-buyer links between sectors. Hence, the usefulness of standard NACE[7] sector classifications is limited for firms in upstream petroleum-related sectors. Therefore Sasson and Blomgren's (2011) *sector* classification (five groups) for the supplier industry is employed. These are defined as follows:

Geology, seismics and reservoir: This is the smallest sector with 149 entities and 4,000 employees in 2009 (the last year in the data set). Activities are

[6] They are substitute terms.
[7] Nomenclature generale des Activites economiques dans les Communautes europeennes (NACE) classification.

divided into computer-assisted modeling of reservoir data (engineering-based services) and acquisition and processing of seismic data (maritime operations).

Drill & well: This is a medium-sized sector consisting of 235 entities with total employment of 20,000. The segment is divided into four subcategories: (1) engineering-based firms running drill and well operations, (2) manufacturing of drill and well equipment, (3) equipment supply, and (4) administration of offshore rigs and floating production storage and offloading (FPSO) units.

Field development topside: This is the largest sector and comprises 404 entities with 43,000 employees. Sector activities include the construction of offshore-related vessels, the construction of surface installations, and the maintenance and modification of onshore and offshore production facilities (abbreviated as MMO). The segment is divided into four subcategories: (1) engineering-based firms, (2) manufacturing of construction-related equipment, (3) equipment supply, and (4) construction and maintenance of onshore and offshore facilities.

Field development subsea: This sector includes 96 entities and employs 13,000 people. The segment is divided into four subcategories: (1) engineering-based design, (2) manufacturing, including design and development, and fabrication of units, (3) construction and maintenance, and (4) maritime-related engineering and services.

Operations support: This is the second-largest sector with 1,393 entities and employment of 34,000. This segment is divided into six subcategories: (1) engineering-based services, consisting of firms providing operational support and firms offering personnel for operations support, (2) manufacturing of equipment for production and safety, (3) equipment supply, (4) construction and MMO, consisting largely of firms providing auxiliary services like scaffolding, insulation, and painting, (5) maritime operations e.g., supply vessels), and (6) support services, such as offshore catering, helicopter transport, land transport, and bases.

As shown in figure 2, total employment in the oil and gas industry has increased over time. This is also the case for most subsectors, as shown in figure 3. All sectors increased their employment from 2000 to 2009. Field development topside experienced the largest fluctuations in employment because it depends

more on new field development projects, which are few, and activities are unevenly distributed over time.

(Figure 3 around here)

Figure 1 shows that value added in the upstream oil and gas industry has also increased rapidly over time and now represents approximately one-fourth of domestic GDP. Figure 4 breaks down value added in the oil and gas industry by subsector[8]. It can be noted that the value added of oil companies is of a higher order of magnitude than the other sectors. This high value added among oil companies reflects the large resource rent that is realized by extracting scarce petroleum resources.

(Figure 4 around here)

These differences in value added between oil companies (operators) and supplier sectors also exist value added is divided by employees. Figure 5 shows value added per employee (VA/L), with oil companies on the right-hand vertical axis and supplier sectors on the left-hand axis. The VA/L measure can be regarded as a measure of labor productivity, but, of course, it also often reflects significant differences in capital intensity (capital-labor ratio) between sectors. All sectors experienced growth in value added from 2000 to 2009. The value added per employee among oil companies increased from $1.5 million US per employee in 2000 to $2.8 million US per employee in 2009. Among the supplier sectors, “Geology & seismics” emerges as having the highest rate of labor productivity growth during the period, and it was the most productive in terms of value added per employee in 2009, with a VA/L of $409,000 US. In 2009, Geology & seismics was followed by the “Drill & well” sector with a VA/L of $344,000 US. The “Field development topside” sector was the least productive with a VA/L of $144,000 US per employee in 2009 and has been the least productive in terms of VA/L in most years.

(Figure 5 around here)

[8] Note that value added of oil companies (operators) is on the right-hand vertical axis and value added of the other sectors is on the left-hand axis.

2.5 Geographic distribution of the upstream oil and gas industry

The spatial distribution of the Norwegian oil and gas industry has only partly been driven by geographic proximity to offshore petroleum resources. The map showing the geographical distribution of petroleum fields on the Norwegian continental shelf indicate that petroleum fields are located far from the Norwegian mainland, typically several hundred kilometers from land (see figure 7). For many oil and gas related activities distance and transportation costs to the fields have only a small economic influence on location choices. The onshore industry has become geographically more diversified as increased demand for capital equipment and services from the sector following its growth and geographic offshore field diversification provided opportunities for firms and labor from different parts of the country. Still, much of the sector's onshore activities are concentrated in western Norway as shown in Table 5 and figure 6. The relatively high concentration of onshore activities in Western Norway is not accompanied by a similar high concentration of offshore petroleum fields along its coastline relative to other parts of the country.

(Table 1 around here)

The perceived Norwegian aptitude of building industrial capabilities has been referred to as "the Norwegian model" because of the framework, policies and actions that the government enforced in order to construct this industry. Heum (2008) argues however, that this is not dissimilar to how other countries, that were less successful, organized their upstream oil and gas industry. Not only does this entail an important story of there not being a "one size fits all" policy for how to organize the upstream oil and gas activities, but it correspondingly calls for an increased need of grasping some of the underlying mechanisms of why this is so.

In the early phase, most oil companies and many suppliers established themselves in the western part of Norway, with a high concentration in the county of Rogaland (see figure 7). The early location pattern was partly driven by a proactive local government that facilitated localization of firms and workers. These places may have become "the place to be" for firms and workers in the industry, partly due to "local buzz" between the workplaces related to inter-firm business transactions but also other arenas. Another potentially

important source of knowledge spillovers is labor mobility across firms and institutions. According to Balsvik (2011) mobility is clearly a channel for knowledge diffusion in Norwegian manufacturing[9]. Labor mobility is one of the key mechanisms for knowledge diffusion (Boschma, Eriksson, and Lindgren 2009). By co-locating firms share labor pool and have higher access to the specialized skills that they need, which in turn shapes the educational patterns of new workers.

3. Empirical model specification and data

In the following sections, the specification and estimations of econometric models that allow us to test for the presence of agglomeration economies in the upstream oil and gas industry will be presented.

This study provides econometric testing of localized external returns to scale using a panel dataset of around 1,500 firms located in various counties in Norway in the period 2000-2009. The data permits testing different hypotheses with respect to geographic co-location and performance as well as differentiating between internal and external returns to scale. The data also allow us to distinguish between intra- and inter-industry agglomeration externalities. In this paper, hypotheses on the existence and scope of external returns to scale in both the sector space and geographic space are tested by estimating econometric models with value added as dependent variables. These models are flexible in several respects, allowing to test a set of hypotheses in internal and external economies (Paul Morrison and Siegel 1999).

The literature that estimates external economies or, more specifically, agglomeration effects, generally includes an external economy index in the production function. For example, Caballero and Lyons (1990) specified the production function, $y = f(\mathbf{x}; E, t) + V$, where y is output, $f(.)$ is the "average" production technology, $\mathbf{x}$ includes inputs, E is an external economy index, t is a productivity index, and V is a random variable representing statistical noise.

The most general model specification to be estimated is

[9] Balsvik (2011) has studied whether labor mobility is a channel for spillovers from multinationals by investigating the Norwegian manufacturing industry.

$$\ln VA_{it} = \mu_i + \Sigma_s \beta_{Ls} \ln L_{it} + \Sigma_s \beta_{LLs} (\ln L_{it})^2 + \Sigma_s \beta_{Ls} \ln L_{st} + \Sigma_s \beta_{st} D_s \Sigma_t D_t + u_{it},$$
$$i = 1,..., N;\ \ s = 1,..., S;\ \ t = 1,..., T,$$

where subscript i refers to firm, subscript t refers to year, s is a subscript for the eight sector definitions used here, and the subscript r refers to three sector definitions used for testing external returns to scale, which will be defined later in this section. The dependent variable VA is value added of the firm, μ_i is a firm-specific effect, L_i is the number of employees in firm i, L_s is the number of employees in sector s, D_s is the dummy variable for sector s, D_t is the dummy variable for year t, and β are parameters to be estimated.

The firm specific effect μ_i accounts for unobserved heterogeneity across firms. This heterogeneity may be related to capital intensity, managerial abilities, worker skills, production processes, and competition in the market segment in which the firm operates, among others. The absence of a capital input variable in the data set means that the firm-specific effect will capture differences in capital intensity (or the capital-labor ratio) across sectors and firms. Furthermore, structural differences exist in economic returns across sectors; in particular, oil companies earn an economic rent from extracting a scarce resource that, depending on the oil price and field characteristics, provides an extraordinary economic return compared to the supplier sectors.

Input of labor is specified with a first and second order term to allow for constant, increasing, or decreasing returns to labor input. Furthermore, the we allow the parameters associated with labor input to be sector-specific because it is reasonable to assume structural differences in production technologies, including labor input elasticities, between sectors. Sector-specific shocks over time are captured by the term $\Sigma_s \beta_{st} D_s \Sigma_t D_t$. This accounts for yearly shocks that are more or less common for the firms within a sector, such as oil price changes or shocks to input prices and productivity.

Regional employment is used as a proxy for regional external economies of scale (agglomeration economies) for various sector definitions.[10] External scale is tested using the sector definitions proposed by Sasson and Blomgren (2011),

[10] Note that with the log-log specification of equation (1) the parameters associated with the external economy proxy variable can be interpreted as elasticities. If there are positive external returns, the parameter associated with the total regional sector employment will be positive.

which was presented in section 2.4. Under this definition, the sector consists of the following petroleum subsectors: (1) *Oil companies* (operators), (2) *Geology, seismics & reservoir* (3) *Drill & well*, (4) *Field development topside*, (5) *Field development subsea*, and (6) *Operations support*. In addition we have added (7) *Downstream petroleum activities* - refineries, transport, and marketing, and finally lumped together in one sector knowledge intensive services (8) *Education, research, finance, consulting, etc*.

Localized external returns to scale are tested at the county level using county employment for three different sector definitions: (1) county employment in the narrower oil and gas subsectors (1)-(8) to which the firm belongs, (2) employment in the total oil and gas sectors in the county, and (3) county employment in oil and gas subsectors other than those to which the firm belongs (i.e. total county oil and gas sector employment minus employment in the subsector to which the firm belongs).

Table 2 presents the summary statistics for the 1,567 firms in the estimating sample with a total of 11,510 observations.[11]

(Table 2 around here)

The types of hypotheses that can be tested depend on the aggregation level of the data used. Ideally, to capture different types of internal and external economies and substitution opportunities, it is preferred to estimate production relationships at the firm level, as done in this paper. In this way, it enables an inclusion of the internal production technology of the firm, the economies of close proximity to other establishments in the same more narrowly defined industry (localization economies), and the advantages accrued from the level of all economic activities within a geographic area (urbanization economies).[12] Recently, several studies using data at the firm and plant level have emerged (Henderson 2003, Holl 2012, Martin, Mayer, and Mayneris 2011).

In this study, firm-level panel data in an econometric model framework is employed which enable estimations of internal scale economies and agglomeration externalities. Furthermore, these data allow potential

[11] The loss of observations are caused by missing employee data.
[12] See Parr (2002, 2004) for a more recent classification of these agglomeration economies.

identification issues that may arise in the estimation of agglomeration economies (Graham et al. 2010, Combes, Duranton, and Gobillon 2011) to be handled. We allow the identification and separation of possible regional inter-industry and intra-industry agglomeration externalities, by using agglomeration indexes related to intra-industry and potentially connected industries' regional activity levels. This distinguishes our study from those that focus on measuring the geographic extent, but not the sectorial extent, of a cluster as defined by agglomeration externalities (Cohen and Morrison Paul 2004).

4. Results and Discussion

This section presents econometric estimates from the general value added production function model specification in equation (1). Two sets of model specifications are tested, one where internal returns to scale (represented by labor input) are restricted to be homogeneous across sectors and one which allows for sector-specific internal returns to scale. For both sets of models, the regional agglomeration indexes using the three different oil and gas sector definitions presented in section 3 are tested.

In table 3, the estimated models (A)-(C) with firm-specific fixed effects and homogeneous internal returns to scale across sectors are presented. Heterogeneity of the intercept μ_i at the firm level is statistically supported by likelihood ratio tests. Due to space considerations, the coefficients associated with the time and sector dummy interaction variables are omitted from the tables. However, these terms suggest significant shifts in value added from year to year with different patterns across sectors, and likelihood ratio tests strongly support their inclusion in the models. Oil price changes during the data period are likely the most significant direct or indirect driver of these shifts in value added over time.

Next, the variable of primary interest – the agglomeration indexes, is examined. For all three agglomeration indexes associated with models (A)-(C), statistically significant external returns to scale are predicted. The elasticity of firm value added with respect to total county employment in the oil and gas subsector to which the firm belongs is 6.5%. Furthermore, the elasticity of firm value added with respect to total county oil and gas sector employment is 5.5%. Finally, the elasticity of firm value added with respect to county employment

in oil and gas subsectors other than those to which the firm belongs is 4.3%. These econometric results provide support that co-location matter for many firms in the Norwegian upstream oil and gas industry. Furthermore, the results suggest that the external economies are stronger when firms within the same subsector are co-located, while the effect of other subsectors located in the same region on external returns to scale is slightly weaker.

(Table 3 around here)

A concern could be that the homogeneous internal returns to scale specification of models (A)-(C) also distorts the estimates of external returns to scale. Consequently, in table 4, models (D)-(F) are presented, where the internal scale parameters associated with firms' employment levels is allowed to be heterogeneous across the eight sectors. The specification of sector-specific internal returns to scale is statistically supported by likelihood ratio tests. Statistically significant external returns to scale are still predicted for all three sector definitions and the estimates have not changed much from table 3. The elasticity of firm value added with respect to total county employment in the subsector to which the firm belongs is 6.7%. Furthermore, the elasticity of firm value added with respect to total county oil and gas sector employment is 4.9%. Finally, the elasticity of firm value added with respect to county employment in subsectors other than the one to which the firm belongs is 4.1%.

(Table 4 around here)

Overall, the results stemming from the empirical analysis indicate that firms in the upstream oil and gas industry benefit from being co-located through external returns to scale and that this is especially true when firms within the same subsector are co-located. These findings are in line with previous contributions, i.e. Henderson (2003) that found that a firm located in a region with several other firms within the same sector is much more productive than firms operating in isolation.

5. Concluding remarks

In this paper we have examined whether localized external economies of scale have a significant effect on the economic performance of companies in the upstream oil and gas industry. The results suggest that co-location increases the productivity of many firms, particularly when firms from the same subsector are co-located. The empirical results seem reasonable when the characteristics of the industry are more closely examined. Firms in the industry produce highly customized knowledge-intensive goods and business-to-business services partly driven by heterogeneous and increasingly demanding characteristics of offshore petroleum reservoirs. Individual firms are likely to benefit from the regional presence of related firms in both innovation and production processes. The gradual process from exploitation of relatively more accessible petroleum resources in the earlier stages of the industry's life cycle to the targeting of technologically much more demanding resources in the latter period has only reinforced these circumstances. Technological relatedness and various kinds of proximity affect the productivity of firms that are geographically close. The process of knowledge generation and exploitation requires a dynamic interplay and transformation of tacit and codified knowledge as well as strong interaction among people. Asheim et al. (2013) argue that despite the trend toward increased diversity and interdependence in the knowledge process, the innovation processes of firms and industries are strongly shaped by their specific knowledge base. Thus, the position of the Norwegian upstream oil and gas industry as internationally leading in some technology areas can partly be explained by the companies' knowledge base and strong interaction of people, as well as their ability to provide services and systems that are custom-made as well as competitive by international standards.

The econometric results imply that the expansion of the petroleum sector with a relative high degree of regional concentration has provided higher value added through the positive effects of localized external returns to scale. Moreover, these agglomeration effects have made it profitable to hire more labor and provide higher wages than would have been possible with a smaller and geographically more dispersed sector.

The Norwegian economy is heavily dependent on the industry, and currently, the petroleum sector faces much lower oil prices than in the previous years.

This has caused significant employment reduction in all petroleum related subsectors. The implication from our econometric results is that a large employment reduction can also lead to significant loss of external returns to scale.

An implication of our results for government is that appropriate policy measures, which can contribute to sustaining long-run profitable employment in oil and gas clusters, will mitigate the loss of localized external returns to scale. Even though expected future oil prices have been revised downwards by oil companies there are still plenty of offshore petroleum prospects in different stages that can provide sufficient economic returns. Government measures may include more efficient and speedier public sector processes for allocating licenses in the exploration, field development and production phases. Another candidate is government stimulus to increased allocation of offshore construction projects to companies located in Norwegian regional clusters rather than foreign companies in e.g. Asia. Of course, such measures must be within the legal framework of international treaties, and with the aim of sustaining and developing firms and clusters, which can be viable in the long run. The particular Norwegian tax regime for the upstream oil and gas industry is another candidate for policy revision if tax regime modifications can contribute to increased productivity and international competitiveness through geographic clustering.

Norwegian firms are increasingly operating in a globalized world, with a focus on the development of research and knowledge-intensive businesses and where localization choices increasingly depend on technological capabilities being present locally. A stagnant or declining offshore oil and gas market along the Norwegian coast due to a decreasing supply of undeveloped petroleum fields means that industry needs to increasingly consider global markets, global interconnections and how this could potentially influence clusters and firms (Duranton and Kerr 2015). It is a central question to what extent the Norwegian oil and gas industry in the future will be able to compete globally and increase its supply of goods and services to other oil and gas regions around the world. The answer to that question depends partly on the extent to which a more export-oriented industry can benefit from regional external scale economies residing in offshore oil and gas activities in the Northern European petroleum region.

Figures

Figure 1. Value added in offshore petroleum production and share of GDP (Source: Statistics Norway). In Norwegian Krone (NOK).

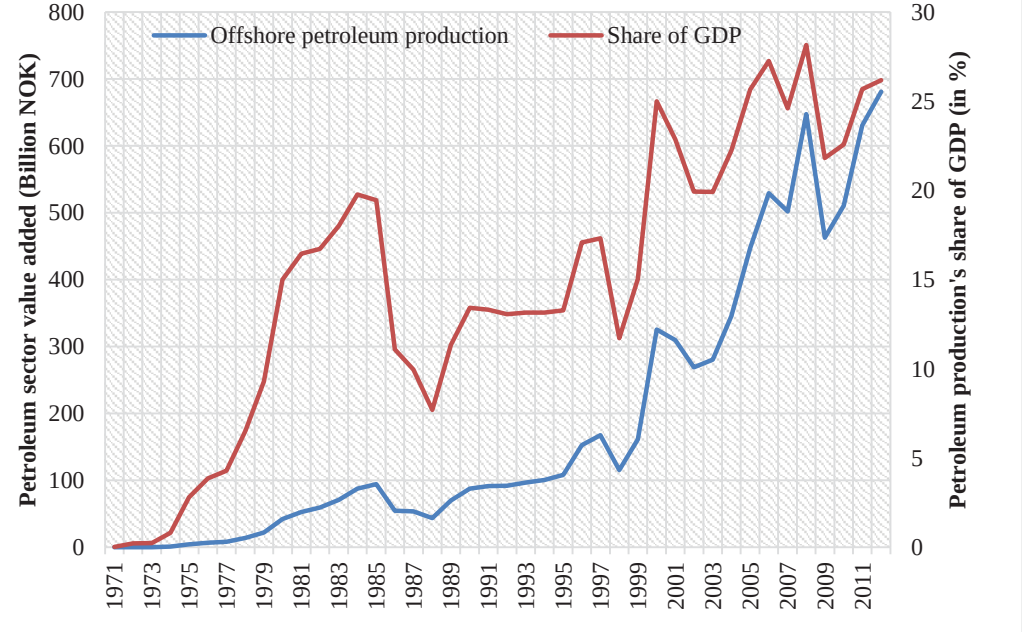


Figure 2. Employment in oil companies and supplier sectors (Source: Sasson and Blomgren (2011)) .

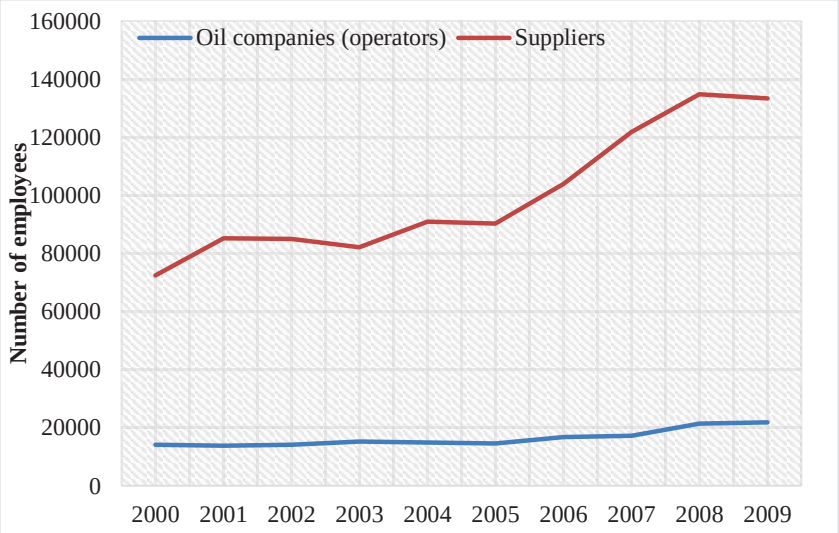


Figure 3. Number of employees in the upstream oil and gas industry (Source: Sasson and Blomgren (2011)).

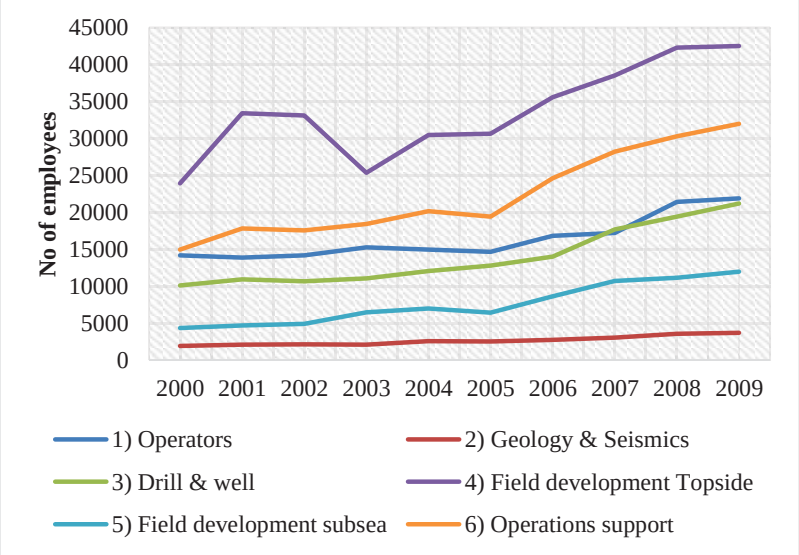


Figure 4. Total value added in upstream oil and gas industry in billion US Dollars (USD hereafter) (exchange rate 6 NOK/USD).

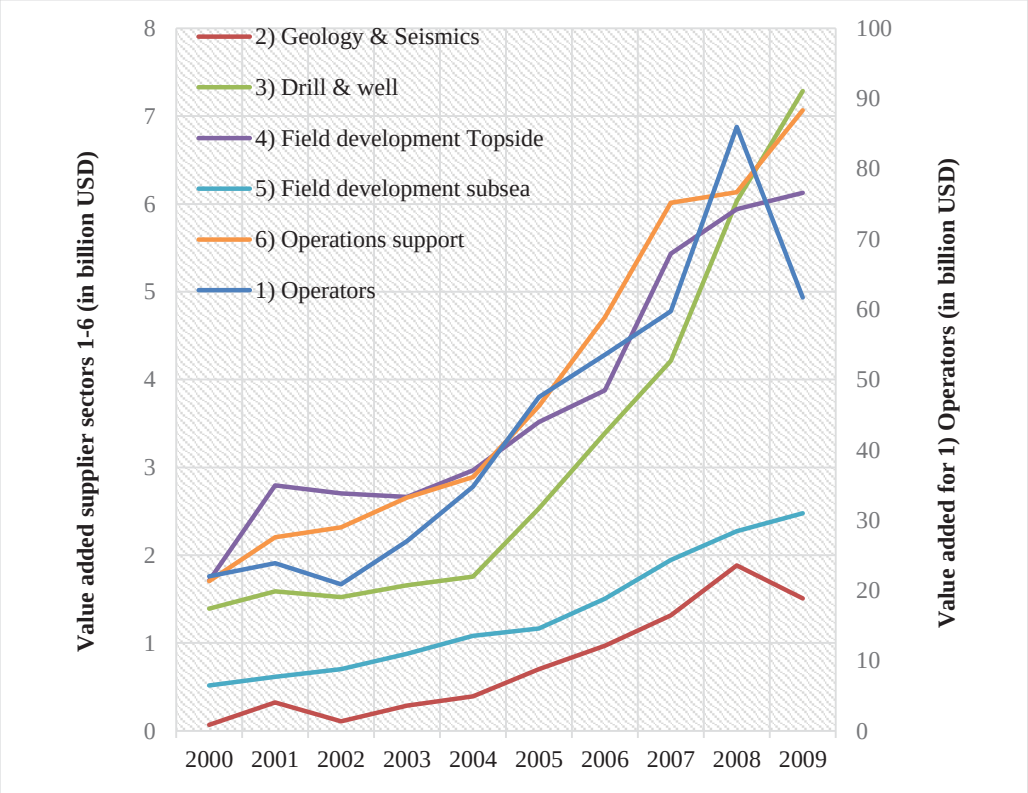
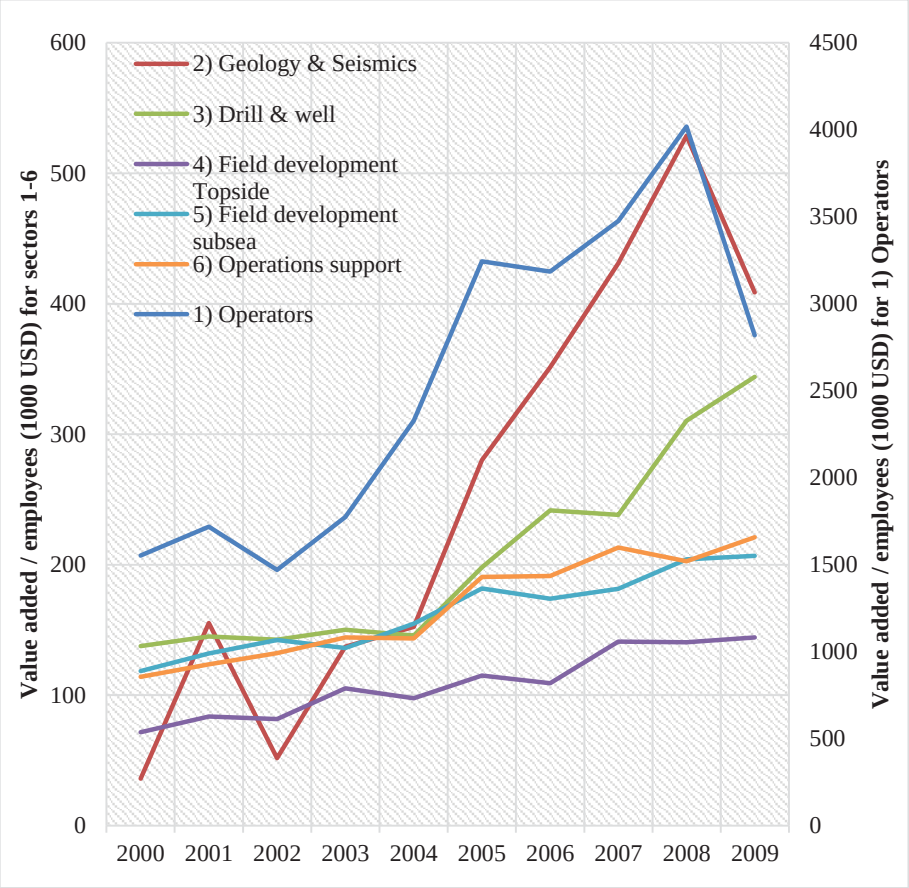


Figure 5. Value added per employee in upstream oil and gas industry (in 1000 USD per employee).



TABLES

Table 1. Number of employees in the oil and gas industry by county (Source: Statistics Norway).

County	2000	2009
ROGALAND	32257	63102
HORDALAND	10357	19913
MØRE OG ROMSDAL	4888	11936
AKERSHUS	2748	9726
VEST-AGDER	1141	5937
OSLO	5946	4027
BUSKERUD	2255	3795
VESTFOLD	1347	3709
SØR-TRØNDELAG	1970	3294
AUST-AGDER	2246	1945
TELEMARK	365	1697
SOGN OG FJORDANE	1092	976
NORDLAND	958	929
NORD-TRØNDELAG	182	905
TROMS	176	469
FINNMARK	133	379
ØSTFOLD	60	177
HEDMARK	75	139
OPPLAND	78	82

Table 2. Descriptive summary statistics of variables in estimating sample Number of observations =11510. Number of firms = 1567.

Variable	Mean	Std. Dev.
Value added (VA)	164359.2	2565025.0
VA/employee	2968.9	62410.0
Employees (L)	73.6	369.3
Employees in firm's oil and gas subsector	3145.5	3194.9
Employees in county oil and gas sector	16173.4	16622.3
Employees in oil and gas subsectors other than the firm's	13027.9	14338.5

Table 3. Panel data model estimates with firm-specific fixed effects and with both internal returns to scale restricted to be homogeneous across sectors*

	Model A	Model B	Model C
ln(employees in firm)	0.558***	0.559***	0.565***
	(0.0251)	(0.0251)	(0.0251)
ln(employees in firm)^2	0.0200***	0.0205***	0.0202***
	(0.00419)	(0.00419)	(0.00418)
ln(employees in subsector)	0.0648***		
	(0.0193)		
ln(employees in oil and gas sector)		0.0545**	
		(0.0233)	
ln(employees in other subsectors)			0.0432**
			(0.0184)
Constant	7.211***	6.955***	7.056***
	(0.144)	(0.209)	(0.161)
Observations	11,510	11,510	11,505
R-squared	0.442	0.441	0.442
Number of firms	1,567	1,567	1,566
log likelihood value	-8419	-8422	-8402
sigma_u	1.050	1.081	1.078
sigma_e	0.543	0.543	0.542
Rho	0.789	0.798	0.798

* Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Interaction terms between sector and year and firm-specific fixed effects have been suppressed due to space considerations.

Table 4. Panel data model estimates with firm-specific fixed effects and sector-specific internal returns to scale.*

	Model D	Model E	Model F
ln(employees in firm)_1	-0.897***	-0.907***	-0.913***
	(0.270)	(0.270)	(0.270)
ln(employees in firm)_2	0.593***	0.627***	0.627***
	(0.117)	(0.117)	(0.117)
ln(employees in firm)_3	0.403***	0.412***	0.464***
	(0.0719)	(0.0718)	(0.0727)
ln(employees in firm)_4	0.739***	0.738***	0.737***
	(0.0532)	(0.0532)	(0.0531)
ln(employees in firm)_5	0.736***	0.732***	0.730***
	(0.0854)	(0.0854)	(0.0853)
ln(employees in firm)_6	0.581***	0.579***	0.579***
	(0.0367)	(0.0367)	(0.0366)
ln(employees in firm)_7	1.083*	1.046*	1.045*
	(0.569)	(0.569)	(0.569)
ln(employees in firm)_8	-0.354	-0.378	-0.379
	(0.265)	(0.265)	(0.265)
$\ln(\text{employees in firm})^2$_1	0.210***	0.211***	0.212***
	(0.0464)	(0.0464)	(0.0464)
$\ln(\text{employees in firm})^2$_2	0.00275	0.000292	0.000354
	(0.0217)	(0.0217)	(0.0217)
$\ln(\text{employees in firm})^2$_3	0.0239**	0.0236**	0.0181
	(0.0119)	(0.0119)	(0.0120)
$\ln(\text{employees in firm})^2$_4	0.0133*	0.0140*	0.0145*
	(0.00759)	(0.00758)	(0.00757)
$\ln(\text{employees in firm})^2$_5	-0.0138	-0.0120	-0.0115
	(0.0137)	(0.0137)	(0.0137)
$\ln(\text{employees in firm})^2$_6	0.0128*	0.0136**	0.0138**
	(0.00683)	(0.00683)	(0.00682)
$\ln(\text{employees in firm})^2$_7	-0.164	-0.152	-0.152
	(0.107)	(0.107)	(0.107)
$\ln(\text{employees in firm})^2$_8	0.129**	0.139**	0.139**
	(0.0616)	(0.0615)	(0.0615)
ln(employees in subsector)	0.0665***		
	(0.0194)		
ln(employees in oil and gas sector)		0.0490**	
		(0.0232)	
ln(employees in other subsectors)			0.0410**
			(0.0183)
Constant	7.202***	7.240***	7.097***
	(0.146)	(0.213)	(0.161)

	Model D	Model E	Model F
Observations	11,510	11,510	11,505
R-squared	0.449	0.448	0.449
Number of firms	1,567	1,567	1,566
log likelihood value	-8343	-8348	-8330
sigma_u	1.236	1.229	1.330
sigma_e	0.540	0.540	0.539
Rho	0.840	0.838	0.859

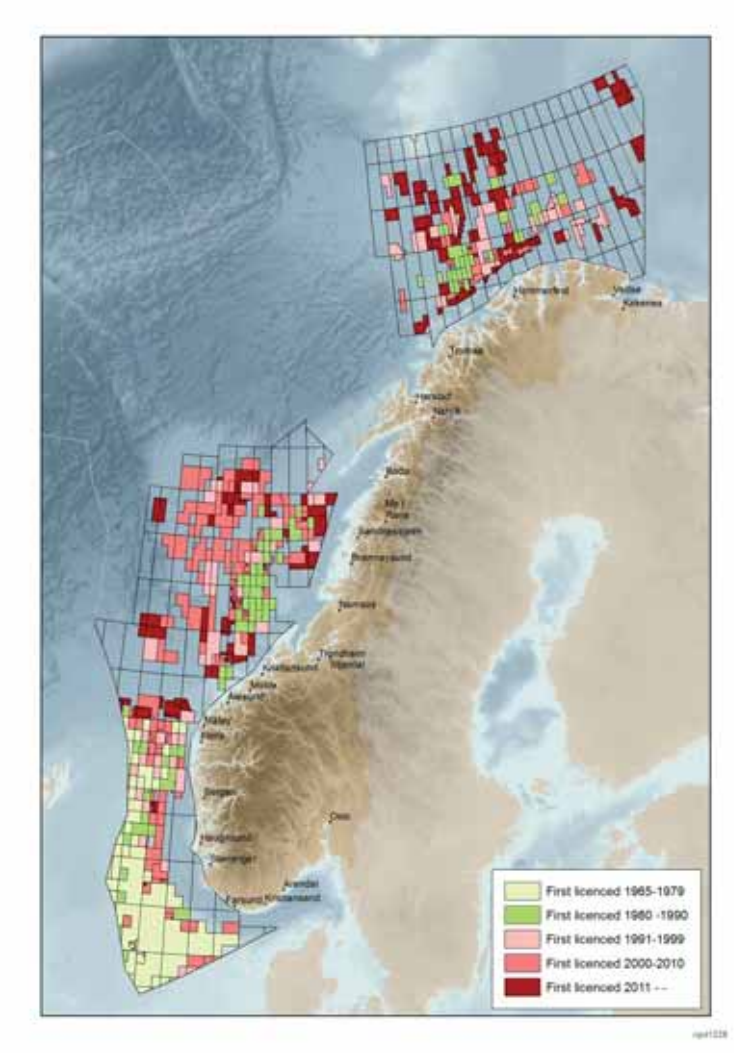
*Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Interaction terms between sector and year and firm-specific fixed effects have been suppressed due to space considerations.

Table 5. Overall number of employees in all industries by county.

County	2000	2008
ROGALAND	189666	229147
HORDALAND	217056	249376
MØRE OG ROMSDAL	122068	131948
AKERSHUS	255112	282408
VEST-AGDER	73820	86183
OSLO	271205	316389
BUSKERUD	122977	135134
VESTFOLD	104345	116426
SØR-TRØNDELAG	132122	152517
AUST-AGDER	48656	54356
TELEMARK	79265	84658
SOGN OG FJORDANE	55315	56960
NORDLAND	113701	118945
NORD-TRØNDELAG	60447	66260
TROMS	76616	81659
FINNMARK	36166	37682
ØSTFOLD	121999	133985
HEDMARK	90014	95073
OPPLAND	91450	95894

Figure 6. Number of employees in the oil and gas industry by county in 2009.

Figure 7. Map of Norway with information on licencing of the Norwegian continental shelf. Source: Norwegian Petroleum Directorate (NPD).



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