Exposure to diverse knowledge as driver of innovation and productivity

by

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Abstract

New and diverse knowledge is constantly being generated. How does this exposure to diverse knowledge affect us as economic actors? How does a firm's exposure to diverse knowledge affect its innovation process? Is there any relationship between a firm's internal search for new knowledge, and the knowledge generated from external channels? Inspired by the distinction between different types of knowledge in the Innovation Mode Approach (Jensen et al., 2007), this dissertation sets up a novel and unified model that distinguishes between firms' innovation modes, taking both internal and external channels in firms' innovation modes into account. The empirical results demonstrate important differences between the firm's internal and external searches for experience-based knowledge, something which has been overlooked in previous research.

In addition, do firms benefit through incorporating "more of all" types of knowledge on their road to innovate? Innovation is widely thought to benefit from the combination of exploration and exploitation capacity, and the combination of different types of knowledge is expected to yield multiplicative effects. A general long-term assumption within Innovation Studies is that scientific and experience-based knowledge are expected to complement each other. Innovative firms benefit from a strong version of both of these knowledge modes (Jensen et al. 2007). However, the assumption that different innovation modes are complementary and reinforce firm-level innovation has not been empirically tested. In this dissertation, this assumption is empirically tested and the results go against the theoretical orthodoxy, providing food for thought about the scope of firms' use of different types of knowledge needed in order for firms to innovate.

How does an individual exposure to diverse knowledge affect their productivity? In the same way that firms innovation performance is

argued to benefit from a use of diverse type of knowledge, diverse knowledge among individuals arguably generates positive economic spillovers and therefore boosts productivity. Inspired by the literature looking at immigrant diversity, this dissertation adds a better understanding about the conditions that help or hinder these knowledge spillovers generated from immigrant diversity. Conditions that encourage interactions across difference should enhance any beneficial effects of immigrant diversity. In this dissertation, I look more deeply into these conditions by examining regional differences in the costs of interaction across diversity. I triangulate across several distinct markers of how welcoming regions are to immigrants in a novel way. The results add up to a better understanding of the importance of regional conditions and our understanding of economic returns from immigrant diversity.

In addition, how are the economic returns from immigrant diversity affected by the assimilation process to the host society? In a diverse society, one likely factor regulating costs of interaction across diversity is immigrants' level of integration into their host society. In many diverse countries, integration is an important policy ambition. This dissertation investigates whether and how assimilation processes affect the relationship between immigrant diversity and worker productivity. To the best of knowledge, no previous work has directly measured the role of assimilation in shaping the economic value of immigrant diversity as in this dissertation. The results indicate a robust positive association between worker productivity and immigrant diversity in Norwegian regions and workplaces. Meanwhile, the results are consistent with evidence that immigrants' integration into Norwegian society reduces the size of these effects.

Abstrakt (Norwegian)

Vi eksponeres nærmest konstant for både ny og et mangfold av ulik type kunnskap. Hvordan påvirkes vi som økonomiske aktører av denne konstante eksponeringen av kunnskap? Klarer vi å benytte oss av dette mangfoldet av kunnskap på en slik måte at det generere oss økt økonomisk produktivitet? I denne doktorgraden ser jeg på hvordan innovative bedrifter og arbeidstakere blir påvirket av det mangfoldet av kunnskap som finnes i omgivelsene deres.

Bedrifter som er nyskapende og innovative, benytter seg av ulike typer kunnskap. Økende konkurranse og hurtige teknologiske endringer gjør at bedrifter blir stadig mer presset til å søke etter ny og relevant kunnskap. Kombinasjoner av forskjellig type kunnskap har vist seg å være viktig for innovasjon. Ofte skiller vi mellom vitenskapelig kunnskap og mer erfaringsbasert og taus kunnskap. Kombinasjonen av begge disse formene for kunnskap blir ofte sett som det ideelle for innovasjon. Avhandlingen finner at dette ikke nødvendigvis er tilfelle. Isolert sett bidrar både vitenskapelig og erfaringsbasert kunnskap til økt innovasjon, men kombinasjonen av dem har ikke en multiplikativ virkning, slik teorien påstår. Avhandlingen peker derfor i retning av varsomhet når vi oppretter tiltak som genererer «mer av all type kunnskap» for å fremme innovasjon i bedrifter. Ikke alle innovative bedrifter trenger å bli eksponert for et mangfold av kunnskap og ikke alle har kapasitet til å håndtere et mangfold av svært ulike typer kunnskap.

På samme måte som bedrifter stadig eksponeres for et mangfold av kunnskap, har arbeidstakere også tilgang til et større mangfold av kunnskap på jobben eller i regionen der de bor. Mangfoldet av kunnskap kan måles på ulike måter. Denne avhandlingen ser på kulturelle og heuristiske forskjeller mellom en gruppe mennesker. En velkjent og enkel empirisk tilnærming er å se på fødelandsmangfoldet i regionen og på arbeidsplassen.

Denne tilnærmingen bygger på at personer som er født i ulike land, har med seg andre tilnærminger og nettverk som gir flere mulige løsninger på problemer og dermed til innovasjon og produktivitet. Forskning fra blant annet USA viser at eksponering for denne type mangfold av kunnskap gir fordeler i form av økt produktivitet for den arbeidstakere som arbeider i mangfoldige bedrifter eller regioner. I denne avhandlingen finner jeg den samme positive sammenhengen i Norge: Å jobbe og bo i mer mangfoldige regioner virker positivt på arbeidstakernes produktivitet. Men resultatene fra avhandlingen viser at effekten av dette mangfoldet varierer. I regioner hvor kulturen er preget av åpenhet til nye perspektiver, har mangfold større effekt enn i regioner med en mer lukket holdning til nyere perspektiver. Resultatene viser også at dersom vi tar hensyn at det er ulike grader av kulturelle forskjeller, som kan bli avslipt ved en større grad av eksponering for like perspektiver, avtar den positive effekten.

Avhandlingen har en kvantitativ tilnærming og benytter seg av registerdata av bedrifter og individ. Ulike empiriske fremgangsmåter benyttes for å svare på de ulike spørsmålene som belyses i hver artikkel. De ulike økonometriske modellene som benyttes tar høyde for både individuelle, bedriftsmessige og regionale forskjeller slik at det som belyses er så isolert som metodene og dataene tillater.

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Papers included in the thesis

Paper I: The external and internal dimension of innovation modes. Developing science- and experience-based knowledge internally and in collaboration with external partners

Paper II: Does combining different types of collaboration always benefit firms? Collaboration, complementarity and product innovation in Norway

Paper III: Do Regional Social Capital and Trust Matter for Immigrant Diversity and Wages?

Paper IV: Does assimilation shape the economic value of immigrant diversity?

1 Introduction

Innovation is an important determinant of economic performance, and knowledge is at the heart of the innovation process. Knowledge and information are distributed across a wide range of different actors in the economy and new knowledge is constantly being generated. Innovation processes cannot rely only on a single type of internal knowledge, as different types of knowledge are considered to be a crucial source of new innovation. Different types of knowledge play different roles in the innovation process, and a variety of diverse types of knowledge is therefore considered desirable (Laursen and Salter, 2006). Voices behind different research stances highlight the benefits of exposure to diverse knowledge. By enabling as many actors as possible to participate productively with their knowledge, diverse knowledge is argued to be one of the best tools and is often called the fundamentally important determinant for achieving economic development (Feldman and Storper, 2018).

The overall assumption for this thesis builds upon a theoretical framework based on theories emphasizing knowledge as one of the important elements in economic performance in terms of firms' innovation performance and individual productivity. This is based on the premise that actors (firms and individuals) obtain new knowledge through interaction with other actors (firms or individuals) in the economy, and diversity among these actors is considered beneficial for economic performance.

As actors in the economy, we are all constantly exposed to a diversity of knowledge from a wide range of different actors. New knowledge is constantly generated. As diverse knowledge enables actors to map out a wider range of approaches, generating new and innovative ideas, actors' ability to handle and use this variety of knowledge, in a way that generates economic advantages, has emerged as an important topic.

While diverse knowledge might generate economic advantages, there is also an important cost related to the use of diverse knowledge that may outweigh the benefits it generates. Interacting with individuals who are different from oneself is likely more costly than interacting with those with whom one is similar or shares the same social context. In the same way, firms' use of diverse types of knowledge from different channels might generate more costs than benefits, as firms may not have the capacity to manage diverse knowledge.

This doctoral thesis builds upon and is aimed at contributing to the research that explores how exposure to diverse knowledge enables actors in the economy to generate economic productivity. This is a tall order to fill and several approaches can be used. This thesis does not intend to generate an exhaustive model for economic productivity, but instead attempts to analyze and shed some new light on how the exposure to diverse knowledge for these economic actors affects their productivity. In this thesis, I will focus on two main approaches. First, I will study firms' exposure to diverse knowledge by studying the link between innovation in firms and their use of a diverse type of knowledge using the *'Innovation mode'* approach. Second, I will focus on individual workers productivity and their exposure to diverse knowledge through cultural differences in their surroundings, using the *'Birthplace Diversity'* approach.

The conceptual approach taken in this thesis can be understood as a process happening at three different levels (Figure 1). At the first level, we find a general discussion about economic actors' exposure to diverse knowledge and its importance for the generation of economic advantages among these actors. As diverse knowledge can have many dimensions, different literatures and research traditions have explored this using different perspectives.

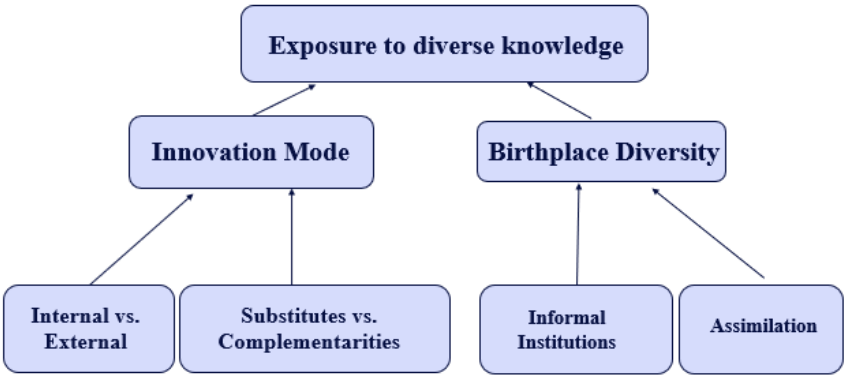

Figure 1 – The conceptual approach

One of these perspectives is the *"Innovation Mode"* approach introduced by Jensen et al., (2007). In this approach there is a focus on firms' exposure to diverse knowledge and its effects on innovation performance. Two different types of knowledge are contrasted, generated from different sources, and both are seen as an important determinant for firms to achieve innovation performance. Within this approach we often talk about these different types of knowledge as firms' innovation modes. The first mode, 'Science, Technology and Innovation' (STI), highlights the importance and use of codified scientific and technical knowledge in the firm's innovation process. The second mode, 'Doing, Using and Interacting' (DUI), is based on the premise that experience-based knowledge through learning-by-doing and learning-by-using is fundamental for innovation.

The importance of diverse knowledge has also been the scope of a wide range of disciplines which contend that heterogeneity among individuals is an important source for economic actors' exposure to diverse knowledge (see e.g. Page, 2008; Kemeny, 2012). One of these approaches is *"Birthplace Diversity"*. This approach builds on the idea that individuals born in different countries carry with them a diverse

perspective and heuristics that enable them to better solve complex problems and thus possibly increase productivity.

However, other relevant approaches also make a distinction between different types of knowledge and how these affect economic actors' performance. For instance, Tether (2002) distinguishes and highlights knowledge generated within and beyond the supply chain as important for innovative firms. Roper and Hewitt-Dundas (2015) and Hewitt-Dundas et al., (2019) focus on existing knowledge within the firm or through prior collaboration and external knowledge flow, while Cassiman and Veugelers (2006) and Love et al., (2014) distinguish only between firms' use of internal vs. external scientific knowledge.

While these, among several others, make important and relevant distinctions between different channels of the exposure of knowledge for economic actors, this thesis has its focus on *"Innovation Mode"* and *"Birthplace Diversity*". These are the approaches underlying the research questions raised and which this thesis aims to cover. Over the last decade, the growing bodies of literature on innovation modes and birthplace diversity have seen the emergence of an agenda within each research stance. While there may be several reasons for this emergence, one rational explanation is the general increase in the complexities of the economy, combined with the rapid change of advanced technologies, making it hard for actors such as firms to rely only on a single type of knowledge. Relying on research from both of these approaches has contributed to our knowing more about economic actors' exposure to different types of knowledge, and how this contributes to these economic actors' performance. However, as researchers we always need to ask additional questions on what is assumed or highlighted as consistent. In this thesis I want to move the debate forward by going one step further in Figure 1. This step forward is inspired by recently research. For instance, inspired by the innovation mode approach, Fitjar and Rodriguez-Pose (2013) highlight the importance of geographical differences in locations for firms' use of innovation mode partners, and

how this affects firms' innovation performance. In the same way, Kemeny and Cooke (2017a) focus on birthplace diversity and highlight that economic benefits from birthplace diversity are determined by regional differences in the costs of interacting across diversity. While both of these contributions still highlight the importance of an exposure to diverse knowledge for actors in the economy, they also underscore how important it is to examine these relationships more deeply.

Within the innovation mode this thesis will try to cover this by looking more into two different approaches, the *"Internal vs External"* and *"Substitutions vs Complementarities"* dimensions, respectively, of firms' exposure to diverse knowledge.

A much-discussed dimension of firm-level innovation strategies focuses on the distinction between using internal or external knowledge sourcing. Traditionally, innovation was thought to be a process mainly taking place within the firm, albeit with some procurement of external knowledge. The development of the networked and open approaches to innovation has fundamentally changed this perception (Freeman, 1987; Powell et al., 1996; Cooke and Morgan, 1999; Chesbrough, 2003). However, this does not imply that firms should cease engaging in internal knowledge activities. Rigby and Zook (2002) have argued that the capacity to combine internal and external knowledge is critical for a firm's competitive advantage. This is also the general idea behind the concept of absorptive capacity (Cohen and Levinthal, 1990), highlighting that in order to make the most of new knowledge being developed outside the organization, firms need to conduct their own internal knowledge development. Looking at the Innovation Mode Approach, the distinction between STI and DUI types of knowledge encompasses internal activities as well as external knowledge sourcing. The internal or external dimensions of innovation modes have rarely featured in the literature. Jensen et al., (2007) classified firms' use of knowledge into four different clusters, according to their use of all STI or DUI indicators in their innovation process. This rather broad

classification does not enable them to say anything about the external and internal dimension of these knowledge sources. This will be covered in this thesis.

The idea of complementarities between firms' use of different knowledge modes has been a long-held assumption within Innovation Studies. One of the key insights from Jensen et al., (2007) was that a combination of a strong version of both innovation modes yields the results for innovation. Firms innovate more when they manage to pursue innovation based on scientific knowledge, and complementing such effort with learning by doing and interacting with other economic actors. Other studies of innovation modes report similar results (Chen et al, 2011; Aslesen et al. 2012; Parrilli and Heras, 2016). However, none of these studies have actually tested this relationship empirically, in the sense that they can show the potential multiplicative effects from these modes. This will be covered in this thesis.

In the same way, within *Birthplace Diversity* this thesis tries to move the debate forward by looking at changes in cost of interacting across diversity, and how this affects the economic returns from diversity. It will do so by taking contextual factors such as *"Informal Institutions"* and *"Assimilation"*, respectively, into account.

Recent research from metropolitan regions in the US context indicates that in regions where the cost is high, the latent benefits from birthplace diversity can be entirely choked off (Kemeny and Cooke, 2017a). In this thesis, I try to understand this relationship better, by broadening the dimensions and refining the measures of regional context that shape immigrant diversity outcomes. I triangulate between different measures of regional context that capture how welcoming regions are to immigrants. This expands and refines our understanding of what elements of the regional context may particularly matter in shaping economic spillovers from immigrant diversity in a novel way that has not been done in earlier research. Additionally, while the US is an interesting

empirical case, it is in many ways also an extreme one. Looking at these relationships in different national contexts than the extant literature has explored also contribute to the literature, and this will be covered in this thesis.

Additionally, one important limitation of existing work regarding birthplace diversity is that it considers immigrants born in a given country to be homogenous. A potentially important way that immigrants might differ is in their level of assimilation into the host society. Assimilation could lower the barriers for immigrants and natives to interact, thereby reducing the cost of interacting and thus enhancing the economic benefits. Alternatively, assimilation could reduce the heuristic differences between immigrants and natives that dampen the economic spillovers. These aspects are not taken into account in other studies examining birthplace diversity and will be covered in this thesis.

Why does this matter? Is it not sufficient to know that exposure to diverse knowledge generates economic benefits, since it is hard to measure the actual cost of interaction across diversity? While this is true, understanding the relationship of firms' and individuals' exposure to diverse knowledge and how this affects their productivity is relevant for several reasons: for the individual innovating firm and for the implementation and targeting of their innovation strategy; for their use of and exposure to diverse knowledge from different channels; for innovation policy that promotes innovative initiatives that benefit from exposure to different types of knowledge generation from different channels; and, for improving our understanding of how contextual factors such as informal institutions or assimilation processes influence the cost of interaction across diversity. In short, it matters because economic actors are increasingly exposed to a more diverse type of knowledge, and more knowledge on these relationships can improve our understanding of relevant questions about economic productivity.

The rest of the thesis is organized as follows. First, this introduction chapter concludes by summarizing the aim, research questions and contributions that make up this thesis. Chapter 2 lays out a review of the two theoretical approaches used in this thesis and identifies the research gaps covered herein. While the bulk of the empirical analysis is spread between the four research articles, Chapter 3 starts by presenting the data and also discusses the empirical approach taken in this research. Chapter 4 summarizes the papers included in the thesis. In chapter 5 summarizes theoretical contributions, policy implications, limitations and further research questions.

1.1 Aim, Research Questions and Contributions

This chapter introduces the two approaches, *Innovation Mode* and *Birthplace Diversity*, which are used in this thesis. The aim of this thesis is to better understand how actors in the economy are constantly exposed to a diversity of knowledge and how this affects their productivity. The chosen theoretical approaches make a natural sub-divided focus on innovative firms on the one hand, and individual workers' productivity on the other.

The overarching research question and the heart of the thesis is a better understanding of the condition of the exposure to diverse knowledge for actors in the economy, and the conditions that affect their productivity. However, in order to make the issue more approachable, it is divided into two more tangible sub questions:

– *How is firms' innovative performance affected by the exposure to diverse knowledge generated from external or internal channels, and are different types of knowledge complements or substitutes?*

– *How are the economic returns from birthplace diversity affected by changes in the costs of interacting?*

The thesis includes four papers that address these questions in different ways. Papers 1 and 2 relate directly to innovative firms and both challenge the Innovation Mode Approach in two different ways. Papers 3 and 4 relate directly to the literature on Birthplace Diversity and contributes to this tradition.

The overall approach in this thesis relates to better understanding the conditions for exposure to diverse knowledge for actors in the economy and the resulting effects on productivity (level 1), while also making a theoretical contribution, a position mainly generated within two strains of research: *Innovation Mode* and *Birthplace Diversity* (level 2). The combined theoretical and empirical results presented in this thesis contribute to the *'Innovation Mode'* approach in two ways. Firstly, by

setting up a new empirical model and taking into account whether the different modes of innovation are generated from internal or external channels. This unified model is novel and the results clearly show that there is a trade-off between firms' use of internal vs external resources that has previously not been taken into account in this approach. Secondly, this thesis also contributes to this approach by empirically testing for complementarities between firms' use of diverse knowledge through their innovation modes. The results challenge long-held assumptions about complementarities between different types of knowledge generated from different sources. Innovative firms do not benefit from "more of all" in their innovation process. These theoretical contributions are more in line with Laursen and Salter (2006), who cautioned against the risk of 'over-searching' for new knowledge and questioned whether most firms have the capacity to manage radically different types of knowledge inputs.

The combined theoretical and empirical results presented in this thesis contribute to the *'Birthplace Diversity'* approach in two ways. First, they confirm that regional differences in contextual factors also matter for economic returns from birthplace diversity in other contextual environments than extant literature has explored. Additionally, they also expand our understanding of what elements of the regional context may be particularly important for economic spillovers from birthplace diversity. The use of regional measures of informal institutions that are more targeted to measuring the costs of interacting with an individual born in a different country contributes to methodological development within this approach.

Secondly, taking the assimilation process into account, the results contribute by setting up a novel way of measuring diversity, by examining how adjustments of the border of what we count as contributing to birthplace diversity affect the size of diversity spillovers. Approximating assimilation in quantifiable units is challenging, as these processes are multifaceted. It is reasonable to assume that they take place

over both short and long periods of time. Thus, any single measure will be incomplete and the empirical approach to assimilation in the last paper in this dissertation relies on multiple proxies that together triangulate some aspects of a dynamic social process.

The strongest common denominators of the thesis are the highlighting of the exposure to diverse knowledge for actors in the economy. The chosen conceptual approach in this thesis leads to a discussion that take place at three different levels. While this might help our understanding of this relationship, it also allows us to put these questions in a wider context. Meanwhile, the exposure of diverse knowledge generated from a wide range of economic actors underscores the importance of examining these more deeply in a sub-set of questions. Overall, it provides a venue for questions related to both theoretical approach and policy concerning how the exposure to diverse knowledge affected actors in the economy.

2 Theoretical framework

As indicated in Chapter 1, the theoretical framework used in this thesis emphasizes the importance of exposure to a diversity of knowledge from different channels. The chosen approaches, *Innovation Mode* and *Birthplace Diversity,* build on different levels of analysis, where the first approach mainly focuses on innovative firms, while the latter often focuses on individual productivity. In the rest of this section, it is appropriate to separate the theoretical framework into these two blocks; Hence, 1) Innovation Mode and 2) Birthplace Diversity.

2.1 Innovation Mode

The Innovation Mode Approach emerged from the influential paper by Jensen, Johnson, Lorenz and Lundvall in 2007. However, it generally started with the idea that knowledge can emerge in different forms, such as tacit or codified knowledge (Polanyi, 1958). Codified knowledge is argued to be transformed into information and therefore easily transmitted, while in contrast, tacit knowledge is more "fuzzy" and cannot be easily transferred. Lundvall (1988) highlights the importance of making distinctions between these different types of knowledge and interactions for better understand innovating processes in the economy. Lundvall (1988) argues that knowledge and interactions leads to what is often called 'know-what' or 'know-why' and 'know-who' or 'know-how' types of knowledge. 'Know-what' or 'know-why' type of knowledge is argued to be related to codified scientific knowledge, while 'know-who' or 'know-how' type of knowledge is argued to be tacit knowledge that is related to specific and selective social relations. Inspired by these ideas, research within innovation studies has emphasis this distinction of knowledge, and we often hear about two innovation modes reflecting these two types of knowledge.

One mode is based on firms use and production of codified scientific and technical knowledge: 'Science, Technology and Innovation' (STI), reflecting the 'know-what' or 'know-why' type of knowledge. The other is an experience-based learning mode based on 'Doing, Using and Interacting' (DUI), reflecting the 'know-who' or 'know-how' type of knowledge.

STI base its premises on research and development (R&D) as the main driver of innovation. Within the firm, STI knowledge is usually generated in R&D departments, following targeted R&D investments by highly trained specialists. Firms can also follow an external, rather than an internal route and collaborate with organizations that produce knowledge, such as universities and research centres. The DUI mode of innovation is built on its premises through a learning-by-doing and learning-by-using process. Within the firm, DUI is usually generated through organisational practices such as project teams, problem-solving groups, and job and task rotation, which promote learning and knowledge exchange. These are considered to contribute to developing the internal 'know-who' and 'know-how' which drives innovation at firm-level, reflecting the 'learning firm' approach (Jensen et al., 2007; Laursen and Foss, 2003; Lorenz, 2005). Firms can also follow an external route and get access to this type of knowledge through collaboration or interaction with external knowledge sources, such a costumers and suppliers that is argued to inherent this type of knowledge.

A firm's innovation strategies often involve a discussion or tradeoff between their use of internal activities or external knowledge sourcing. This distinction between internal vs external approaches to innovation is an important discussion in the innovation literature. While innovation was traditionally thought to be a process mainly taking place within the firm, albeit with some procurement of external knowledge, the networked and open approaches to innovation have fundamentally changed this perception (Freeman, 1987; Powell et al. 1996; Cooke and Morgan, 1999; Chesbrough, 2003). However, within the Innovation

Mode approach, both STI and DUI encompass internal activities as well as external knowledge sourcing. Yet, these the internal vs external dimensions of innovation modes have rarely featured in the literature. Jensen et al. (2007) classified firms' use of knowledge into four different clusters according to their use of all STI or DUI indicators in their innovation process that enable them to say anything about the external and internal dimensions of these modes. Hence, the question of whether the benefits of external or internal knowledge sourcing depend on the type of knowledge being sourced remains unanswered. Past research has either combined internal or external knowledge activities into one mode, following Jensen et al., (2007) or mainly focus on external knowledge activities (e.g. Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016; Apanasovich et al., 2016). In this thesis, I will cover this gap by distinguishing between internal and external dimension within each innovation mode.

Research emerged from Jensen et al., (2007), within innovation studies often discusses both innovation modes to be important for firm innovation. A central claim in the emerging research is that STI and DUI are complementary. They argue that firms rarely use only one innovation mode, and the most innovative firms are those that operate with combined innovation modes (Herstad and Brekke, 2012; Isaksen and Karlsen, 2011; Jensen et al., 2007). A key insight within this approach is that the combination of both modes yields the best results for innovation. Jensen et al. (2007:690) argue that "what really improves innovation performance is using mixed strategies that combine strong versions of the two modes". However, the Jensen et al., (2007) findings are not sufficient to prove complementarities between the modes, as was also mentioned in their paper. Despite this caveat, many others have followed up on the notion (Chen et al., 2011; Aslesen et al., 2012; Parrilli and Heras, 2016). In this thesis, I raise questions to the assumed argument of complementarities between these modes and empirically test for this relationship.

2.2 Birthplace diversity

There is also a growing focus on diverse knowledge among individuals and its importance for various economic outcomes, especially workers' productivity (e.g. Ottaviano and Peri, 2006: Bakens et al., 2013; Alesina et al., 2016; Kemeny and Cooke, 2017a; Cooke and Kemeny, 2017) and innovation (Ozgen et al., 2013; Lee, 2014; Solheim and Fitjar, 2018). While there are several ways of exploring distinct types of diverse knowledge among individuals, birthplace diversity is used in this thesis.

This area of research builds on the idea that when people with diverse backgrounds, (such as born in different countries) interact, they contribute with their different perspectives and knowledge that ought to enhance problem solving, creativity and generate new and innovative ideas (Hong and Page, 2001, 2004; Page, 2008). Problem solving and novel approaches should contribute positively to productivity (Kemeny and Cooke, 2017b). With heuristics and perspectives partly shaped by demographic characteristics (Page, 2008) birthplace diversity generated by increasing and diversifying immigration flows should have at least latent positive spillover effects.

However, the economic benefits of diversity are not automatic; if their realization depends on intercultural interaction, then it follows that benefits should vary with the costs of that interaction (Kemeny, 2012). Interacting with individuals who are different from oneself is likely more costly than interacting with those with whom one is similar or shares the same social context, all else equal. Different perspectives can also make a problem difficult to communicate and lower the level of trust, generating economic disadvantages (Nisbett and Ross, 1980; Alesina and Ferrara, 2005). Influential urbanists like Florida (2003) highlighted the economic benefits of various forms of urban diversity, seen as helping firms share ideas and innovate. Theory within economic geography builds on the premise that economic interaction coheres

externally and at a higher scale[1] to individuals and firms, but within a subnational area (Moretti, 2004). There is empirical support for the idea that costs of interaction affect the economic returns from diversity at the national scale (Alesina and La Ferrara, 2005), as well as at the subnational scale (e.g. Kemeny and Cooke, 2017).

There are several factors that might influence the cost of interaction among, and institutions are frequently argued to be important. Institutions are widely thought of as a system of formal and informal rules and norms facilitating interaction among actors within the national or regional scale (Rodríguez-Pose and Storper, 2006). North (1990) argue that institutions regulate the cost of interactions in an economy. In discussions on institutions, we often talk about formal or informal institutions. While formal institutions are often proxied by laws or regulations, informal institutions, also known as 'soft' or 'community' institutions, include a series of features of group life such as norms, social connections, interpersonal contacts and relationships (Rodríguez-Pose and Storper, 2006; Rodríguez-Pose, 2013). Informal institutions are assumed to have a local and regional variation (Rodríguez-Pose and Storper, 2006). Past research point to the crucial role these play in shaping regional development (e.g. Morgan, 2007; Acemoglu and Robinson 2012; Crescenzi et al., 2013; Rodriguez-Pose, 2013; Rodriguez-Pose and Di Cataldo, 2014; Boschma and Capone, 2015; Antonietti and Boschma, 2018; Cortinovis et al. 2017; Feldman and Storper, 2018).

With a special topic on birthplace diversity, recent empirical research indicates that in metropolitan areas in the US context, latent benefits of diversity can be entirely choked off (Kemeny and Cooke, 2017a). They find that in areas where the cost of interacting is higher, the economic benefits from diversity is lower. While this study gives us a better

[1] We can think of diversity as a public good, generating costs or benefits that are not fully captured by individuals.

understanding of the regional contextual factors impact on productivity spillovers related to immigrant diversity, there are still questions to be raised. Specifically, there is a lack use of measures which particularly shape interactions with immigrants. Hence, regional contextual factors that are expected to facilitate interaction among individuals born in different countries, would contribute to a better understanding of the relationship between birthplace diversity for economic performance. This will be covered in the thesis.

In the same way as institutions, another likely factor regulating interaction costs is immigrants' level of integration into their host society. Societies may use various approaches to deal with immigrant diversity, often through types of integration or assimilation policies. The typical aims of these policies are to educate migrants about the language, culture and laws of their host country, and to enable their full participation in the country's educational system, labor market and social arenas (Haus-Reve et al., 2019). Any direct results of these policies are impossible to measure. However, there are questions to be asked about the indirect processes of these integration or assimilation policies. Assimilation can be seen as a sociotemporal dimension of immigration: immigrants begin as unassimilated, and in most cases become progressively more integrated into their host country over time. This assimilation could affect the association between diversity and productivity in two contrastingly predicted ways. On the one hand, assimilation may lower the cost of intercultural interaction, thereby enhancing immigrant diversity spillovers. The other possibility is that assimilation might, through the adoption of the host country culture, reduce their cultural distinctiveness. If this also reduces their heuristic distinctiveness, then assimilation could dampen spillovers from immigrant diversity. Past research has considering variation in immigrants' human capital and other more narrowly 'economic' factors, but extant research has considered individuals from a given country to be identical in terms of their potential to generate spillovers. These

theoretical predictions and scant of existing empirical evidence is a motivated for asking questions about how the assimilation process affect the economic spillovers from birthplace diversity. This will be covered in this thesis.

3 Data and Methodological approach

The general research design chosen in this thesis was to take advantage of comprehensive empirical data that covers a wide range of firms and individuals in Norway. The four different papers take advantage of three distinct sources of data at three different levels: individual, firm and regional levels. Several data sets are merged: The Community Innovation Survey (CIS), Individual and Firm-level-register data (LEED) and survey data generated from the Norwegian Monitor Data (MI). These data provide a platform for studying economic actors, such as firm and individual exposure to diverse knowledge, using different approaches. At the same time, taking advantage of the high-quality data enables performing advanced econometric analyses that are beneficial for examining these complex relationships.

Linked Employer-Employee data (LEED) generated from different data sources is mainly from Statistics Norway. The annual data spans the period 2001 to 2011 and covers all inhabitants in Norway over the age of 16 who are employed in the private sector, and all establishments located in Norway. The registers provide a range of information about individual workers, such as their place and year of birth, mothers' place of birth, sex, educational background, place of residence and employment, employer, working hours, and annual wage. At the establishment level, the registers include information on location, industry and number of employees. Additional establishment level variables are calculated from the individual registers based on the composition of each establishment.

The Norwegian CIS data applies the definitions and type of questions defined in the OECD Oslo Manual (2005); it provides information on the innovation activities of firms and comprises firm-level surveys conducted every two years. Due to the strategy of sampling firms, the Norwegian CIS surveys are highly representative and equivalent to one

third of firms and two thirds of employees in the sampling population of Norwegian firms with more than five employees. In the first paper, CIS data from 2010 are mainly used, while the empirical analysis in Paper 2 uses three consecutive waves of the CIS, covering the period 2006-2010. Over this period, the Norwegian CIS has used similar survey questionnaires that give consistent indicators available throughout the survey period. The CIS data are widely used in empirical research (Castellacci, 2011; Fitjar and Rodriguez-Pose, 2013; Crescenzi and Gagliardi, 2018; Gagliardi and Iammarino, 2018; Hewitt-Dundas et al., 2019; Haus-Reve et al., 2019). The Norwegian CIS differs from the harmonized surveys in that from 2006 and onwards, all respondents report innovation collaboration activities independent of their innovation status. This unique feature of the Norwegian CIS data makes it possible to analyze the relationship between firms' collaboration and actual innovation outcomes. Participation in the CIS is mandatory for sampled firms in Norway and non-respondents are fined. This results in a response rate ranging from 94 percent of sampled firms in 2006, to 97 percent in 2008 and 2010. This high response rate almost rules out the risk of non-response bias. The sample includes the full population of Norwegian firms with 50 or more employees, as well as all firms with 10-49 employees that have reported significant R&D activities in the previous waves of the survey. Other firms with 5-49 employees are sampled through a procedure which stratifies firms by size and industry, with higher likelihood of inclusion for larger firms. This gives 6412 firm observations in the 2006 survey, 5980 in 2008, and 6532 in 2010.

One of the drawbacks of the early CIS surveys has been that they have not been able to fully capture different types of knowledge exchange and organizational changes that happen within the firm to promote firm level innovation. However, with the growing interest in the organizational dimension of innovation, this raised a debate in the early 2000s about existing measures of innovation in the CIS survey poorly capturing innovation processes in services and less R&D intensive sectors. This

debate led to the 2005 version of the Oslo Manual expanding measures for firms' innovation to also include a separate measure for organizational and marketing innovation. While this is also the case for the Norwegian CIS survey from 2006, it is still far less clear whether the Oslo Manual 2005 is able to fully cover Freeman`s (1995) arguments, among others, of developing a better understanding of the interdependencies of firms' organizational change on the one hand, and firms' product innovation outcome on the other (see Lorenz, 2005 for similar arguments).

However, in the 2010 Norwegian CIS survey a unique battery of questions was included that asked participating firms what kind of internal activities or organizational change the firm had engaged in to promote firm-level innovation. This battery of questions makes it possible to identify firms' internal organizational mechanisms and changes that are implemented to promote firm level innovation. These questions are novel and are only included in the 2010 version of the Norwegian CIS survey. The questions make it possible to find out more about firms' organizational changes, and how they affect firms' innovation outcomes.

In Papers 3 and 4, LEED is the main data source used. Based on individuals' country of birth, where they live and where they work, these data enable us to construct a birthplace diversity measure at the firm and regional levels. This provides a clearer picture of the level at which and to what extent externalities from diversity emerge. The LEED richness of individual data enables us to calculate and use more information about immigrants, such as immigrants' length of stay since arrival to the country, if they have taken part in any educational training, whether they are part of second generation immigrants or are coming from a culturally close country, allowing us to construct diversity measures for different sets of immigrants that are used in the empirical analysis in Paper 4.

In addition, Norwegian Monitor Survey data is used in Paper 3 to operationalize and measure regional differences in informal institutions. Norwegian Monitor is a survey conducted biennially covering the time period 1985 to 2010. The survey has a sample size of 2200 in the first wave in 1985, and more than 4000 in the last three years. The survey is conducted by a private market research institute, Ipsos, and covers close to 3000 questions. An interviewer asks introductory questions over the phone, while the major parts are included in self-completion questionnaires sent to each participating individual. The sample is representative of the population over 15 years, for age and covers all economic regions in Norway. The response rate is between 60-65 percent for those that have first been contacted by phone. All surveys contain a standard question for individuals actively interacting in different kinds of associations during the previous year. In addition, the survey also covers attitudes to foreign-born individuals and trust in local government. The demographic measures, such as where the participants live, are used to aggregate these as into proxies for trust at the economic region level. Questions on individuals actively interacting in different kinds of associations have been part of the survey since the first wave in 1985, while attitudes to foreign-born individuals and their trust in local government was introduced in 1990.

The methodological approach used in this thesis is quantitative, based on different sub-sets of the LEED data set. In Paper 1 and 2, I use firm level data covering 2008–2010 and 2004 -2010, running a binary logit model. A fixed effects approach is used in the two last papers. This approach enables me to take into account pertinent stationary unobserved heterogeneity that could be present at different levels, e.g. individual, firm or regional level, that is impossible to fully control in the models. Additionally, given the richness of the data, it provides possibilities to include a range of relevant control variables that are found in empirical research relevant for each research question.

Table 1 – Data sources used in the various papers in the thesis

Paper	Data Source	Additional information	Source of Data
Paper 1	Community Innovation Survey (CIS) and Linked Employer - Employee data (LEED)	Cross-sectional data. Individual data from LEED in 2010, Firm-level data from CIS, 2008-2010	Statistics Norway
Paper 2	Community Innovation Survey and Linked Employer - Employee data	Unbalanced panel data - Individual data from LEED in 2004-2010, Firm-level data from three consecutive waves of CIS, 2004-2010.	Statistics Norway
Paper 3	Linked Employer - Employee data and Norwegian Monitor Survey Data	Panel data on 'stayers' in the economic regions, LEED from 2001-2011 and regional data from Norwegian Monitor from 1989-2011	Statistics Norway and IPSOS Norway
Paper 4	Linked Employer - Employee data	Panel data on 'stayers' in economic regions, 2001-2011	Statistics Norway

4 Empirical context of Norway

The empirical analysis in the four articles that compose this dissertation focuses on firms and individuals in Norway within the time period 2001-2011. Norway is known for having good official and accessible data that provides important substance to this thesis.

However, as economic performance is assumed to be socially and contextually embedded, to fully understand these processes the institutional and cultural contexts need to be taken into account (Asheim, 2012). This section will provide some relevant aspects of the Norwegian economy that could have an impact on the interpretation of the data as well as the generalization of the results.

Norway has 5.8 million inhabitants (Statistics Norway, 2019), 18 administrative counties and 78 economic regions. The economic region-level in Norway as defined by Statistics Norway (2010) is comparable with EU NUTS 4 regions. Norway is a small and open economy with a generally strong maritime industry that naturally has its location along the coastline. This industry and its pertinent supporting industries make up a generally even distribution of economic activity in all regions in Norway. Norway has four big city regions: Oslo, Bergen, Trondheim and Stavanger. Peripheral regions and all other regions that are not regarded as a big city region include 74 regions in all.

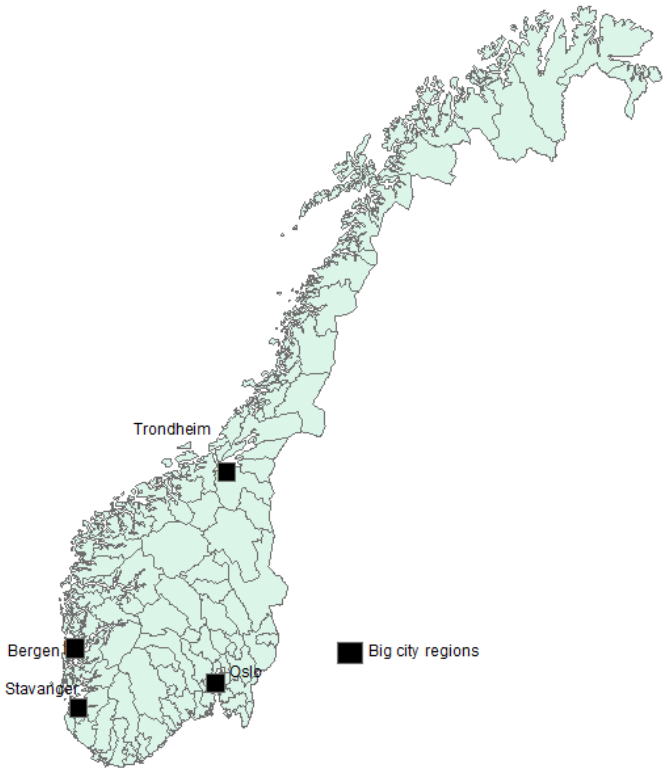

Figure 2 – Maps of Norway with 78 economic regions and four big city regions

This thesis emphasizes the importance of including both big city regions and peripheral regions, in order to cover 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 individual regions. All papers in this thesis are estimated on observations covering all regions in Norway. However, in Papers 3 and 4 an additional distinction is made between working individuals in big city regions and peripheral regions, in order to be sure that the results from these papers are not driven by some underlying differences in characteristics found in these regions.

The overall results from this thesis will be transferable to other Nordic countries and other European countries with an active innovation policy.

The increasing trend of globalization and a more mobile workforce creates increasing exposure to knowledge diversity through immigrant diversity, a relevant issue for most western countries. However, also in this case, these results would be more relevant for other advanced countries where there are similarities in the composition of the workforce.

4.1 Norwegian firms' exposure to diverse knowledge

Norwegian firms have tended to pursue collaborative innovation strategies, interacting more with external partners and investing less in intramural R&D than most other European economies (Fagerberg et al., 2005). Firms in the private sector also report relatively low levels of R&D expenditures, which has triggered an increase in policies that prioritize collaboration and knowledge transfer between innovative firms and industries, universities and research institutes (Thune, 2007). Furthermore, innovation policy has traditionally also had a strong focus on regions and policy instruments that aim to promote regional development and growth of clusters (Hanssen et al., 2011). Overall, Norway has an innovation policy that has actively promoted collaboration from different channels by using different knowledge partners as important factors for economic development and innovation. This makes Norway a good context to study innovative firms' use of different types of knowledge through different channels. The Nordic countries have also been the center of the development of the "Innovation Mode Approach" used in this thesis. Additionally, different versions of research examining innovation as part of a contextual system, e.g. National Innovation System (Lundvall, 1994) or Regional Innovation System (Asheim, 2012), have long traditions and have been developed and heavily studied within this context. While this thesis does not directly incorporate elements or concepts related to innovation

systems specifically, these types of systems have been important sources for innovation policies within this context.

4.2 Birthplace Diversity in Norway

Like most modern economies, Norway is becoming more diverse. In 1970 less than 2 percent of the population were immigrants. This is less than 60,000 people, of which more than 80% were European. By 2018, this had grown to more than 900,000, equivalent to 14% of the population, of which less than half were European (SSB, 2018). Immigration of foreign workers coming to Norway has been important in developing the Norwegian maritime industry and its supporting industries (Solheim and Fitjar, 2018). Followed by an increasing trend in labor demand, particularly for low skilled workers, migration rates grew, following the 2004 expansion of the European Union[2], have been important factors for the increase in diversity. The employment amongst immigrants is high in Norway compared to other countries in Europe (SSB, 2018). The industry structure and the natural geographical diffusion of natural resource-based industries all along the coastline of Norway have given an increase in immigrants as part of the working force in all parts of Norway, not just particularly evident in large city regions. This is also shown looking at the time trend of share of immigrants, Figure 3. While the big city regions have a relatively higher share than the more peripheral regions, both types of regions seem to follow more or less the same trend over time.

[2] The expansion of the European Union opened for labour migration from Central and Eastern Europe

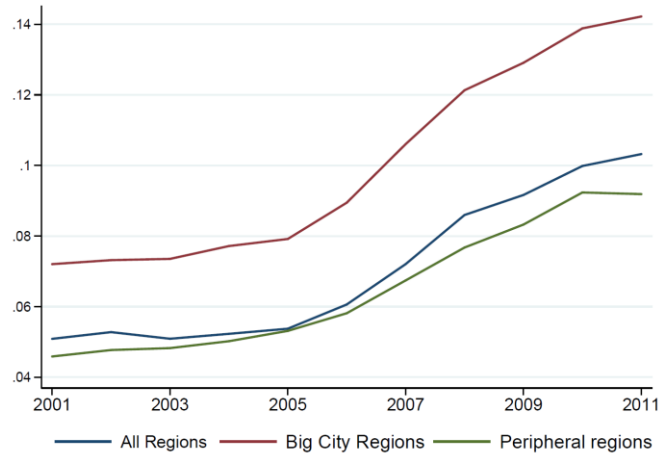

Figure 3 – Share of immigrant in Norway in all regions, big city regions and peripheral regions. 2001–2011

Immigrants from over 230 different nationalities contribute to diversity. The highest shares are from Poland, followed by Lithuania, Sweden, Somalia and Syria. Norway also has an increasing trend in fractionalization among the immigrants, where it is the peripheral regions that contribute most to this increase, as shown in Figure 4.

Figure 4 – Fractionalization among immigrants in Norway, 2001–2011. All regions, big city regions and excluding big city regions. Note: excluding big city regions is the same label peripheral regions in figure 3.

5 Summary

Building on the previous chapters, I will start this chapter with a summary of the papers that are included in this thesis. Each paper explores and investigates the effect of exposure to diverse knowledge from different channels on economic actors, such as innovative firms or working individuals. Together and combined with the theoretical framing presented in the previous sections, they contribute to sketching a wider picture of how the exposure to diverse knowledge from different channels affects firms' innovative performance and individual workers' productivity.

5.1 Summary of papers

In Paper 1, I raise questions together with co-authors on the initial approach to different types of firms innovation modes that have been dominating within this research since its introduction by Jensen et al., (2007). While innovative firms' benefits from a use of different types of knowledge generated from different channels is widely covered in the literature, this paper argues that there is a tendency that these approaches have been developed rather separately. In this paper we set up a unified model, where we account for both the external and internal dimensions of firms' use of different innovation modes. By combining the internal and external approach, this paper analyses four dimensions behind innovation: both internal (R&D expenditures within the firm) and external (e.g. collaboration with consultants, universities, and research centres) science, technology and innovation (STI); and internal (brainstorming, job rotation, creativity training) and external (collaboration with suppliers and customers) doing, using and interacting (DUI). The paper assess the effects of each of these dimensions on innovation using Norwegian Community Innovation Survey data from 2010. The overall results from this paper show that firms' internal search for knowledge is as important for firm innovation outcome as external

search. External STI is not significantly related to any innovation outcomes, while DUI knowledge is. In particular this paper shows that external DUI knowledge exchange is a fundamental driver of innovation. This holds when we control for other important variables that we know from theory and empirical studies are important for firms' innovation outcome.

Paper 2 is also inspired by the Innovation mode approach introduced by Jensen et al. (2007). In this paper, I, together with co-authors, empirically test for complementarities or substitution effects between innovative firms' use of different innovation modes. Following previous research (e.g. Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016), we distinguish between collaboration with scientific and supply-chain partners, using these as our proxy for firms' innovation modes. Scientific collaboration (STI) includes collaboration with universities, research institutes and consultancy firms. Supply-chain collaboration (DUI) encompasses linkages with suppliers and customers. Using an unbalanced panel sample of 8337 firm observations in Norway, covering the period 2006–2010, this paper makes an important contribution by adding to the discussion whether there is any complementarity or substitution effect between firms' use of different knowledge channels in their innovation process. It employs a variety of regression tests that consistently point in a direction that challenges long–held assumptions about complementarities between different types of knowledge from different channels. While innovative firms benefit from an individual use of different knowledge types from different sources, the results from this paper indicated no complementarity effect between these different types of knowledge.

Papers 3 and 4 examine how a change in the costs of interaction across diversity affects the economic benefits of immigrant diversity. Paper 3 explores how regional differences in the regional contextual factors affect individual workers' economic benefits from birthplace diversity at the establishment and regional levels. By triangulating across several

measures that differently capture the differences of interacting across the difference, we find that regional context matter for enhancing beneficial effects of diversity in Norway. In this paper, we contribute by broadening the dimensions and refining the measures of regional context that shape immigrant diversity outcomes. We triangulate between different measures of regional context that capture how welcoming regions are to immigrants. This expands and refines our understanding of what elements of the regional context may particularly matter in shaping economic spillovers from immigrant diversity in a novel way that has not been done in earlier research. In this paper, in keeping with recent contributions (Kemeny and Cooke, 2017), the empirical approach accounts for a wide range of potentially confounding factors to identify the context-specific effects of diversity on productivity. Using longitudinal microdata, estimates are done on how workers' annual wages change as the diversity of immigrants in their region and their workplace also change. Regional variation allows for consideration of how the relationship between wages and diversity varies across different informal institutional settings. Furthermore, the analysis is limited to wage changes within job spells (where individual workers remain in a single workplace and region for at least two years). This allows for the use of fixed effects to absorb bias from multiple sources of stationary heterogeneity, helping address concerns about sorting and other selectivity issues. The result highlights the importance of taking the regional context into account when looking at economic returns from immigrant diversity. In particular, economic benefits from diversity are found to be higher in regions that are more open-minded to interact across the difference measure with general high regional trust for individuals born in another country.

Paper 4 explores the change in cost of interacting across diversity by looking at the role of assimilation of immigrants into the host society. Using Linked Employer-Employee Data from Norway, this paper uses a similar empirical approach as in Paper 3, but contributes further by

taking into account the different aspects of assimilation processes among the immigrants into the model. In this paper, diversity measure indices at the regional and workplace levels reflect different aspects of the assimilation processes. In this paper, several fractionalization indices to measure diversity are constructed, using detailed information about the immigrants contributing to the diversity measure. These measures differ from each other by reflecting various aspects of the assimilation processes, allowing this paper to capture how long they have been in the country and other important aspects related to integration into their host society. The findings from this paper indicated consistent evidence that immigrants more assimilated into their host society dampens the social benefits of knowledge diversity coming from immigrant diversity at the regional scale.

Table 2 – Overview of research papers included in the dissertation

Research papers	**Quantitative approach**	**Unit of analysis**	**Authorship**	**Status**
1 - The external and internal dimension of innovation modes	Logit model	Firms in regions	Silje Haus-Reve, Rune Dahl Fitjar and Andrès Rodriguez-Pose	To be submitted
2 - Does combining different types of collaboration always benefit firms? Collaboration, complementarity and product innovation in Norway	Logit model and Fixed effect approach and Tobit model	Firms in regions	Silje Haus-Reve, Rune Dahl Fitjar and Andrès Rodriguez-Pose	Published in Research Policy 48 (2019) 1476–1486
3 - Understanding the Regional Drivers of Productivity Benefits from Immigrant Diversity: Evidence from Norway's Variation in Regional Institutional Inclusiveness	Fixed effects approach	Individuals in regions	Silje Haus-Reve and Abigail Cooke	In review in Regional Studies
4 - Does assimilation shape the economic value of immigrant diversity?	Fixed effects approach	Individuals in regions	Silje Haus-Reve, Abigail Cooke, Rune Dahl Fitjar and Tom Kemeny	To be submitted

6 Concluding discussion

This dissertation aims to highlight the importance of exposure to diverse knowledge for actors in the economy, and how these conditions affect their productivity and innovation. On the overall level, voices from different research stances highlight the benefits of diverse knowledge (Lundvall, 1998; Jensen et al., 2007: Feldman and Storper, 2018). This thesis contributes as it adds new nuances about the exposure to diverse knowledge for economic actors. The overall results support an exposure to diverse knowledge for economic actors, while they also highlight that the cost of handling the variety of diverse knowledge can outweigh the economic returns. This supports earlier research also pointing in the direction to some concerns that too much diverse knowledge can be too much for economic actors to handle, Laursen and Salter (2006). In the following, I will present the thesis' theoretical contributions within the two chosen approaches. Then I will conclude with some policy implications, limitations of this research and an outlook for future research.

6.1 Theoretical contributions

This thesis' findings contribute and have important implications for research on firms' use of different knowledge modes in their innovation process:

- The internal and external dimensions of innovation modes ought to be taken into account when we want to know which types of knowledge are important for firms' innovation performance.
- The hidden role of internal experience-based knowledge for firms' innovation performance ought to be incorporated to a greater extent in further research looking at these dimensions.

- Firms' internal investment in experience-based knowledge does not seem to increase their absorptive capacity, as theory suggest.
- The findings in this thesis also challenge the dominating theoretical views about the complementarities of both innovation modes and firms' innovation performance.
- Innovation firms do not automatically benefit from an exposure to diverse and more types of knowledge.

- Moreover, this thesis' findings also contribute and have important implications for research on birthplace diversity:
- Contextual factors that generate differences in the cost of interaction need to be taken into account when looking at economic benefits from birthplace diversity.
- Specifically, more targetable measures which arguably shape interactions with immigrants ought to be taken into account.
- Assimilation and integration processes do affect the economic returns from diversity.
- Theory should further take into account that individuals born in different countries contribute differently to the diversity of knowledge.
- Immigrants' different contributions to diversity should be incorporated in theory on economic returns from immigrant diversity.

6.2 Policy implications

This dissertation provides several recommendations for policymakers. Following the focus in the thesis, it is relevant to look at these as: 1) Recommendations in terms of policies that aim to foster economic productivity through stimulating innovation activities in firms, and 2) Policy related to integration of immigrants in regions.

Firstly, innovation policy should not overlook firms' internal initiatives for stimulating innovation. Firms' internal initiatives, like brainstorming, job rotation and so on, can generate important internal ties that stimulate new knowledge development which can be important, at least in the short run.

Additionally, policies that aim to foster economic productivity through stimulating innovation activities in firms should be careful to adapt a policy where all "more of all" knowledge inputs are better for all. Firms may not need all different kinds of knowledge inputs or have the capacity to manage them. This is in accordance with Laursen and Salter (2006), who cautioned against the risk of over-searching and questioned whether most firms have the capacity to manage radically different types of knowledge inputs. As this dissertation demonstrates, collaborating with scientific partners like universities, research institutes or consultancies, and supply-chain partners like suppliers or customers, individually lead to greater firm-level innovation. However, firms which simultaneously collaborate with these partners do not yield greater innovation. Policies to stimulating innovation activities in firms should therefore be careful of requiring an use of different knowledge partners as the one critical requirement to generate innovation. Analytical and scientific knowledge may be less important in industries where experience-based learning is at the heart of the innovation and vice versa (Asheim, 2005). These important differences between industries and firms need to be taken into consideration when developing these policies.

While this thesis contributes to a more general understanding of the importance of contextual factors behind the economic returns to individual productivity, it is also possible to translate these findings into policy recommendations. Policies that aim to foster an open culture seem to be able to subtract more of the latter positive externalities from diversity than a more close and social bonding culture. Hence, policies should aim to not only emphasize an inward-focused policy dimension of a region. This is particularly relevant to consider with the apparent rise of nativist sentiment in many Western countries.

The policy recommendation from the last paper is an integration policy that aims to integrate immigrants to that extent that they do not lose their cultural differences that are the initial source of economic benefits generated from immigrant diversity. Policy makers should still continue the integration of migrants. However, this does mean that integration policies need to incorporate the benefits of allowing migrants to also maintain their native culture. Wiping out cultural differences between migrants and the native population means that there is less potential for migrants to make a unique positive contribution to their firms and regions by providing alternative perspectives and new ideas.

6.3 Limitations and further research questions

This thesis has some limitations that need to be addressed and the results need to be look at with these in mind. Meanwhile, these limitations also yield further research questions, which will also be discussed in this section.

Firstly, economic actors can use other various channels to access new knowledge that are important for their economic performance, than those which have been highlighted in this thesis. For instance, innovating firms

might gain new knowledge from recruitment, acquisition and formal as well as informal exchanges with other actors. Informal exchanges of knowledge with other actors might be generated from local knowledge spillovers from actors located in the same area (Asheim and Coenen, 2005; Roper et al. 2017) or from related industries (Fitjar and Timmermans, 2018). Learning from prior experience and knowledge with one type of partner, e.g. universities, is also highlighted as important for firms' innovation performance (Hewitt-Duandas, 2013; Hewitt-Duandas et. al., 2019). This also emphasizes that innovation as a dynamic process is included in firm strategy decisions that depend on factors that vary over time. This dissertation does not look deeply into the dynamic aspect of the innovation process.

This thesis relies on birthplace diversity but the literature of diversity also offers and uses other dimensions or measures of diversity. While birthplace diversity is a primary diversity characteristic that is given at birth and one cannot change, secondary diversity includes elements that one can change. Secondary diversity, such as experience and education, are not used in this thesis and can be important in future research. Other measure of diversity such as sex, gender and race might also contribute to the debate.

In addition, in research on economic spillovers from immigrant diversity, more deep-level differences related to attitudes, beliefs and values to immigrant might benefit this discussion. While the proxy of regional trust in foreign-born individuals is pointing in this direction, more research in this direction is needed. Additionally, measures that are able to say something about if and how much the underlying and assumed interactions between immigrant and natives actually happen will be important.

It is also generally hard to measure how the cost of interacting across diversity changes. In this thesis, I use different measures that account for differences in informal institutions at the regional level. This work

extends previous empirical research, by triangulating between several measures that are in different ways argued to affect the cost of interacting across diversity. However, as in previous research, our measures are also built upon assumptions of an indirect relationship. We do not know if there is actually any interaction that happens between immigrants and natives, nor how much it is affected by the costs of interacting. Further research that is able to take this more into account will contribute to our understanding of the relationship between the underlying effects of birthplace diversity and productivity. The chosen quantitative methodological approach used in this thesis makes it difficult to move the discussion into a study about a firm or groups of individuals. This would to some extent have been covered more using a qualitative approach, but then we would lose some of the benefits of using a quantitative methodological approach that enables us to talk about a relationship that is valuable for the average firm or individual. However, this raises some concern about heterogeneity differences among the economic actors, such as firms and individuals, that are studied in this thesis. The overall adapted econometric methods in the thesis are able to account for a wide range of threats to internal validity so that heterogeneity issues related to individuals, firms and regions are almost ruled out, yet there is still a concern in all these types of research. While it is a hard task to fulfill, further research that aims to take this into account might contribute to the discussion. For instance, exploring sectoral contrasts in more detail may provide further insight and suggest more refined or more sector-specific policy priorities for the prediction in this thesis generated from the innovation modes approach.

In further research, it would be interesting to look more into whether questions raised in one of these papers are also relevant and valued in the other papers. For instance, do we find substitution or complementarity effect between firms' use of internal versus external types of knowledge? Does this result change if we take into account regional differences in informal institutions? How is firms' innovation performance affected by

birthplace diversity in the firm? And, is this affected by the assimilation process of these individuals? Are innovative firms affected by the regional informal institutional setting when they choose where and how to generate new knowledge?

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Paper I - IV

Paper I

The external and internal dimension of innovation modes

Developing science- and experience-based knowledge internally and in collaboration with external partners

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Abstract

This paper integrates two research strands at the heart of innovation studies by examining the distinctions between innovation modes and external and internal approaches to innovation. By combining these two strands, we are able to analyse four dimensions behind innovation: a) internal (R&D expenditures within the firm) and external (collaboration with consultants, universities, and research centres) science, technology and innovation (STI); and b) internal (brainstorming, job rotation, creativity training) and external (collaboration with suppliers and customers) doing, using and interacting (DUI). We assess the effects of each of these dimensions on innovation at the level of the firm using Norwegian Community Innovation Survey data from 2010. The empirical analysis demonstrates that a firm's innovation capacity depends to a large extent on its different levels of exposure to external and internal STI and DUI. While external STI is not significantly related to any innovation outcomes, external DUI knowledge exchange is a fundamental driver of innovation. Internal STI and DUI both have a significant and positive effect on firms' innovation output. We also find no complementarities between firms' use of internal knowledge types, such as internal DUI or internal STI, and the benefits from using external knowledge sources. In contrast, internal STI can, to some extent, substitute for external knowledge sourcing from both DUI and STI partners.

Keywords: Innovation, STI, DUI, R&D, collaboration, firms, Norway.

Introduction

Firms generally do not only rely on in-house knowledge and internal processes to develop innovation. They often innovate by using externally generated knowledge (von Hippel, 1986; Freeman, 1987; Powell et al., 1996; Lundvall, 1988; Rigby and Zook, 2002; Chesbrough, 2003, 2006). Since the introduction of the 'Open Innovation' approach (Chesbrough, 2003), research within innovation studies has paid considerable attention to how openness and interaction with external knowledge sources shape innovation. Firms are considered to innovate by searching for knowledge from external sources (Pavitt, 1984; von Hippel, 1986; Laursen and Salter, 2006; Vega-Jurado et al., 2009; Garriga et al., 2013, Laursen and Salter, 2014).

However, not all knowledge – such as tacit or experience-based knowledge (Polanyi, 1958; Nelson and Winter, 1982; Pavitt, 2002; Storper and Venables, 2004) – is easily and costlessly available through external sources. Therefore, firms also frequently result to building their own knowledge. Firms' experience-based knowledge is argued to be socially embedded. It resides in organizational routines and shared norms that can be revealed through daily practice within firms (e.g. Nonaka, 2007), but also transmitted through social networks (Lam, 2010). The latter generally occurs within 'systems of innovation' (Lundvall, 1994; Asheim and Gertler, 2005) or networks and value chains (e.g. Powell and Grodal, 2005). Internal experience-based knowledge is produced in 'shared contexts' or common 'communities of practice' within the firm that facilitate experience- and interaction-based learning (Nonaka, 2007). Internal knowledge also aids in recognizing the value of external knowledge (Cohen and Levinthal, 1990; Laursen and Salter, 2006), making it crucial for firm level innovation (Foss and Laursen, 2003; Jensen et al., 2007; Lundvall and Nielsen, 2007). Consequently, firms that invest in improving their internal organizational designs are more likely to improve their absorptive capacity, which, in turn, allows them to maximize the returns from external knowledge sources in the innovation process (Cohen and Levinthal, 1990; Foss et al., 2011).

While the distinction between internal and external approaches to innovation has been central in the innovation literature, Jensen et al., (2007) have proposed an alternative and, arguably, equally important, dimension of innovation processes: the division between firms using an R&D-based, science-oriented approach to innovation and those resorting to a more experience-based one. The first mode of learning and knowledge at firm-level has been called 'Science, Technology and Innovation' (STI). It refers to the use of scientific knowledge for the development of new technologies that form the basis of new products or processes within the firm. The alternative mode – 'Doing, Using and Interacting' (DUI) – refers to on-the-job problem-solving based on the exchange of experiences and know-how, allowing firms to find solutions to problems that arise in the innovation process. The latter is usually tacit and often highly localized within firms, but can also be developed in collaboration with

external knowledge sources within the supply-chain (Kline and Rosenberg, 1986; Jensen et al., 2007; Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016).

While there is no shortage of literature looking at both internal and external knowledge and at STI and DUI, research has been hesitant to integrate these two approaches. Hence, the question of whether the benefits of external or internal knowledge sourcing depend on the type of knowledge being sourced remains largely unanswered. Do STI and DUI modes of innovation have different requirements for external or internal knowledge sourcing? While STI and DUI innovation modes encompass both internal and external knowledge sourcing, past research has so far either combined internal and external activities into one innovation mode (Jensen et al., 2007) or mainly focused on external knowledge sourcing activities as proxies for identifying the innovation mode at firm level (e.g. Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016; Apanasovich et al., 2016).

This paper combines internal and external knowledge sourcing with the analysis of different modes of innovation to supersede past research on three counts. First, we bring to the fore the hitherto hidden role of internal experience-based knowledge in firms' innovation process. We demonstrate that firms' experience-based internal knowledge is as important for their innovation performance as the external use of this type of knowledge.

Second, we distinguish between internal and external dimensions within each innovation mode. We classify internal STI as firms' investment in internal R&D activities, and external STI as firms' use of external scientific partners such as universities, research institutes or consultancies. External DUI encompasses linkages with customers and suppliers, while internal DUI is measured by firms' use of different types of organizational design and forms of work organization to promote internal interaction, such as interdisciplinary workgroups, job rotation or incentives to develop new ideas. External and internal DUI are tested in conjunction with external and internal STI. This enables much greater nuance in explaining how different forms of interaction and collaboration within and outside the firm influence different types of innovation. For STI and external DUI we rely on concepts and measurements that have been tried and tested in earlier research[1] (e.g. Fitjar and Rodríguez-Pose, 2013). Our approach to internal DUI is, by contrast, completely novel in the literature.

Third, the division between external and internal DUI interaction allows us to address new questions related to the interaction between internal and external dimensions of experience-based knowledge. Previous work focusing on firm-level absorptive capacity argued that external knowledge sources were always essential to promote organizational learning (Cohen and Levinthal, 1990; Cassiman and Veugelers, 2002). Our empirical results, however, show that this is not the case for science-based knowledge. Firms in Norway do not benefit more from externally generated knowledge if they

[1] While previous studies on innovation modes have not distinguished between internal and external STI, many have included internal R&D investments – our measure of internal STI – as either a control variable (e.g. Fitjar and Rodríguez-Pose, 2013) or as part of their composite STI measure (e.g. Jensen et al., 2007).

conduct more in-house R&D. On the contrary, internal STI can to some extent substitute for engaging in external innovation activities.

In the analysis we use a set of questions unique to the 2010 Norwegian Community Innovation Survey (CIS). This survey contained detailed information about individual firms' internal – brainstorming and the presence of interdisciplinary workgroups to promote firm-level innovation – and external knowledge sources. This distinction provides vital information about the different channels through which innovation is achieved and is crucial to fully understand the innovation processes within a firm (Laursen and Foss, 2003; Laursen and Salter, 2006; Jensen et al., 2007; Fitjar and Rodríguez-Pose, 2013; Haus-Reve et al., 2019). Following recent research, we distinguish between different types of innovation at the firm level: product, radical product, and process innovation. This threefold classification allows for a deeper understanding of how different firms' use of internal and external STI and DUI affects different types of innovation. Moreover, since participation is mandatory in the Norwegian CIS, the risk of non-response bias is virtually eliminated. The Norwegian CIS data also includes data on all firms' use of different knowledge sources to promote innovation, rather than asking these questions only to innovative firms.

The rest of the paper proceeds as follows: In the next section, we look at the internal and external dimensions of the different modes of innovation. We then present the methodology and data, followed by the empirical analysis. The final section concludes the conclusions.

2 Modes of innovation within and outside the firm

2.1 Innovation modes

Jensen et al., (2007) established what is now a popular distinction between two ideal types of firm-learning mechanisms to achieve innovation. One mode is based on the production and use of codified scientific and technical knowledge: 'Science, Technology and Innovation' (STI). The other is an experience-based learning mode based on 'Doing, Using and Interacting' (DUI).

In STI, research and development (R&D) is the main innovation driver. It relies mainly on know-what and know-why types of knowledge (Lundvall et al., 1994). The production and transfer of STI knowledge commonly relies on universally accessible sources of knowledge, such as books, scientific articles or internet sites. Within the firm, STI knowledge is usually generated in R&D departments, relying on targeted R&D activities conducted by highly trained specialists. Firms can also follow an external, rather than an internal, route and collaborate with organizations that produce knowledge,

such as universities and research centres. Hence, in the STI mode innovation relies on R&D, human capital, and research collaboration (Romer, 1990; Cohen and Levinthal, 1990; Griliches, 1995).

The DUI mode of innovation is built on the ideas that learning-by-doing and learning-by-using are fundamental for generating new knowledge (Lundvall et al., 1994). Interacting and collaboration with customers and/or suppliers are basic sources of such knowledge. However, in-house interactions reflecting the 'learning firm' approach (Jensen et al., 2007) are also critical. Organisational practices such as project teams, problem-solving groups, and job and task rotation, which promote learning and knowledge exchange, can contribute to developing and sharing experience-based knowledge within the organisation (Laursen and Foss, 2003; Lorenz and Valeyre, 2006).

2.2 External and internal approaches to innovation

Another much-discussed dimension of firm-level innovation strategies focuses on the distinction between using internal or external knowledge sourcing. Traditionally, innovation was thought to be a process taking place within the firm, albeit with some procurement of external knowledge. The development of the networked and open approaches to innovation has fundamentally changed this perception (Freeman, 1974; Powell et al., 1996; Cooke and Morgan, 1998; Chesbrough, 2003). A core idea in this literature is that external collaboration is more than just a strategy for enhancing access to new knowledge. As new ideas are created in the meeting between different bodies of knowledge, the nexus of innovation is in the network (Powell and Grodal, 2005). Hence, firms simply cannot innovate without engaging with external actors.

However, this does not imply that firms should cease pursuing internal knowledge activities. Rigby and Zook (2002) argued that the capacity to combine internal and external knowledge is critical for a firm's competitive advantage. The absorptive capacity (Cohen and Levinthal, 1990) of a firm highlights that, in order to make the most of new knowledge developed outside the organization, firms need to engage in internal knowledge-creation activities. From this perspective, understanding the role of organizational learning becomes important to grasp how internal knowledge affects the innovation process within the firm (Owen-Smith and Powell, 2004; Lam, 2005; Powell and Grodal, 2005; Ferreras-Méndes et al., 2016).

Innovation is thus increasingly regarded as a result of both external and internal knowledge inputs (e.g. Cassiman and Veugelers, 2006; Laursen and Salter, 2014; Rodriguez et al., 2017; Giannopoulou et al., 2019). However, some have cautioned against the risk of 'over-searching' and question whether most firms – and especially small- and medium-sized firms – have the capacity to manage different type of knowledge inputs (Laursen and Salter, 2006; Haus-Reve et al., 2019). Firms may also worry about knowledge leakage when they engage in formal external collaboration (Cassiman and Veugelers, 2002; Laursen and Salter, 2014). Furthermore, the "paradox of openness" stresses that

firms that open up to outside sources of knowledge in an innovation process may weaken their potential to capture rents or the right value from that knowledge.

2.3 Combining the approaches

As we have seen, both STI and DUI encompass internal activities as well as external knowledge sourcing. However, these two dimensions of innovation modes have rarely featured in the literature. Jensen et al., (2007) classified firms' use of knowledge into four different clusters according to their use of STI or DUI in the innovation process. This rather broad classification did not enable them to say anything about the external and internal dimensions of these knowledge sources.

However, STI and DUI are bound to work differently depending on whether firms rely mainly on internal activities or on external knowledge sourcing when implementing them. To address this important gap in our knowledge, we intersect the two basic divides in the process of innovation to identify four stylized dimensions of innovation: Internal STI, external STI, internal DUI, and external DUI. These represent the different approaches by which firms aim to develop innovation.

None of these dimensions are new. A cursory look at the innovation studies literature reveals that a considerable body of research has targeted each of these four dimensions. Table 1 shows each of the four dimensions and the main research areas specifically discussing each type. However, each dimension has usually been considered separately. Few attempts have been made at integrating all of them into a unified model of innovation. In this paper, we bring the four dimensions together and compare their effects on firm-level innovation in an integrated model.

Table 1
Dimensions of innovation

	Internal	External
STI	Internal STI (e.g. economics of R&D literature)	External STI (e.g. university-industry interaction literature)
DUI	Internal DUI (e.g. learning organisations literature)	External DUI (e.g. clusters and industrial districts literature)

2.3.1 Internal STI

In the internal STI mode, innovation is achieved by promoting science, technology and innovation processes within the firm with the aim of developing new science-based knowledge. In short, we can associate this with formal R&D conducted within the firm. From the pioneering work of Bush (1945), it has been posited that investment in R&D is at the root of the production of new technology and, consequently, innovation. Economic models of innovation typically employ some variation of a knowledge production function, in which R&D investments – mainly by firms – are seen as the main

input to the innovation process (e.g. Griliches and Mairesse, 1981; Crépon et al., 1998). Endogenous growth theory further explains how firm-level R&D investments result in economic growth at the macro scale (e.g. Romer, 1990; Grossman and Helpman, 1994). In these models, innovation is the outcome of conscious decisions by firms to invest in R&D. This process typically involves some level of uncertainty over the outcome, and a degree of knowledge spillovers that also benefit other firms (Griliches, 1995).

The presence of these knowledge spillovers implies that firms need to worry about appropriability, or the degree to which they will be able to capitalise on their R&D investments (Levin, 1988). The public nature of scientific knowledge (Jaffe, 1989; Griliches, 1995) and the difficulty and cost of appropriating it may discourage firms from investing in R&D, in the hope that they can free-ride on the research carried out by other firms. However, the returns to R&D investments can also be mediated by the type of externalities inherent to the environment in which the firm operates. Hence, a core issue for policy-makers is how to develop appropriability conditions that provide sufficient incentives for firms to invest in R&D while also enjoying the benefits of knowledge spillovers and diffusion of new innovations.

However, R&D investments may provide various benefits for firms. They can strengthen the firm's internal knowledge and competence (Winter, 1986), increase possibilities to become first movers in the market (Cohen and Levinthal, 1990), increase their absorptive capacity (Cohen and Levinthal, 1990; Gilsing et al., 2008), and improve competitiveness by augmenting their technology capacity (Bilbao-Osorio and Rodríguez-Pose, 2004). Hence, firms will often benefit from investing in R&D, even when formal appropriability is difficult.

On this basis, we can formulate the following hypothesis:

H1: *Firms that use STI internal are, everything else being equal, more likely to innovate than firms that do not.*

2.3.2 External STI

Not all firms, however, are capable or possess the right incentives to invest scarce internal resources in promoting internal access to scientific knowledge. In these circumstances, firms may try to overcome the disadvantage of not investing directly in R&D through collaboration with external scientific actors, such as universities and research centres. This is the external STI mode, in which innovation is a consequence of science, technology and innovation being developed in collaboration with external – mainly science-based – partners, i.e. universities or research institutes.

Research on the role of scientific knowledge from external sources on firms' innovation performance has grown rapidly (Mowery and Sampat, 2005). Universities and research centres are viewed as pivots in national and regional systems of innovation (Lundvall and Johnson, 1994; Asheim and Gertler,

2005). They generate and spread a large share of the scientific knowledge that allows firms to innovate, in particular in the case of high-tech industries (Acs et al., 1998 Saxenian, 1994; Powell et al., 1996). Consequently, firms located close to universities or more likely to innovate (Jaffe, 1989).

This type of external collaboration is, however, not without problems (Kaufmann and Tödtling, 2001). The differences in norms and incentives between actors represent a serious barrier for innovation (Thursby and Thursby, 2007). This is the 'two-worlds' paradox of university-industry collaboration (Hewitt-Dundas et al., 2019), which holds that universities and firms have fundamentally different orientations related to the public or private nature of knowledge (Bruneel et al., 2010). While academics want to publish and disseminate their ideas as far as possible, firms want to patent or protect their knowledge in order to appropriate the returns.

However, with increasing pressure at universities and research centres to generate more applied research and to commercialise their findings, the incentive gap between firms on the one hand, and external scientific actors on the other, is narrowing (Hagedoorn, 2002; Perkmann, et al., 2012). While this may also involve more conflicts – e.g. over intellectual property rights – firms also learn to collaborate and build trust in universities (Bruneel et al., 2010; Hewitt-Dundas et al., 2019). More empirical research (e.g. Cohen et al., 2002; Arundel and Geuna, 2004) has further stressed the relevance of academic research for innovation. A scientific involvement by firms and the development of ties with scientists result in more technology (e.g. Zucker et al., 2001), enhanced capabilities for exploration and exploitation (Bishop et al., 2011), and a higher likelihood of product and radical product innovation (e.g. Cassiman and Veugelers, 2006).

A common feature in all of these theories and empirical studies is an instrumental approach to university-research institutes-firm interaction: Reaching out to universities and research centres allows firms to access the scientific knowledge needed in the innovation process. On this basis, we can formulate the following hypothesis:

H2: *Firms that use external STI are more likely to innovate than firms that do not.*

2.3.3 Internal DUI

The highly specific nature of the know-how involved in scientific knowledge is not required for all types of innovation and is often more relevant for specific sets of firms within selected industries (Pavitt, 1984; Cassiman and Veugelers, 2007). For most other firms, experience-based knowledge can be more important. Experience-based knowledge is usually produced by inter-organizational collaboration and learning in the workplace (Kline and Rosenberg, 1986; Freeman, 1987; Lam, 2005; Arundel et al., 2007), facilitating the "learning organizations" at the base of innovation (see e.g. Levitt and March, 1988). This is the internal DUI mode, which sees innovation as the consequence of processes of learning by doing, using and interacting within the firm.

Different forms of in-house collaboration and interaction can encourage responsibility and facilitate the creation of the 'know-how' and 'know-who' knowledge that triggers many types of innovation in the firm. In particular, organizational practices, such as project teams, problem-solving groups, job and task rotation, decentralization of decisions, and rights and incentives can contribute positively to innovation performance (Jensen, et al., 2007; Laursen and Foss, 2003).

Three main arguments have been highlighted as to why collaboration within a firm can affect innovation. First, the organization of the firm may stimulate or deter interaction among employees with diverse types of experience and competence, enhancing or stifling creativity. Second, delegating responsibility for problem solving to a wide range of employees can enhance the drive and competence of workers, easing the transformation of ideas into innovation (see. e.g. Arundel et al., 2007). Third, financial and other incentives given to the employee can increase motivation and individual engagement in the development of new ideas (Bloom and Van Reenen, 2011).

Few studies, however, have used quantitative methods to explore these complex within-firm links. The exceptions (e.g. Laursen and Foss, 2003; Jensen et al., 2007) have found a positive correlation between the frequency of product and process innovation and the use of what has been called 'high-involvement' work practices, such as autonomous teams, flexible demarcations in work task, and broad involvement of employees in the innovation process.

Nonetheless, follow up research has been unable to replicate these results in multiple contexts. The main reason for this may be the absence of good and relevant measures to capture internal innovation-related organizational characteristics across a large number of firms. Many of the results are piecemeal, reach contradictory results, and/or focus exclusively on one aspect of internal organization. Lerner and Wulf (2007) and Kanama and Nishikawa (2017), for example, have examined the relationship between the use of financial incentives and innovation, reporting a positive and significant connection between compensation of senior executives and firms' R&D performance. By contrast, Yanadori and Cui (2013) find that the compensation of skilled employees with R&D competence is irrelevant for a firm's innovation performance.

This research, however, falls far short of the comprehensive definition developed by Jensen et al., (2007) of firm-level experience-based knowledge. The internal dimension of experience and know-how exchanges within the firm remains therefore overlooked. Taking this into account, we formulate the following hypothesis:

H3: *Firms that use internal DUI are more likely to innovate than firms that do not.*

2.3.4 External DUI

DUI, in general, and learning-by-doing, in particular, rely on the accumulation of experience (Arrow, 1962). Experience can be derived, as indicated above, from internal collaboration. However, collaboration with external partners – and, fundamentally with customers, suppliers and competitors – is also a rich source of learning-by-doing and learning-by-using. This is the external DUI mode, in which innovation results from interactions with external industrial partners in which experience-based and tacit knowledge is produced and exchanged.

Customers and suppliers not only volunteer ideas and knowledge, but also push firms to modify products and shape the direction of their innovation path and improve market competitiveness (von Hippel, 1986; Coen et al., 2002). The notion that firm-level innovation performance is influenced by external DUI is central in several innovation approaches. From research on clusters (e.g. Porter, 1986) to the industrial district literature (Marshall, 1890), the spatial proximity between firms and their suppliers and customers is thought to breed the positive externalities at the base of innovation. Interaction with competitors is considered more informal and less likely to lead to knowledge spillovers (Porter, 1986). Such knowledge spillovers – in contrast to the knowledge exchanges in firms working closely with suppliers and customers (Laursen and Salter, 2006; Lichtenthaler, 2008) – are more an unintended consequence of the establishment of a link than its main purpose (von Hippel, 1989).

More recently research has made the distinction between two ways of accessing knowledge by firms: by collaboration within (through customers and suppliers) and outside the supply-chain (with competitors) (Un, et al., 2010; Fitjar and Rodriguez-Pose, 2013; Haus-Reve et al., 2019). These studies find a positive and significant effect on firm-level innovation from collaborating within the supply-chain, but no effect or a negative effect from collaborating outside it.

Based on this, for external DUI we can formulate the following hypothesis:
H4: *Firms that use external DUI are more likely to innovate than firms that do not.*

2.4 The interaction between internal and external knowledge sourcing

One of the limitations of the diverse approaches presented above is that they are built on the premise that there is a *direct* relationship between the use of different types of knowledge by firms and their innovation performance. While such a direct relationship may exist, the relationship may also be indirect. Organizational practices mediate how firms search for and use knowledge from agents within and outside the value-chain (Foss et al., 2011). This argument has been developed furthest in the literature on absorptive capacity, which sees internal and external knowledge production as complementary processes. The ability of firms to identify and use external knowledge depends on

having sufficient absorptive capacity, for which internal investments in knowledge creation are important (Cohen and Levinthal, 1990). In particular, this literature considers internal investment in R&D crucial for the ability of firms to recognise the value of external knowledge and apply it in their own innovation process (Cohen and Levinthal, 1990). As such, firms conducting internal STI should be expected to benefit more from external collaboration.

However, other approaches to absorptive capacity underscore the importance of factors beyond R&D in supporting the ability of firms to exploit external knowledge (Schmidt, 2010). Zahra and George (2002) highlight the need for social integration within the firm and its role in information sharing. Organisational mechanisms such as job rotation or inter-departmental connectedness may be highly important for developing absorptive capacity (Jansen et al., 2005; Vega-Jurado et al., 2008; Lewin et al., 2011). Hence, internal DUI would also be expected to improve how firms benefit from external collaboration, allowing us to formulate the following hypothesis:

H5: *Firms that invest in internal knowledge, such as internal DUI or internal STI, are more likely to benefit more from external knowledge than firms that do not.*

By contrast, the use firms make of external knowledge may also create disadvantages. For example, firms may need to protect their knowledge when they engage in formal external collaboration (Cassiman and Veugelers, 2002; Laursen and Salter, 2014). This is often referred to as the "paradox of openness": firms that open up to outside sources of knowledge may be jeopardizing their own capacity to capture rents derived from their own in-house innovation (Laursen and Salter, 2014; Arora et al., 2016), leading to our final hypothesis.

H6: *Firms that use external knowledge, such as external DUI or internal STI, are less likely to benefit from similar internal knowledge than firms that do not*.

Our approach in these final two hypotheses hints at the fact that internal and external DUI may be substitutes rather than complements. This has not been previously tested in the literature and represents and additional step in our understanding of innovation at firm-level.

3 Methodology

3.1 Data

We test the hypotheses presented above using data from the Norwegian section of the Community Innovation Survey (CIS) from 2010. The CIS is based on the 2005 Oslo Manual and provides information on the innovation activities of firms, including detailed data about how and where firms exchange knowledge for innovation. One of the drawbacks of previous CIS surveys is that they were not able to capture what kind of knowledge exchange happens *within* the firms (Lorenz, 2005). The 2010 Norwegian CIS[2] survey addressed this shortcoming by asking questions about the kind of activities firms engage in to promote internal knowledge exchange. These questions make it possible to identify internal organizational mechanisms that are implemented to promote innovation. We use this as a measure of the internal dimension of 'doing, using and interacting' or experienced-based knowledge.

We further distinguish between firms' use of DUI partners as the external dimension of DUI, and of STI partners as the external dimension of STI. We proxy internal STI by means of firm-level R&D expenditure. This separation between external and internal STI and DUI allows us to provide greater nuance in explaining how different forms of interaction may affect different types of innovation. These measures are described in detail below.

One of the advantages of the Norwegian CIS is that participation is mandatory for sampled firms. Non-respondents are fined. This results in a response rate of almost 97 percent. The sample includes the full population of Norwegian firms with 50 or more employees, as well as all firms with 10-49 employees that have reported significant R&D activities in the previous waves of the survey. Other firms with 5-49 employees are sampled through a procedure which stratifies firms by size and industry, with higher likelihood of inclusion for larger firms. This results in a sample of 6289 firms. These represent around a third of firms and two thirds of employees in the population of Norwegian firms with more than five employees. In addition, we merge CIS data with linked employer-employee data (LEED) from Statistics Norway to add information on the location and human capital endowment of each firm.

[2] These questions are only included in the Norwegian 2008-2010 CIS survey and are unfortunately not included in the follow-up surveys.

3.2 Econometric Approach

In the econometric model, we use three different proxies for innovation performance as dependent variables. These are product innovation, new-to-market product innovation, and process innovation. Product innovation is registered if the firm has introduced new or significantly improved goods or services to the market in the preceding three years. 22.5 percent of Norwegian firms report this type of innovation. New-to-market product innovation only includes product innovations that were new to the firm's market, and excludes innovations that were new to the firm but already existed in the market. 18.1 percent of the sampled firms recorded this type of innovation. Process innovation refers to the introduction of new or significantly improved methods for the production or delivery of goods or services. 16.2 percent of firms in the sample reported this type innovation. Table 1 provides information on the dependent variables used in the analysis.

Table 2
Description of dependent variables.

Variable name	Description	Mean	Std.	Min	Max
Product Innovation	1 if the firm has introduced new or significantly improved goods or services for the period 2008-2010, 0 if not	0.225	0.417	0	1
Radical product innovation	1 if the firm has introduced a product innovation new to the market during the period 2008-2010, 0 if not	0.181	0.385	0	1
Process Innovation	1 if the firm has introduced a process innovation new for the firm during the period 2008-2010, 0 if not	0.165	0.371	0	1

In all cases dealing with a binary dependent variable the most appropriate choice is a logit model. The analysis is based on the innovation production function, which relates firms' innovation outputs to the knowledge inputs in the innovation process (see e.g. Griliches, 1995). The three measures of innovation and the empirical approach have been previously used in similar analyses (see e.g. Fitjar et al., 2013; Parrilli and Heras, 2016; Haus-Reve et al., 2019).

We fit three different regression models to the data. First, we specify a simple main effects model in order to test H1-H4:

$$logit\big(P(innovation_i)\big) = \alpha + \beta_1 Internal\ STI_i + \beta_2 External\ STI_i + \beta_3 Internal\ DUI_i + \beta_4 External\ DUI_i + \beta_5 Controls_i + \varepsilon_i \quad (1)$$

Second, we test H5 by including an interaction term between the internal and external dimensions of each innovation mode:

$$logit\big(P(innovation_i)\big) = \alpha + \beta_1 Internal\ STI_i + \beta_2 External\ STI_i + \beta_3 Internal\ DUI_i + \beta_4 External\ DUI_i + \beta_5 Internal\ STI_i * External\ STI_i + \beta_6 Internal\ DUI_i * External\ DUI_i + \beta_7 Controls_i + \varepsilon_i \quad (2)$$

Finally, we test H6 by including an interaction term between the internal dimension of one mode and the external dimension of the other:

$$logit\big(P(innovation_i)\big) = \alpha + \beta_1 Internal\ STI_i + \beta_2 External\ STI_i + \beta_3 Internal\ DUI_i + \beta_4 External\ DUI_i + \beta_5 Internal\ STI_i * External\ DUI_i + \beta_6 Internal\ STI_i * External\ DUI_i + \beta_7 Controls_i + \varepsilon_i \quad (3)$$

3.3 Independent variables and control variables

In line with previous research (e.g. Fitjar & Rodríguez-Pose, 2013; Apanasovich et.al., 2016), innovation collaboration with different partner types is used as a proxy for external STI and DUI innovation modes. DUI *external* encompasses firms' collaboration with suppliers or customers. 10.9 percent of the sampled firms use external DUI. STI *external* encompasses collaboration with universities, research institutes, and consultancy firms and is used by 9.6 percent of the sampled firms.

Other variables reflecting a firm internal activities related to each mode are also included in the analysis. For STI *internal*, we use R&D expenditures – as a continuous log-transformed variable – reflecting the size of R&D expenditures. 23.1 percent of the firms report some investment in internal R&D activities.

While all of the above variables have been used in previous studies (e.g. Jensen et al., 2007), the proxy for internal DUI is completely novel. Following the organizational management literature, we examine internal DUI using the development of within-the-firm organisational practices to promote, exchange or develop experience-based or tacit knowledge. This includes activities like brainstorming, interdisciplinary workgroups, job rotation, and firms' use of creativity training. We additionally measure firms' use of financial and non-financial incentives for employees to develop new ideas or incentivize creativity.[3] The CIS includes information on firms' use of each of these practices during the previous three years. We distinguish between whether firms used one or several of these practices, and if they regarded these practice(s) as important for their innovation performance. On average, 40 percent of all firms in our sample resorted to at least one of these practices and regarded it as essential for innovation. Brainstorming and interdisciplinary workgroups were the most widely used. The internal innovation-enhancing practices, identified as DUI *internal*, are introduced in the analysis as an index, where a value close to one indicates a high intensity of internal DUI. The index has a satisfactory degree of internal consistency (Cronbach alpha coefficient = 0.75). The mean score on the DUI *internal_index* is 0.46, indicating that many firms use several of these activities simultaneously.

Table 2 displays the descriptive statistics for the variables included in the analysis. Table A.1 in the appendix shows the full list of variables comprised in the internal DUI index.

[3] For all these dimensions, the questions ask whether these practices are used to promote new ideas and innovation performance.

A number of firm-level controls are incorporated in the estimations to account for other factors potentially affecting firm-level innovation performance. *Firm size* is the number of full-time employees in the firm. This variable is based on linked employer-employee data from tax registers, from which we count the number of people listed as employed in the firm in 2010. *Firm age* is proxied by the number of years in which the firm is present in the register data between 2000 and 2010. *Share of educated employees* is the percentage of the firm's workers who have completed a higher education degree. This variable is drawn from linked employer-employee data, using the Norwegian education database for details on each employee's educational background. The average share of workers with higher education is 27.1 percent. These variables are all log-transformed because of skewness in the distributions.

Different industrial sectors are characterized by different incentives and propensities of firms to engage in innovation activities. We control for industry by including a set of dummy variables for separate industries. In total, 58 different NACE two-digit industries are present in the data. We further include dummy variables for economic regions. These are defined at the level of economic regions according to Statistics Norway, corresponding to local administrative units at level 2 (LAU 2).[4]

A lagged dependent variable is used as a control in all models. This lag accounts for firms' past innovation record, capturing unobserved heterogeneity in firms' ability to innovate.

Table 3
Description of independent and control variables

Variable name	Description	Mean	Std.dev	Min	Max
STI internal	Firm`s expenditures on R&D, continuous variable	1.882	3.481	0	13.81
STI external	1 if the firm has collaborated or interacted with private research institutes, universities or consultants to promote innovation during the period 2008-2010, 0 if not	0.096	0.295	0	1
DUI internal	Index between 0 and 1, where a value close to one indicates a high intensity of internal practices brainstorming, interdisciplinary groups or so on to promote innovation during the period 2008-2010	0.468	0.436	0	1
DUI external	1 if the firm has collaborated or interacted with suppliers or customers to promote innovation during the period 2008-2010, 0 if not	0.109	0.311	0	1
Firm size	The number of full-time employees in the firm.	93	397.1	5	17,702
Firm age	Proxy by the number of years for which we observe the firm in the register data between 2000 and 2010	9.13	2.89	1	11
Share of educated employees	Percentage of the firm's workers who have completed a higher education degree	0.217	0.190	0	0.693

Note: For all variables, N = 6289. Firm size and data on employees' education are based on linked employer-employee data from 2010. 58 different two-digit industries located in 78 different economic regions are present in the data.

[4] Regions that are functionally integrated into the same labour market are merged, building on a classification by Gundersen and Juvkam (2013). This leaves 78 labour market regions, matching a classification previously used in similar studies (e.g. Fitjar and Timmermans 2017; Haus-Reve et al., 2019).

4 Empirical results

Table 3 presents the main results of estimating model [1]. As expected, internal STI has a significant and positive effect on all innovation outcomes, supporting H1. The effect is stronger for product innovation and for radical product innovation than for process innovation. The coefficients is not directly comparable with the other variables as internal STI is measured on a continuous, rather than a dichotomous, scale. Nonetheless, it is worth pointing out that a one unit increase in the log of R&D expenditures has a larger marginal effect[5] on product innovation than switching form not doing to doing any of the other innovation modes. Hence, internal STI is arguably the key factor in the innovation process, in particular when it comes to product innovation.

External STI, by contrast, displays an insignificant coefficient, signalling a lack of support for H2. The coefficient is negative, albeit close to zero, for product innovation, and weakly positive for radical product innovation and for process innovation. Hence, external STI – in contrast to internal STI activities – does not appear to be a predictor of innovation. This most likely reflects the 'two-worlds' problem of university-industry interaction, as discussed above (Bruneel et al. 2010; Hewitt-Dundas et al., 2019).

The use of internal DUI knowledge to promote innovation is significant and positive for all innovation outcomes, supporting H3. Implementing organisational changes that aim to foster experience-based learning and knowledge exchange within the organisation improves the likelihood of succeeding with both product and process innovation, including radical product innovation. Moreover, this effect is independent of the effects of internal STI and of external DUI, as internal DUI remains a positive and significant predictor of innovation even when controlling for these alternative routes to innovation. Moreover, internal DUI does not absorb the positive effect from internal STI and external DUI. By including, this variable stepwise in our models, the coefficients for the other innovation modes are only slightly reduced (results available on request). Both continue to be significant and positive for all innovation outcomes.

Finally, external DUI has a positive and significant coefficient for all outcomes, indicating a support for H4. Firms that collaborate with external industrial partners, such as suppliers and customers, in the innovation process find this a useful channel for developing or exchanging experience-based knowledge that helps them introduce all types of innovation. The coefficient is somewhat higher than for internal DUI, although a z-test reveals these differences not to be statistically significant.

[5] Given that our models are nonlinear, this build on the premises that the predicted marginal effects of STI external, at the average level of all variables, is higher than the predicted marginal effect for production innovation switching from not doing to doing any of the other innovation modes.

Table 4
Logit regression estimation of model [1]

	Product innovation	Radical product innovation	Process innovation
	(1)	(2)	(3)
Product innovation t-1	1.047***		
	(0.107)		
Radical pr. innovation t-1		0.936***	
		(0.136)	
Process innovation t-1			0.900***
			(0.105)
STI external	-0.009	0.086	0.119
	(0.191)	(0.183)	(0.171)
STI internal	0.261***	0.261***	0.163***
	(0.014)	(0.015)	(0.014)
DUI external	1.342***	1.197***	1.169***
	(0.176)	(0.171)	(0.161)
DUI internal	0.326***	0.288***	0.602***
	(0.095)	(0.103)	(0.097)
Firm size (log)	-0.123***	-0.178***	-0.027
	(0.039)	(0.043)	(0.037)
Firm age (log)	0.049	0.031	-0.006
	(0.101)	(0.108)	(0.099)
Share of educated emp. (log)	0.382	0.540*	-0.319
	(0.301)	(0.319)	(0.313)
Observations	6,270	6,239	6,239
Pseudo R2	0.360	0.341	0.210
Log Likelihood	-2143.0	-1938.4	-2201.3

Note: Industry and regional fixed effects are included in each model. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$.

Table 4 presents the results for models [2] and [3], including the interactions between internal and external modes. These analyses are used to test H5, assessing if external and internal knowledge sourcing activities within each mode are complementary or substitutes (first column for each dependent variable), and H6, assessing complementarity and substitutability between external and internal activities across modes (second column).

The results do not support the expectations of complementarities between internal and external activities, either within or across innovation modes. All interaction terms are either non-significant or negative and significant, in the latter case suggesting that the external and internal dimensions are to some extent substitutes (albeit imperfect ones, as we still find significant positive coefficients for each mode when controlling for the others). The non-significant coefficients apply to combinations involving internal DUI, both when interacted with external DUI and with external STI. Internal DUI appears to work independently of external innovation and does not provide either complementarity or substitution effects with any forms of external collaboration. In contrast, internal STI has a significant and negative interaction with external STI as well as external DUI. This reflects some degree of

substitution between internal STI and external innovation activities, suggesting that firms make decisions about whether to make or buy/collaborate in innovation processes (Veugelers and Cassiman, 1999).

Table 5
Logit regression estimation of model [2] and [3].

	Product innovation		Radical product innovation		Process innovation	
	(1)	(2)	(3)	(4)	(5)	(6)
Product innovation t-1	1.041***	1.016***				
	(0.107)	(0.108)				
Radical prod. innovation t-1			0.929***	0.906***		
			(0.133)	(0.132)		
Process innovation t-1					0.886***	0.869***
					(0.104)	(0.104)
STI external	1.388***	0.139	1.354***	0.138	1.480***	0.248
	(0.275)	(0.255)	(0.286)	(0.250)	(0.258)	(0.232)
STI internal	0.290***	0.300***	0.286***	0.301***	0.193***	0.207***
	(0.014)	(0.015)	(0.015)	(0.015)	(0.014)	(0.015)
DUI external	1.212***	2.549***	1.116***	2.447***	1.212***	2.462***
	(0.267)	(0.216)	(0.263)	(0.218)	(0.234)	(0.203)
DUI internal	0.287***	0.299***	0.258**	0.239**	0.608***	0.573***
	(0.100)	(0.101)	(0.108)	(0.111)	(0.104)	(0.105)
DUIext*DUIint	-0.222***		-0.190***		-0.203***	
	(0.033)		(0.033)		(0.030)	
STIext*STIint	0.156		0.080		-0.107	
	(0.329)		(0.319)		(0.283)	
STIext*DUIint		0.028		0.144		0.010
		(0.323)		(0.312)		(0.286)
DUIext*STIint		-0.239***		-0.226***		-0.229***
		(0.028)		(0.028)		(0.026)
Observations	6270	6270	6239	6239	6239	6239
Pseudo R2	0.384	0.3875	0.367	0.371	0.240	0.245
Log Likelihood	-2064.0	-2052.9	-1875.55	-1865.49	-2136.32	-2122.9

Note: Industry and regional fixed effects are included in each model. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$.

5 Conclusion

In this paper, we have connected the internal and external dimensions of innovation with the innovation modes approach, which distinguishes between a science-based and an experience-based route to innovation. This yields four approaches to innovation that can all be expected to contribute to a firm's ability to introduce new products or processes. First, the traditional in-house research and development approach, which we label internal STI, has a strong positive impact on all types of

innovation and remains an indispensable part of firms' innovation processes. Second, a networked approach focusing on links to scientific partners, such as universities or research institutes, which we dub external STI, does not seem to affect innovation, reflecting the difficulties of university-industry interaction. Third, the in-house approach focusing on improving the conditions for experience-based learning and knowledge exchange within the firm through methods such as job rotation and inter-departmental work groups leads to greater innovation. This approach, which we call internal DUI, has a significant positive effect on innovation, independently of other approaches to innovation. Finally, a networked approach focusing on linking to sources of experience-based knowledge, such as suppliers or customers – named external DUI – also has a significant positive effect on innovation.

Both of the STI innovation dimensions have featured in previous studies (e.g. Jensen et al., 2007). However, the distinction between the external and internal dimensions of DUI is novel. The internal dimension of the DUI approach originally proposed by Lundvall (1988) is thought to be one of the most important sources of firm innovation but has seldom been brought into empirical models. One of the reasons for this has been lack of sufficient data measuring this type of activity at firm level. The attraction of the Open Innovation approach by Chesbrough (2003) has also put the external dimension of DUI in a privileged position, perhaps to the detriment of internal learning mechanisms and processes. However, research within other disciplines, e.g. Human Resources and Strategy, has included the internal dimension of DUI in its frontier research. The overall results from this research show that what happens within the firm is important for innovation outcomes (Foss and Laursen, 2003; Jensen et al., 2007; Lundvall and Nielsen, 2007).

The results of the analysis confirm that internal and external dimensions of the innovation modes have independent and to some extent differing effects on innovation, highlighting the need for research on innovation modes to distinguish between internal and external approaches to innovation. For DUI, the effects of internal and external activities are not significantly different. However, the effects are independent insofar as both internal and external DUI contribute uniquely to improving the innovation capacity of the firm. For STI, the effects stem mainly from internal STI. External knowledge sourcing can partly substitute for internal STI, but the strongest improvements to innovation capacity emerge when firms engage actively in internal STI activities. These results challenge the traditional view of how firms develop their absorptive capacity: firms are not able to extract higher value or benefit more from their internal knowledge search by actively seeking collaboration with external knowledge sources.

These results have important implications for research on firms' use of different knowledge dimensions in innovation processes. We explore the role of internal experience-based knowledge for firms' innovation performance and highlight the importance of incorporating this dimension of knowledge, together with the traditional modes of innovation, to better understand firm level

innovation performance. However, our empirical results fail to support the idea that firms' internal investment in this type of knowledge increases their absorptive capacity, as firms that pursue this route in their innovation quest fail to secure greater innovation benefits from the knowledge they can extract from external partners. Our findings have implications for firms' innovative practices, as firms needs to pay attention to that their cost related to use of internal experience-based knowledge does not exceeds their benefits for their innovation performance.

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Appendix

Table A1
Indicators for STI and DUI innovation collaboration mode, external and internal

STI *internal*	
Expenditure on R&D within the firm	Firm`s expenditures on R&D, continuous variable
STI *external*	
Collaboration with STI-partners	1 if the firm has collaborated or interacted with private research institutes, universities or consultants to promote innovation during the period 2008-2010, 0 if not
DUI *internal*	*Index [0,1] triangulated of:*
Brainstorming	1 if the firm has used brainstorming to promote new ideas or creativity in the period 2008-2010, 0 if not
Interdisciplinary workgroups	1 if the firm has used interdisciplinary workgroups to promote new ideas or creativity in the period 2008-2010, 0 if not
Job rotation	1 if the firm has used in job rotation of employees to other departments or plants to promote new ideas or creativity in the period 2008-2010, 0 if not
Financial incentives	1 if the firm has used financial incentives for employees to develop new ideas in the period 2008-2010, 0 if not
Non-financial incentives	1 if the firm has used non-financial incentives for employees to develop new ideas in the period 2008-2010, 0 if not
Creativity training	1 if the firm has educated or trained employees specifically to develop creativity or new ideas in the period 2008 - 2010, 0 if not
DUI *external*	
Collaboration with DUI-partners	1 if the firm has collaborated or interacted with suppliers or customers to promote innovation during the period 2008-2010, 0 if not

Table A1
Correlation matrix

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)	Product innovation	1.000												
(2)	Product innovation, t-1	0.424	1.000											
(3)	Process innovation	0.472	0.256	1.000										
(4)	Process innovation, t-1	0.272	0.550	0.419	1.000									
(5)	Radical product inno.	0.873	0.401	0.419	0.246	1.000								
(6)	Radical product inno, t-1	0.354	0.728	0.227	0.439	0.357	1.000							
(7)	STI *external*	0.342	0.272	0.303	0.233	0.342	0.234	1.000						
(8)	STI *internal*	0.570	0.499	0.399	0.364	0.547	0.439	0.497	1.000					
(9)	DUI *external*	0.402	0.309	0.351	0.241	0.398	0.283	0.742	0.497	1.000				
(10)	DUI *internal*	0.324	0.242	0.282	0.210	0.296	0.217	0.234	0.361	0.244	1.000			
(11)	Firms size	0.072	0.215	0.090	0.218	0.050	0.178	0.132	0.201	0.141	0.108	1.000		
(12)	Firms age	0.047	0.120	0.025	0.094	0.030	0.095	0.013	0.045	0.016	0.007	0.142	1.000	
(13)	Share of edu. level	0.231	0.195	0.137	0.120	0.229	0.164	0.963	0.336	0.183	0.234	-0.001	-0.048	1.000

Paper II

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Does combining different types of collaboration always benefit firms? Collaboration, complementarity and product innovation in Norway

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ABSTRACT

Product innovation is widely thought to benefit from collaboration with both scientific and supply-chain partners. The combination of exploration and exploitation capacity, and of scientific and experience-based knowledge, are expected to yield multiplicative effects. However, the assumption that scientific and supply-chain collaboration are complementary and reinforce firm-level innovation has not been examined empirically. This paper tests this assumption on an unbalanced panel sample of 8337 firm observations in Norway, covering the period 2006–2010. The results of the econometric analysis go against the orthodoxy. They show that Norwegian firms do not benefit from doing "more of all" on their road to innovation. While individually both scientific and supply-chain collaboration improve the chances of firm-level innovation, there is a significant negative interaction between them. This implies that scientific and supply-chain collaboration, in contrast to what has been often highlighted, are substitutes rather than complements. The results are robust to the introduction of different controls and hold for all tested innovation outcomes: product innovation, new-to-market product innovation, and share of turnover from new products.

1. Introduction

Networking and collaborating with external agents are widely seen as essential factors for innovation (e.g. Powell et al., 1996; Chesbrough, 2003). Knowledge and information are distributed across a wide range of different actors in the economy and new knowledge is constantly being generated. Firms thus cannot only rely on in-house knowledge and internal processes to develop innovation. Collaboration with various types of partners is a crucial path to new innovation. Different types of collaboration – with suppliers (e.g. Liker et al., 1996; Bidault et al., 1998), customers or users (e.g. von Hippel, 1986; Bogers et al., 2010), competitors (e.g. Hamel, 1991; Gnyawali and Park, 2011), universities (e.g. Perkmann and Walsh, 2007; Ponds et al., 2010), consultants and other research organisations (e.g. Tether and Tajar, 2008) – facilitate access to new knowledge and accelerate the propensity to innovate. But diverse types of collaboration play different roles in a firm's knowledge network, as each type of partner has its own perspective and access to different sources of knowledge and information. Using a variety of different partners is therefore considered desirable, as it provides a variety of knowledge that contributes to enhancing a firm's innovation potential (Faems et al., 2005; Laursen and Salter, 2006).

Innovation research focusing on collaboration has frequently argued for combining interactions and collaborations with suppliers and customers, on the one hand, and with universities and other research organisations, on the other, as the right mix to foster firm-level innovation. Supply-chain and scientific partners are considered to bring different types of knowledge to the firm. These different knowledge strands are mostly regarded as complementary (e.g. Tether, 2002; Faems et al., 2005). However, most studies examine the two types of collaboration separately and can only uncover whether there is an additive effect of collaboration (e.g. Faems et al., 2005; Fitjar and Rodríguez-Pose, 2013). Whether scientific and supply-chain collaboration are actually complementary – in the sense that using both types of partners simultaneously has a multiplicative effect on firm-level innovation – has seldom been tested.

The idea of complementarity of collaboration types brings the literature on collaboration scope into contact with that on innovation modes. Jensen et al. (2007:680), for example, refer to a "tension between two ideal type modes of learning and innovation". These are a) the Science, Technology and Innovation (STI) mode and b) the Doing, Using and Interacting (DUI) mode. A key insight in their work is that the combination of both modes yields the best results for innovation. Firms that manage to pursue innovation based on science and

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complement such efforts with learning by doing and interacting with other economic actors innovate more. Other studies of innovation modes report similar results (Chen et al., 2011; Aslesen et al., 2012; Parrilli and Heras, 2016). Jensen et al. (2007) address the complementarity between modes of innovation by dividing firms into four mutually exclusive clusters. They find coefficient estimates for the DUI/STI cluster which are roughly similar to the sum of the coefficients for the DUI and STI clusters. Parrilli and Heras (2016) use a comparable approach, focusing on collaboration partners, and reach the same results. These approaches, while pushing the boundaries of our knowledge, also focus on the additive rather than the potential multiplicative effects of scientific and industrial collaboration (see e.g. Laursen and Foss, 2003; Love et al., 2014). If the two are complementary, we should expect their product to be greater than the sum of its parts.

In this paper, we move the debate forward by formally testing for complementarities between the two types of collaboration. In line with previous literature on innovation modes (e.g. Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016) and on collaboration scope (e.g. Faems et al., 2005; Vega-Jurado et al., 2009), we focus on collaboration with scientific and supply-chain partners. The analysis is conducted on an unbalanced panel sample of 8337 firm observations in Norway, covering the period 2006–2010. The panel is constructed using data from three waves of the Community Innovation Survey, supplemented with linked employer-employee data on the composition of each firm's workforce. On this dataset, we first examine the effects of collaborating with scientific and supply-chain partners on the likelihood of firms introducing product innovations and their share of turnover from these innovations. Second, we test whether scientific and supply-chain collaboration are complementary. We specifically assess whether a firm's likelihood of introducing innovations increases to a greater extent from collaborating with scientific partners when they also collaborate with supply-chain partners, and vice versa.

This paper contributes to the literature in several ways. First, by formally examining complementarities between scientific and supply-chain collaboration with the inclusion of an interaction term, it tests a core proposition in the literature stressing that combining different types of collaboration is beneficial to innovation. Second, no previous research on innovation modes has used comparable fine-grained panel data to analyse the effects of scientific and supply-chain collaboration on innovation performance. Third, the use of reliable data from the Norwegian part of the Community Innovation Survey (CIS) – where participation is mandatory – practically eliminates the risk of non-response bias and provides data on the full population of larger firms. The Norwegian CIS furthermore allows for a meaningful examination of the effects of collaboration on innovation, as all firms (not just innovative ones) are (since 2006) required to report collaboration.

The paper is organized into four sections. In the next section, we discuss theory and earlier research on the role of different sources of knowledge and their complementarity for firm innovation. We present the case and describe the data in section 3, while section 4 presents the results from the empirical analysis of the relationship between collaboration and innovation outcomes. Conclusions and suggestions for future research are presented in the final section.

2. The role of different types of collaboration partners for innovation

2.1. Collaboration with scientific and supply-chain partners

The knowledge, skills and resources necessary for innovation are widely distributed, and the ability of firms to identify, access, absorb and use these is crucial for innovation (Cohen and Levinthal, 1990). Innovation depends critically on how firms absorb external knowledge and combine it with their own internal knowledge to develop new market offerings (Chesbrough, 2003). Firms can use various channels to access external knowledge. These include recruitment, acquisition, and formal as well as informal exchanges with other actors. They can also source knowledge from individuals (e.g. crowdsourcing) as well as from organizations. However, collaboration with other organizations is considered to be one of the most important mechanisms for innovation, as it allows for mutually beneficial exchanges in which both sides make long-term investments (Hagedoorn, 2002; Nooteboom, 2004). We define collaboration as active participation by both partners in a joint R&D or innovation project (Cassiman and Veugelers, 2002).

Firms have the option of using various types of organizations as partners in such collaboration. These partners may serve different functions. Tether (2002) distinguishes between collaborations within and beyond the supply-chain. The benefits from each form of collaboration differs. Collaboration with suppliers and customers allows firms to extend pure market transactions into long-term strategic relationships characterized by mutual trust. This gives them more information about customers' needs as well as access to new and potentially tailor-made solutions from suppliers. Collaborations beyond the supply-chain include interactions with competitors and with universities and other research or knowledge-broking organizations. These do not emerge from a market relationship, but are set up separately for a variety of reasons.

Collaborations with universities and research organizations are typically more explorative, aiming at the creation of new knowledge, with sometimes uncertain commercial applications. Collaboration with suppliers and customers tend, by contrast, to optimize core competencies, helping firms to exploit technological and market opportunities (Faems et al., 2005). Knowledge from research organizations is also less targeted to firms' needs and places higher demands on their absorptive capacity (Vega-Jurado et al., 2009). Turning to scientific and supply-chain partners in innovation collaboration can also be linked to the broader literature on modes of innovation (Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016).

This literature emerged from Jensen et al.'s (2007) distinction between two ideal types of firm learning mechanisms: 'Science, Technology and Innovation' (STI) and 'Doing, Using and Interacting' (DUI). STI refers to innovation "based on the production and use of codified scientific and technical knowledge" (Jensen et al., 2007:680). The DUI mode refers to innovation based on learning from experience in making or using products, or from interacting with those who do (Jensen et al., 2007). STI and DUI innovation modes encompass both internal activities as well as external knowledge sourcing. In the latter dimension, they relate to different types of collaboration partners.[1] While universities and research organizations are important in the STI mode, the DUI mode relies more on collaboration with suppliers and customers. On this basis, these two types of collaboration have sometimes been used as proxies for innovation modes (e.g. Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016).

The literature highlighting the importance of different modes of collaboration leads us to the formulation of our first two hypotheses:

H1. Firms that collaborate with scientific partners are more likely to innovate than firms that do not collaborate with scientific partners.

H2. Firms that collaborate with supply-chain partners are more likely to innovate than firms that do not collaborate with supply-chain partners.

[1] While Jensen et al.'s (2007) definition of STI and DUI includes both internal and external activities related to each dimension, the internal and external dimensions are not necessarily aligned. Firms may instead focus on working with external collaboration partners that complement their internal strengths. For instance, firms with established internal DUI processes may collaborate with scientific partners to source in new types of knowledge (see e.g. Hoang and Rothaermel, 2010 for a related argument). Conversely, external collaboration can depend on internal absorptive capacity in the same innovation mode. For instance, the returns to scientific collaboration may depend on internal R&D activities (Cohen and Levinthal, 1990). We leave these discussions for future research.

These hypotheses are not new and have been tested in previous literature (e.g. Faems et al., 2005; Vega-Jurado et al., 2009; Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016). Most studies tend to confirm both hypotheses. However, supply-chain partners are often found to be more important for incremental product innovation, while scientific partners drive more radical and new-to-market product innovation (Faems et al., 2005; Parrilli and Heras, 2016). There are also differences across sectors in the importance of each type of collaboration (Vega-Jurado et al., 2009; Fitjar and Rodríguez-Pose, 2015).

2.2. Complementarity of collaboration types

How firms best organize their use of different sources of knowledge is a strategic challenge. Major theoretical approaches provide conflicting guidance on this issue. Transaction cost theory has often been used to inform this discussion (e.g. Veugelers and Cassiman, 1999; Love et al., 2014). In terms of the choice between external sourcing and internal knowledge, transaction cost theory considers them substitutes: a 'make or buy' decision (Coase, 1937; Arrow, 1962; Veugelers and Cassiman, 1999). However, other theories stress the complementarity between them, as firms need internal capabilities to 'absorb' external knowledge (Cohen and Levinthal, 1990). A similar approach can be used to develop theories about interactions between the use of scientific and supply-chain partners. Different types of partners may be substitutes, allowing firms to switch between them. However, they may also be complements, as scientific and industrial partners provide access to different types of knowledge. In this latter case, collaborating with both types of partners simultaneously becomes crucially important for innovation. Theory, however, does not necessarily offer unambiguous hypotheses, providing a clear role for empirical research.

Different types of collaboration can have additive effects. Firms with larger search scope and search depth are more likely to innovate, as they can draw on a wider range of ideas (Laursen and Salter, 2006). However, the literature on innovation modes goes beyond this to claim that STI and DUI are also complementary, i.e. that there are multiplicative effects of using both modes. Jensen et al. (2007: 690) argue that "what really improves innovation performance is using mixed strategies that combine strong versions of the two modes". Similarly, literature in organizational learning sees exploration and exploitation as complementary processes (Tushman and O'Reilly, 1996; Hoang and Rothaermel, 2010). In order to benefit fully from their exploration activities, firms also need exploitation capacity. Conversely, exploitation cannot survive long without exploration to generate new ideas.

Equally, scientific collaboration can give access to potentially valuable new knowledge from research. However, firms may not be able to exploit this knowledge without working closely with suppliers in developing the production process, or with customers to identify how they would use new technology. On the flipside, customers or suppliers may come up with new ideas that can only be developed in collaboration with research communities. Such complementarities can manifest themselves in different ways. First, they may increase the likelihood of introducing new products by enabling new combinations of different types of knowledge. Second, they can enhance the market success of new products, by improving the exploitation of new ideas generated from exploration. They could also improve the quality or complexity of new products, or allow firms to introduce a larger variety of innovations.

The research that has questioned the complementarity of innovation modes is, in contrast, much more limited (e.g. González-Pernía et al., 2012; Parrilli and Elola, 2012; Malaver Rodríguez and Vargas Pérez, 2013). Yet, there may also be tensions between different types of collaboration. Laursen and Salter (2006) raise the notion that firms may 'over-search' for knowledge, as excessive search scope may produce too many ideas for a firm to absorb and devote proper attention. This can apply in particular to knowledge derived from scientific and supply-chain collaboration, as these types of knowledge are, by nature, very different and hence more demanding to process. Experience-based knowledge from suppliers or customers is often more tacit, and core aspects of the idea may be lost in the translation to a more research-based innovation process. Meanwhile, suppliers and customers often lack the absorptive capacity to understand and fully exploit new ideas emerging from scientific collaboration. Furthermore, sectors differ in their reliance on scientific and experience-based inputs (Pavitt, 1984; Asheim and Gertler, 2005), suggesting that scientific knowledge may be less important in sectors where experience-based learning is at the heart of innovation, and vice versa.

The question of complementarities has been important in the broader innovation literature (e.g. Young, 1993; Golovko and Valentini, 2011; Ballot et al., 2015) and in relation to innovation collaboration specifically. As mentioned above, there has, in particular, been considerable debate over whether the use of external collaboration complements or substitutes internal R&D (Veugelers and Cassiman, 1999; Cassiman and Veugelers, 2006; Schmiedeberg, 2008; Hagedoorn and Wang, 2012; Love et al., 2014). However, this literature has so far not focused on potential complementarities between collaboration with different types of partners. In this paper, we delve into this gap in the literature by analysing to what extent collaboration with scientific and supply-chain partners is associated with higher probabilities of innovation and if so, whether the two types of collaboration are complementary. On the basis of the above discussion, the literature on innovation modes generally expects scientific and supply-chain collaboration to be complementary, but arguments of over-searching and sector specificity suggest they may also be substitutes.

This leads to our third, two-pronged, hypothesis:

H3a. The effect of collaborating with scientific partners on the likelihood of innovation is larger for firms that also collaborate with supply-chain partners, and vice versa.

H3b. The effect of collaborating with scientific partners on the likelihood of innovation is smaller for firms that also collaborate with supply-chain partners, and vice versa.

These two variants of our third hypothesis have not been tested by previous literature. As a footnote in Jensen et al. (2007:690) acknowledges, their findings are not sufficient to prove complementarities between the innovation modes. Nonetheless, many have followed up on the notion that the STI and DUI modes are complementary (e.g. Chen and Guo, 2010; Chen et al., 2011; Aslesen et al., 2012; Isaksen and Karlsen, 2012; Isaksen and Nilsson, 2013; Nunes and Lopes, 2015; Apanasovich et al., 2016). This includes research focusing specifically on collaboration with scientific and supply-chain partners (Parrilli and Heras, 2016). Despite the richness of this literature, no previous studies have taken up the baton of trying to demonstrate that scientific and supply-chain collaboration (or STI and DUI more broadly) are actually complementary, in the sense that their effects are multiplicative. Previous literature has mostly followed Jensen et al.'s (2007) original approach in examining the combination of the two as a separate category and comparing it with firms which exclusively rely on scientific or on supply-chain collaboration. They subsequently compare the effect of the combined mode with the effects of the two individual modes, finding a higher likelihood of innovation in the combined mode. This approach has, however, the drawback that it is not able to identify whether these outcomes are simply the result of independent additive effects of scientific and supply-chain collaboration, or whether there is an interaction between them – and if so, whether they are complements or substitutes. As there is no prior test of such an interaction, we cannot say a priori whether the effects of scientific and supply-chain collaboration are additive or multiplicative.

3. Methods

3.1. Sample and data

We test the hypotheses presented above using data from the Norwegian part of the Community Innovation Survey (CIS). Three consecutive waves[2] of the CIS are used – covering the period 2006–2010 – in order to create an unbalanced panel of firms. This approach has been used in previous analyses of CIS data for Norway (e.g. Castellacci, 2011; Clausen and Pohjola, 2013; Srholec, 2014) and other countries (e.g. Frenz and Ietto-Gillies, 2009; Parrilli and Heras, 2016; Criscuolo et al., 2017; Crescenzi and Gagliardi, 2018; Gagliardi and Iammarino, 2018).

The CIS data provides information on the innovation activities of firms and comprises firm-level surveys conducted every two years in the survey period. Over this period, the Norwegian CIS has used similar survey questionnaires, including consistent indicators for product innovation and for types of collaboration partners in innovation processes. The same indicators for firm's innovation collaboration and innovation output are therefore available throughout the survey period. The Norwegian CIS differs from the harmonized survey in that – from 2006 onwards – all respondents report innovation collaboration activities independent of their innovation status. This unique feature of the Norwegian data makes it possible to analyse the relationship between collaboration and actual innovation outcomes. We furthermore merge the CIS data with linked employer-employee data (LEED) from Statistics Norway to add more information on each firm.

Participation in the CIS is mandatory for sampled firms in Norway and non-respondents are fined. This results in a response rate ranging from 94 percent of sampled firms in 2006 to 97 percent in 2008 and 2010, almost ruling out the risk of non-response bias. The sample includes the full population of Norwegian firms with 50 or more employees, as well as all firms with 10–49 employees that have reported significant R&D activities in the previous waves of the survey. Other firms with 5–49 employees are sampled through a procedure which stratifies firms by size and industry, with higher likelihood of inclusion for larger firms. Overall, the sample comprises 6412 firm observations from the 2006 survey, 5980 from 2008, and 6532 from 2010. We combine these into an unbalanced panel with 18,924 observations in total. The sample is equivalent to a third of firms and two thirds of employees in the sampling population of Norwegian firms with more than five employees. All the empirical models are run with lagged dependent variables in order to control for unobserved heterogeneity. This restricts the sample to firms that participate in two consecutive surveys. Hence, the final sample consists of 8337 observations. There are slight variations in the sampling procedure from year to year, due to both entry and exit of firms and varying survey samples (see Wilhelmsen and Foyn, 2012 and earlier editions for details). This implies that sample averages and other descriptive statistics cannot be compared directly across years.

3.2. Dependent variables

We use three measures of innovation from the CIS as dependent variables: product innovation, new-to-market product innovation, and share of turnover from new products. This allows us to test for complementarities in the likelihood of introducing new products, in the novelty of these products, and in their market success. A product innovation is registered if the firm has introduced new or significantly improved goods or services to the market in the preceding three years. On average, 24 percent of all firms, and 32 percent of those present in two consecutive periods, report product innovation. New-to-market product innovation only includes product innovations that were new to the firm's market, excluding innovations that were new to the firm but already existed in the market. An average of 15 percent of firms observed in any given survey, and 20 percent of those present in two consecutive periods, report this type of innovation. New-to-firm and new-to-market product innovation are generally associated with similar procedures. However, new-to-market innovation is more explorative and therefore expected to be more closely associated with scientific collaboration than new-to-firm innovation (Parrilli and Heras, 2016). These measures are similar to those used in previous studies (Jensen et al., 2007; Parrilli and Heras, 2016).

Additionally, we go beyond these binary measures and also examine the share of turnover from new products as a dependent variable.[3] This allows for more variance across observed firms and enables us to distinguish between innovative firms with a higher and lower share of innovative products in their portfolio. This measure has been utilised by other studies using CIS data (e.g. Cassiman and Veugelers, 2006; Laursen and Salter, 2006).

3.3. Independent variables

Following previous research (e.g. Faems et al., 2005; Vega-Jurado et al., 2009; Fitjar and Rodríguez-Pose, 2013; Parrilli and Heras, 2016), we distinguish between collaboration with scientific and supply-chain partners. Scientific collaboration (STI) includes collaboration with universities, research institutes and consultancy firms. Supply-chain collaboration (DUI) encompasses linkages with suppliers and customers. The responses to the question about firms' collaboration partners are binary: 1 if the partner is used and 0 if not. Unfortunately, the data do not include information on the intensity of collaboration, or on the number of different partners of each type.

Throughout the period, supply-chain collaboration is used by 12.5 percent of firms, while scientific collaboration is used by 12.0 percent. Among firms present in two consecutive surveys, over 18 percent of firms report both types of collaboration. The correlation matrix (Appendix Table A.1) shows that there is a significant positive correlation between the two types of collaboration (R = 0.70).

Positive correlations between the activities, here innovation collaboration, is neither necessary nor sufficient for determining complementarity between them (Arora, 1996). However, pairwise correlations indicate that firms that engage in one type of collaboration are more likely also to engage in the other type of collaboration. The other correlation estimates tend to be low, suggesting that severe multicollinearity is not a problem.

3.4. Control variables

We control for several characteristics that could influence collaboration as well as innovation performance: *Collaboration with competitors, Firm size, Firm age, Export focus, R&D expenditure* and *Share of educated employees.*[4]

Collaboration with competitors is a dummy variable taking the value 1 if the firm collaborated with any of its competitors during the preceding

[2] We examine innovation outcomes and collaboration using CIS2006 (covering the 2004-2006 period), CIS2008 (covering the 2006-2008 period), and CIS2010 (covering the 2008-2010 period). In addition, we use lagged dependent variables that also include data from CIS2004 (covering the 2004-2006 period).

[3] The CIS asks firms to distribute their turnover in the survey year over new or significantly improved products introduced in the preceding three years, and unchanged or not significantly improved products. These add to 100 percent. The 2010 survey also distinguishes between turnover from new-to-firm and new-to-market products, which we add to obtain an equivalent measure to the 2004, 2006 and 2008 surveys of the share of turnover from all new products.

[4] The variables *Firm size*, *Firm age*, *R&D expenditure* and *Share of educated employees* are all log-transformed because of skewness in the distributions.

three years. This is drawn from the questionnaire item on collaboration partners used above. Collaboration with competitors has been treated separately by previous literature and has been found to have a negative effect on innovation (Fitjar and Rodríguez-Pose, 2013).

Firm size is the number of full-time employees in the firm. This variable is based on linked employer-employee data from tax registers, from which we count the number of people listed as employed in the firm in the year of the survey. Larger firms have the resources to cope with the risks associated with innovation processes and are more likely to engage in innovation activities (Schumpeter, 1939). However, smaller firms benefit from less rigidity in their innovation process (Cohen, 1995).

Firm age is proxied by the number of years for which we observe the firm in the register data between 2000 and the year of the survey. It is thus censored at 6, 8 and 10 years for the 2006, 2008 and 2010 survey, respectively. However, it is used to distinguish young firms from more established ones. Older firms may benefit from building on previous routines and capabilities (Levitt and March, 1988), but may also have drawbacks in the form of a rigid organizational structure (Coad et al., 2016).

Export focus is a dummy variable taking value 1 if the firm has the European or international arena as its main market of reference (using local and national market as the baseline). This variable is based on a question in the CIS data asking firms to indicate which of four markets they perceive to be the most important for their products. Firms operating in the international market tend to be more innovative (Salomon and Jin, 2008).

R&D expenditure is the total amount of internal expenditure on research and development by the firm in the year preceding the survey. Expenditure on internal R&D is assumed to increase internal knowledge and the ability to utilize this knowledge (Cohen and Levinthal, 1990). We also control for the *share of educated employees* in the year the CIS survey was conducted. This is defined as the percentage of the firm's workers who have completed a higher education degree. This variable is drawn from linked employer-employee data, using the Norwegian education database for details on each employee's educational background.

Industry is also controlled for by means of a set of dummy variables for the two-digit NACE industry of the firm. In total 58 different two-digit industries are present in the data. We also include dummies for each *year* of observation to account for any time trends. Finally, dummy variables for economic *regions* are used in the analysis.[5]

We also include lagged dependent variables to control for consistent innovation activities and absorb some of the bias related to heterogeneity among firms. In order to keep as many observations as possible, we also use data from CIS2004 to construct this variable.[6] Due to the inclusion of lagged dependent variable, the analysis focuses on firms that participate in at least two consecutive waves of the survey (e.g. CIS2006 and CIS2008).

Table 1 shows descriptive statistics for the variables included in the analysis. For comparison, the first column shows the mean values for the full sample, while the second column shows the mean values for the firms participating in two consecutive periods (which are included in the empirical analyses). Overall, firms participating in two consecutive periods have higher rates of innovation and collaboration, making this a more relevant sample for investigating whether different collaboration types have complementary or substitutive effects on innovation. They are also larger, and spend more on R&D. This is expected, as the CIS includes the full population of larger and more R&D intensive firms, and only a sample of smaller and less R&D intensive ones (see Section 3.1).

3.5. Estimation strategy and identification approach

In order to test H1-H3, we first fit our basic regression model, which takes the following form:

$$logit\ (P(Innovation_{i,t})) = \beta_0 + \beta_1 \boldsymbol{C}_{i,t} + \beta_2 \boldsymbol{Z}_{i,t} + \beta_3 Innovation_{i,t-1} + \varepsilon_{i,t} + \alpha_i \quad (1)$$

$P(Innovation_{i,t})$ is the probability of product innovation or new-to-market product innovation for firm i at time t. Firms' collaboration is captured by the vector $\boldsymbol{C}_{i,t} = (STI_{i,t}, DUI_{i,t})$. STI refers to scientific collaboration, while DUI refers to supply-chain collaboration, both included as dummies that take the value 1 if firm i is using one of the collaboration types at time t and 0 otherwise. $\boldsymbol{Z}_{i,t}$ are the controls. The specification also controls for sectoral, time and regional fixed effects. $Innovation_{i,t-1}$ is included to control for previous innovation by the firm, which can capture some unobserved heterogeneity in firms' ability to innovate.

For the models using share of turnover from new products as the dependent variable, $Innovation^*_{i,t}$, we fit an equivalent Tobit model:

$$Innovation^*_{i,t} = \beta_0 + \beta_1 \boldsymbol{C}_{i,t} + \beta_2 \boldsymbol{Z}_{i,t} + \beta_3 Innovation^*_{i,t-1} + \varepsilon_{it} + \alpha_i \quad (2)$$

The use of a logit model (as in model 1) is consistent with previous studies of innovation modes (Jensen et al., 2007; Fitjar and Rodríguez-Pose, 2013; Apanasovich et al., 2016; Parrilli and Heras, 2016), while the Tobit model has featured in e.g. Faems et al. (2005) and Laursen and Salter (2006).

Due to unobservable time-invariant influences at e.g. firm, sectoral or regional level, endogeneity remains a concern in this type of analysis. Ideally, a panel model could account for this, and as a robustness check of our models, we also estimate Eq. (1) using a panel fixed-effects model (see Table 6). This approach allows us to control for firm-level heterogeneity which could cause bias. However, the lack of variation in core variables, such as innovation outcome and collaboration, imply that these analyses are on a significantly smaller sample of firms. While the use of panel data mitigates to some extent the issue of firm heterogeneity, the issue of endogeneity and therefore reverse causality may still occur. Another approach would be to use instrumental variable regression, but these have generally proved unsuccessful in research using CIS data (Mohnen and Röller, 2005; Cassiman and Veugelers, 2006), due to the lack of strong exogenous instruments.

Instead, in all our basic models, we control for time-invariant characteristics by including a lagged dependent variable in the analysis. This will capture some of the heterogeneity across firms by controlling for whether or not the firm innovated in the preceding period.[7] In addition, a large battery of control variables are considered in the model, comprising sectoral and regional fixed effects, as well as firm-level control variables. We nevertheless acknowledge the potential for endogeneity, even with the robustness checks done, and recognize that our results must be interpreted in this light.

[5] These are defined at the level of economic regions according to Statistics Norway, corresponding to local administrative units at level 2 (LAU 2). Regions that are functionally integrated into the same labour market are merged following Gundersen and Juvkam (2013). This leaves a total of 78 different economic regions which are roughly equivalent to labour market regions. These economic regions have been commonly used in previous studies on the impact of location on firm innovation in Norway (e.g. Herstad and Ebersberger, 2015; Aarstad et al., 2016; Fitjar and Timmermans, 2017).

[6] Questions pertaining to collaboration were only asked to all firms from CIS2006 onwards. In CIS2004, only innovators or firms with ongoing or abandoned innovation activities were asked these questions – as is still the case in most other countries. Hence, we consider collaboration measures only from 2006 onwards. However, as information on innovation outcomes for all firms from CIS2004 is available, this information is included in the empirical analysis.

[7] Indeed, the variation in e.g. product innovation is higher between firms (0.31) than across time (0.24), suggesting that innovation outcomes are relatively consistent across time.

Table 1
Descriptive statistics.

Variables	Description	Total		Two consecutive periods	
		Obs.	Mean (Sd.)	Obs.	Mean (Sd.)
Product innovation	Dummy variable taking the value 1 if the firm introduced any new or significantly improved products in the preceding three years.	18,924	0.240 (0.427)	8,337	0.318 (0.461)
New-to-market product innovation	Dummy variable taking the value 1 if the firm developed any product innovations that were new to the firm's market.	18,924	0.150 (0.357)	8,337	0.208 (0.401)
Product innovation t_1	Dummy variable taking the value 1 if the firm introduced any new or significantly improved products in the preceding three years. Lagged one survey period.	8,337	0.349 (0.476)	8,337	0.349 (0.469)
New-to-market product innov. t_1	Dummy variable taking the value 1 if the firm developed any product innovations that were new to the firm's market. Lagged one survey period.	8,337	0.198 (0.398)	8,337	0.198 (0.398)
Scientific collaboration, STI	Dummy variable taking the value 1 if the firm collaborated with universities, research institutes or consultancy firms in the preceding three years.	18,924	0.120 (0.324)	8,337	0.187 (0.390)
Supply-chain collaboration, DUI	Dummy variables taking the value 1 if the firm collaborated with suppliers or customers in the preceding three years.	18,924	0.125 (0.330)	8,337	0.188 (0.391)
Collaboration with competitors	Dummy variables taking the value 1 if the firm collaborated with competitors in the preceding three years.	18,924	0.038 (0.192)	8,337	0.051 (0.231)
R&D expenditure (log)	Total amount of internal expenditure on research and development by the firm.	18,924	1.885 (3.448)	8,337	3.001 (4.032)
Firm size (log)	Number of full-time employees in the firm in the year of the survey.	18,924	3.377 (1.273)	8,337	4.120 (1.261)
Firm age (log)	Number of years the firm is present in register data since 2000.	18,924	0.210 (0.982)	8,337	0.493 (0.780)
Share of educated employees (log)	Share of the firm's workers who have completed a higher education (university) degree.	18,924	0.211 (0.196)	8,337	0.220 (0.181)
Innovation active	Dummy variable taking the value 1 if the firm reported positive innovation expenditure, collaboration in innovation processes, or any kind of innovation outcome.	18,924	0.481 (0.500)	8,337	0.600 (0.481)
Export focus	Dummy variable taking the value 1 if the firm's most important market is non-domestic.	18,924	0.140 (0.347)	8,337	0.198 (0.398)
Innoshare (log)	Share of turnover in the survey year from new or significantly improved products developed in the preceding three years.	18,679	0.694 (1.363)	8,337	0.902 (1.471)
Innoshare(log) t_1	Share of turnover in the survey year from new or significantly improved products developed in the preceding three years. Lagged one survey period	8,337	0.961 (1.491)	8,337	0.961 (1.481)

4. Empirical results

Table 2 presents the results of the estimation of Eq. (1). Columns (1) and (2) show the estimates for product innovation, and (3) and (4) show the estimates for new-to-market product innovation.

In the basic models, (1) and (3), firm innovation is a function of innovation in the previous period and innovation collaboration. Firms that reported innovation in the preceding period are significantly more likely to innovate also in the following period. Furthermore, the estimates confirm that firms collaborating with scientific as well as supply-

Table 2
Estimated result. Reported coefficient from the binary logit model, product and new-to-market product innovation (1) – (4).

	(1) Product innovation	(2) Product innovation	(3) New-to-market prod. innov.	(4) New-to-market prod. innov.
Product innovation t_1	1.747***	1.281***		
	(0.067)	(0.072)		
New-to-market prod. innov. t_1			1.536***	1.066***
			(0.076)	(0.081)
Scientific collaborations, STI	0.973***	0.384***	0.908***	0.358***
	(0.108)	(0.122)	(0.113)	(0.118)
Supply-chain collaboration, DUI	1.141***	0.891***	0.973***	0.672***
	(0.105)	(0.120)	(0.110)	(0.120)
Collaboration with competitors		−0.054		−0.043
		(0.158)		(0.138)
R&D expenditure (log)		0.232***		0.240***
		(0.010)		(0.012)
Firm size (log)		−0.088***		−0.101***
		(0.030)		(0.031)
Share of educated employees (log)		−0.074		−0.015
		(0.294)		(0.326)
Export focus		0.034		−0.052
		(0.090)		(0.089)
Firm age (log)		0.013		0.075
		(0.052)		(0.057)
Constant	−2.740***	−3.172***	−2.895***	−3.380***
	(0.532)	(0.567)	(0.561)	(0.607)
Observations	8,198	8,195	8,095	8,092
Log Likelihood	−3529.6	−3209.9	−3096.3	−2816.5
Firms	4,612	4,612	4,534	4,534
Pseudo R^2	0.315	0.377	0.263	0.329

Note: Robust standard errors clustered over firms in parentheses. All models includes year, industry and regional fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3
Reported estimated coefficient. Tobit model. Dependent variables: Share of turnover in the survey year from new or significantly improved products developed in the preceding three years.

	(1)	(2)
Share of turnover t_1	0.826***	0.532***
	(0.026)	(0.027)
Scientific collaboration, STI	1.180***	0.351***
	(0.127)	(0.124)
Supply-chain collaboration, DUI	1.383***	0.870***
	(0.124)	(0.123)
Collaboration with competitors		0.055
		(0.141)
R&D expenditure (log)		0.339***
		(0.013)
Firm size (log)		−0.181***
		(0.034)
Share of educated employees (log)		−0.095
		(0.342)
Export focus		0.017
		(0.099)
Firm age (log)		0.006
		(0.007)
Sigma	2.760***	0.305***
	(0.038)	(0.010)
Constant	−3.454***	−1.201***
	(0.625)	(0.169)
Observations	8,262	8,259
Log Likelihood	−8324.4	−7920.1
Pseudo R^2	0.167	0.207

Note: Robust standard errors clustered over firms in parentheses. Both models includes year, industry and regional fixed effects. Share of turnover related to product and new-to-market product innovation. 5720 observations are left-censored. * p < 0.1, ** p < 0.05, *** p < 0.01.

chain partners are also more likely to innovate. In column (2) and (4), we include additional firm-level control variables. The patterns remain the same. Hence, we find support for H1 and H2 for all innovation outcomes.

The results for the controls are in line with expectations. R&D expenditure has a significant effect on innovation, as does firm size. However, education, firm age and export focus are not significantly correlated with any of the innovation outcomes.

Table 3 shows the results from Eq. (2), where the dependent variable is the share of turnover from new or significantly improved products in the preceding three years. The overall results are similar to those in the logit regression. Scientific and supply-chain collaboration both have a significant and positive effect on innovation. These results hold when all the controls and the lagged dependent variable are included. Overall, the analysis confirms the results from the logit regression also for a more fine-grained measure of innovation.

4.1. Measuring and estimating complementarities

Next, we turn to our main contribution and examine the relationship of interest for H3, i.e. whether scientific and supply-chain collaboration are complementary or substitutes. The concept of complementarity implies that the implementation of one activity pays off more if the complementary activity is present too. In a standard framework, complementarity between a set of variables means that the marginal returns to one variable increases with the level of another variable. For instance, if scientific and supply-chain collaboration are complementary, the marginal effect of scientific collaboration on innovation is higher when the firm also conducts supply-chain collaboration and vice versa. The study of complementarities between activities can be traced back to the theory of supermodularity (e.g. Milgrom and Roberts, 1990, 1995; Topkis, 1998).

To analyse complementarities, we first estimate the function given by an expanded version of Eq. (1). While Eq. (1) included two separate variables for innovation collaboration, we expand it to also take into consideration the interaction terms between the innovation collaboration types to observe in greater detail how firm-level innovation is affected when firms practice both types of interactions.

By expanding Eq. (1), we get:

$$logit\,(P(Innovation_{i,t})) = \beta_0 + \beta_1 Innovation_{i,t-1} + \beta_2\, STI_{i,t} + \beta_3\, DUI_{i,t} + \beta_4\, STI_{i,t} \times DUI_{i,t} + \beta_5 \mathbf{Z}_{i,t} + \varepsilon_{i,t} + \alpha_i \quad (3)$$

The independent variables in Eq. (3) are as in Eq. (1). We add an interaction term between the two different collaboration types in firm *i* at time *t*. Table 4 presents the results of running a logit model on Eq. (3) and the equivalent Tobit model.

For comparison, Table 4 first shows the basic model for all dependent variables without any interaction terms, as in Tables 2 and 3, while the next column includes the interaction term between the innovation

Table 4
Estimated results. Product innovation, New-to-market product innovation and Share of turnover.

	(1) Product innovation	(2) Product innovation	(3) New-to-market prod.innov	(4) New-to-market prod.innov	(5) Share of turnover	(6) Share of turnover
Product innovation t_1	1.281***	1.276***				
	(0.072)	(0.072)				
New-to-market prod.innov t_1			1.066***	1.066***		
			(0.081)	(0.081)		
Share of turnover t_1					0.532***	0.530***
					(0.027)	(0.027)
Scientific collaboration, STI	0.384***	0.715***	0.358***	0.789***	0.351***	0.809***
	(0.122)	(0.162)	(0.118)	(0.156)	(0.124)	(0.174)
Supply-chain collaboration, DUI	0.891***	1.221***	0.672***	1.072***	0.870***	1.259***
	(0.120)	(0.164)	(0.120)	(0.154)	(0.123)	(0.152)
STI*DUI		−0.744***		−0.887***		−0.910***
		(0.235)		(0.215)		(0.228)
Constant	−3.172***	−3.181***	−3.380***	−3.401***	−3.602***	−3.603***
	(0.567)	(0.568)	(0.607)	(0.606)	(0.578)	(0.581)
Observations	8,195	8,195	8,092	8,092	8,259	8,259
Sigma					2.528***	2.527***
					(0.037)	(0.037)
Log Likelihood	−3209.9	−3203.6	−2816.5	−2806.8	−8324.4	−7920.1
Firms	4,612	4,612	4,534	4,534	2,539	2,539
Pseudo R^2	0.377	0.378	0.329	0.332	0.167	0.207

Note: Robust standard errors clustered over firms in parentheses. All models includes all controls, year, industry and regional fixed effects. Share of turnover related to product and new-to-market product innovation. 5720 observations are left-censored in model (5) and (6). * p < 0.1, ** p < 0.05, *** p < 0.01.

Table 5
Average marginal effects of innovation collaboration at mean values of all other variables.

	New-to-market prod. innovation		Product innovation	
	Supply-chain collaboration		Supply-chain collaboration	
Scientific collaboration	0	1	0	1
0	0.17 (0.01)	0.30 (0.02)	0.28 (0.05)	0.45 (0.02)
1	0.26 (0.01)	0.29 (0.02)	0.37 (0.02)	0.45 (0.02)

Note: Robust standard errors in parentheses. All coefficients are significant at 1 percent level.

collaboration types, STI*DUI. This allows us to examine how the likelihood of product innovation changes when firms collaborate with both scientific and supply-chain partners. The coefficients show a negative and significant interaction between the two for all three innovation outcomes. Separately, scientific and supply-chain collaboration both increase the likelihood of product innovation, new-to-market innovation and share of turnover from product innovation. However, the interaction term indicates that they are substitutes, meaning that there are declining returns to collaborating with both types of partners.

As the estimation model in models 2 and 4 is a nonlinear (logit) model with an interaction term, the marginal effects of collaborating with different types of partners on the probability of innovation are given by the cross-partial derivation of the interaction term. Table 5 presents the marginal effects of the different types of collaboration at the average levels of the control variables in the model[8] for product innovation and new-to-market innovation.

Scientific and supply-chain collaboration appear to be substitutes rather than complements. We can illustrate this more clearly by examining the estimated marginal effect for STI and DUI in greater detail. The marginal effects of scientific collaboration on the probability of firm innovation conditional on supply-chain collaboration are shown in Fig. 1.

Fig. 1 shows that collaboration with scientific partners increases the probability of innovation substantially for firms that do not collaborate with supply-chain partners (blue solid line, DUI = 0). The probability of product innovation is 28 percent for firms that do not collaborate with any partners, compared to 37 percent for firms that collaborate with scientific partners only. However, there is no effect of reaching out to scientific partners for firms that already engage in supply-chain collaboration (red line, DUI = 1). The slope of the line has a slightly negative trajectory, although the difference is marginal. For practical purposes, the probability of innovation remains the same if firms collaborate only with supply-chain partners, or if they collaborate with both scientific and supply-chain partners. On the flipside, the probability of innovation is much higher for firms collaborating with supply-chain partners than for firms not participating in any partnerships.

Fig. 2 shows the effects on new-to-market product innovation. Collaboration with scientific partners increases the probability of innovation substantially for firms that do not collaborate with supply-chain partners (blue solid line, DUI = 0). The probability of new-to-market product innovation is just below 17 percent for firms that do not collaborate with any partners, compared to 26 percent for firms that collaborate with scientific partners only. However, if firms already collaborate with scientific partners, supply-chain collaboration does not increase the probability of innovation.

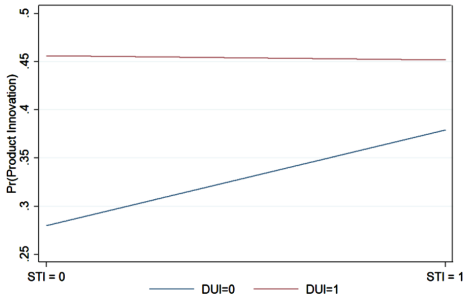

Fig. 1. Combining scientific and supply-chain collaboration and the probability of product innovation.

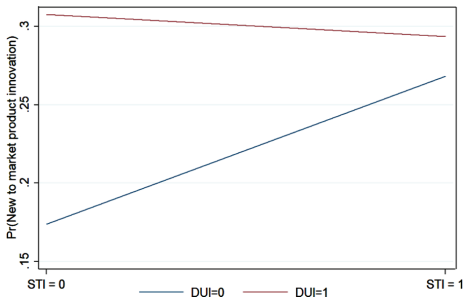

Fig. 2. Combining scientific and supply-chain collaboration and the probability of new-to-market product innovation.

4.2. Robustness checks

We perform two checks on the robustness of our main findings. In particular, we run a panel fixed-effect model on our data. This approach allows us to control for firm-level heterogeneity which could cause bias. However, given the structure of the data and the lack of variation in the main dependent variables, the sample size decreases substantially. Table 6 shows the estimated results for the fixed-effect model for a balanced panel data set. Overall, the effects of both scientific and supply-chain collaboration are positive and significant also in this model. The interaction term is negative, but not statistically significant. The direction of the coefficient is consistent with the results of the previous analyses. Overall, this indicates that H1 and H2 are supported, while there is no evidence to substantiate H3a with the panel model. The negative sign of the interaction term shows a story consistent with the previous analysis.

As a further robustness check, we also run our models restricting the analysis to innovation-active[9] firms (Table 7). The results are very similar to those of the full sample. The effects of scientific and supply-chain collaboration are both positive and significant, but the interaction between them is negative. The interaction term is significant only for

[8] In nonlinear models, such as a logit model, one needs to be careful when assessing the marginal effect of interactions in isolation. The risk in the interpretation is derived from a potential skewness in the tail of the logit distribution. The marginal effect is dependent on the values of other variables in the model, which may also affect the significance level for the marginal effect within the variance of other variables. There are several ways of dealing with this potential problem. One would involve examining changes in the odds ratio (e.g. Buis, 2010). The alternative we follow involves analysing the marginal effect at the average level of all variables (e.g. Cameron and Trivedi, 2005).

[9] Innovation-active firms are defined as those reporting positive innovation expenditure, collaboration in innovation processes, or any kind of innovation outcome (Herstad et al., 2014). In total, 8,337 firms of the original 18,924 firms are innovation-active.

Table 6
Fixed effect model, Product innovation and New-to-market innovation. Unbalanced panel, time-period 2006–2010.

	(1)	(2)	(3)	(4)
	Product innovation	Product innovation	New-to-market prod.innov.	New-to-market prod.innov.
Scientific collaboration, STI	0.640***	0.812***	0.517***	0.736***
	(0.161)	(0.233)	(0.168)	(0.239)
Supply-chain collaboration, DUI	0.830***	0.985***	0.570***	0.757***
	(0.141)	(0.212)	(0.145)	(0.201)
STI*DUI		−0.406		−0.448
		(0.300)		(0.305)
Collaboration with competitors	−0.038	−0.002	0.038	0.068
	(0.204)	(0.225)	(0.188)	(0.215)
R&D expenditure (log)	0.193***	0.193***	0.152***	0.151***
	(0.024)	(0.022)	(0.020)	(0.020)
Firm size (log)	0.217	0.213	0.329**	0.328*
	(0.183)	(0.141)	(0.168)	(0.173)
Share of educated employees (log)	1.156	1.107	−0.726	−0.720
	(1.302)	(1.361)	(1.093)	(1.035)
Export focus	0.260	0.266	0.345*	0.354*
	(0.206)	(0.176)	(0.190)	(0.187)
Observations	3,081	3,081	2,714	2,714
Numbers of firms	1,196	1,196	1,042	1,042
Log Likelihood	−925.16	−924.2	−838.5	−837.0

Note: Balanced data set. Bootstrapped standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7
Only innovation-active firms. Product innovation and New-to-market innovation.

	(1)	(2)	(3)	(4)
	Product innovation	Product innovation	New-to-market prod. innov.	New-to-market prod. innov.
Product innovation t_1	1.107***	1.106***		
	(0.077)	(0.077)		
New-to-market prod. innov t_1			0.963***	0.964***
			(0.078)	(0.078)
Scientific collaboration, STI	0.290***	0.337**	0.309***	0.533***
	(0.111)	(0.146)	(0.107)	(0.143)
Supply-chain collaboration, DUI	0.648***	0.695***	0.525***	0.729***
	(0.107)	(0.144)	(0.106)	(0.137)
STI*DUI		−0.105		−0.457**
		(0.209)		(0.196)
Constant	−1.648***	−1.652***	−2.263***	−2.285***
	(0.595)	(0.596)	(0.618)	(0.619)
Observations	4,948	4,948	4,916	4,916
Firms	2,892	2,892	2863	2863
Pseudo R^2	0.228	0.228	0.205	0.206
Log Likelihood	−2637.8	−2637.7	−2531.1	−2529.3

Note: Robust standard errors clustered over firms in parentheses. All models includes all controls, year, industry and regional fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

new-to-market innovation. Once again, the hypothesis of complementarity between the innovation modes cannot be supported.

5. Conclusion

Prior literature has argued that firms combining science-based and experience-based knowledge in innovation processes are more likely to innovate as a consequence of the complementarities between the two types of knowledge. This is a core tenet of the literature on innovation modes since the publication of Jensen et al.'s (2007) seminal article. They suggested that a combination of STI and DUI resulted in higher levels of innovation. Literature on innovation collaboration has also suggested that different types of partners provide access to different knowledge and a wider scope of new ideas. Scientific partners give access to knowledge from a different realm than do suppliers and customers, and combining both scientific and supply-chain collaboration is therefore ideal for innovation (Faems et al., 2005). However, some have cautioned against the risk of 'over-searching' and questioned whether most firms have the capacity to manage radically different types of knowledge inputs (Laursen and Salter, 2006).

Testing of whether this complementarity really exists and benefits innovation has, however, never taken place. In this paper, we have conducted such an analysis by evaluating the interaction between collaboration with scientific and supply-chain partners in Norway. The results show that there is a need to rethink the assumption that the two types of collaboration are complementary. Engaging in more supply-chain collaboration for firms already conducting scientific collaboration – and vice versa – is unlikely to unleash complementarities that lead to radically higher levels of innovation. The results demonstrate that, at least in the case of Norway, scientific and supply-chain collaboration rather than being complementary, appear to be substitutes or – at best – that they only have additive effects on innovation. The analysis finds a negative interaction effect between scientific and supply-chain collaboration for innovation. Firms benefit strongly from collaborating with scientific or supply-chain partners, but collaborating with both types of partners simultaneously does not yield multiplicative benefits. On the contrary, the effect of collaborating with scientific partners is more limited for firms that also collaborate with supply-chain partners.

These findings challenge the dominating views about the benefits of different types of collaboration and their complementarity. However,

they should be considered with some caution, given, first, that the analysis focuses exclusively on product innovation. Furthermore, the binary structure of the dependent variables places some limitations on our understanding of the scope of the innovation. While to a considerable extent the share of sales from new products takes this to account and leads to the same conclusion, we do not know how many new products were introduced by each firm and have no information on the quality or complexity of these products. Therefore, complementarities in these dimensions cannot be ruled out. Certainly, more complex and advanced innovations may, to a greater extent, require different types of inputs. We also do not have information on the intensity or the number of partners of each type and can therefore only examine effects of whether or not different types of partners were used. Finally, we have not been able to explore how firms integrate the knowledge from scientific and supply-chain collaboration into internal innovation practices.

Taking these caveats into account, the results, nevertheless, provide considerable food for thought about the scope of collaboration that is needed for firms to innovate. More research covering other areas of the world will be needed in order to corroborate or challenge these results. Overall, the results supply new ideas about how to collaborate and what types of collaboration are needed to increase innovation at the level of the firm. Collaboration is clearly an important factor for innovation. Firms engaging in scientific or supply-chain partnerships independently from one another innovate more. However, our results raise questions about the prevailing wisdom about how much collaboration is needed in order to maximise innovation outputs and about whether firms need to consider more of different types of collaborations. They also represent a challenge for officials and decision-makers in their quest to design policies that would create more adequate conditions and environments for firms to innovate, as promoting more and more complex types of collaboration for innovation does not always help firms to become more innovative and competitive.

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Paper III

Do Regional Social Capital and Trust Matter for Immigrant Diversity and Wages?

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Abstract

Recent studies suggest that greater immigrant diversity in regions and workplaces increases productivity, and inclusive regional conditions are found to be important for this mechanism. Seeking to better understand this relationship, this paper broadens the dimensions and refines the measures of regional context pertaining to immigrant diversity outcomes. Regional measures of trust in foreigners and trust in government are tested under the hypothesis that regions with higher trust will have larger associations between rising immigrant diversity and increasing local wages. Additionally, we hypothesize that the benefits from immigrant diversity will be higher in regions with a strong social bridging culture, while the opposite will be the case in regions with a high level of social bonding. Looking across these novel and more nuanced dimensions of regional context, we find that they each matter in shaping the effects of diversity. Specifically, we find that spillovers from regional diversity are higher in regions with low levels of social bonding and in regions with high levels of trust, confirming the hypotheses. Evidence on regional variation in bridging social capital does not confirm the hypothesis. Using high quality longitudinal matched employer-employee data from Norway from 2001-2011, this paper provides a new case in the empirical diversity-productivity literature and novel evidence on the regional dimensions that shape this relationship.

Keywords: Diversity, immigration, productivity, regions, institutions, social capital, trust, bridging, bonding

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1 Introduction

Researchers in a wide range of disciplines contend that people with different demographic characteristics carry with them different perspectives and that the combination of these perspectives can impact economic outcomes. Economic advantages can arise because interaction within a diverse population allows a wider range of approaches, finding innovative solutions to problems that can increase economic performance. Drawbacks could be caused by the difficulties and costs that individuals from different backgrounds experience when interacting, hampering the establishment of trust and common ground. Given these contradictory forces, the net effect of diversity on productivity likely hinges on transaction costs.

Many empirical studies find a positive correlation between immigrant diversity and productivity (e.g., Ottaviano and Peri, 2006; Trax et al., 2015; Kemeny and Cooke, 2018), suggesting that the advantages of immigrant diversity generally outweigh the costs. However, the regional conditions shaping this outcome are less well understood. If transaction costs are fundamental to the nature of this relationship, attending to regional variation in institutions, which regulate transaction costs, should be a key component in the relevant regional conditions. North (1990) argues that incentives and constraints set by a common trust, culture, religion, and social norms – that is, informal institutions – impact individual actions in an economy. Acemoglu and Robinson (2012) argues that regions with *inclusive* institutions have lower interaction costs between different groups of individuals. Specific to topic at hand, Kemeny (2012) has argued that informal regional institutions that encourage interactions across difference should enhance any beneficial economic effects of immigrant diversity. Empirical evidence from metropolitan areas across the United States supports this proposition (Kemeny, 2012; Kemeny and Cooke, 2017).

While the US is an important empirical case, in many ways it is also an extreme one. In this paper, we first ask whether there is evidence of regional institutional differences in shaping the diversity-productivity relationship in a very different national context than the extant literature has explored: that of Norway. Norway is known for its strong institutional setting (Westlund, 2006; Mehlum and Torvik, 2006) and has a strong national identity. However, its geography and history have also shaped local identities and distinct regional characters (Fitjar and Rodríguez-Pose, 2011). Regions across the country are relatively isolated from one another by large distances and rugged terrain, which has contributed to building strong local communities or regions. Thus the first contribution of this paper is to expand the body of empirical evidence on whether regional context shapes diversity spillovers.

Additionally, there are challenges inherent in operationalizing the hard-to-measure concept of informal institutions. Though Kemeny and Cooke (2017) address some of

this difficulty by triangulating across two distinct markers of how welcoming regions are to immigrants, there is important conceptual nuance in regional informal institutions that may impact the productivity spillovers related to immigrant diversity. In this paper, we distinguish between bridging and bonding social capital (Knack and Keefer, 1997), hypothesizing that strong bridging social capital should enhance positive spillovers (as in Kemeny, 2012; Kemeny and Cooke, 2017), but strong bonding social capital, with its support of intra-group ties (Granovetter, 1973; Woolcock et al., 2001) may dampen the ability of a region to adopt new perspectives from diversity. We also explore the role of trust, which is argued to reduce interaction costs (Fukuyama, 1995) and may encourage involvement in the social community that enables the achievement of collective actions through cooperation, solidarity, and public-spiritedness (Putnam, 2000a). Specifically, we explore two distinct measures which should particularly shape interactions with immigrants: trust in public government and trust in foreign-born individuals, both of which we expect to facilitate interaction and enhance the benefits of diversity for economic performance. Thus, the second contribution of this paper is to expand our understanding and refine the measures of regional context pertaining to immigrant diversity outcomes in a novel way.

In this paper, in keeping with recent contributions (Kemeny and Cooke, 2017; Trax et al., 2015), we use an empirical approach that accounts for a wide range of potential confounding factors to identify the context-specific relationship between diversity and productivity. Using longitudinal microdata, we estimate how workers' annual salaries change as the diversity of immigrants in their region and their workplace change. We limit our analysis to salary changes within job spells, capturing continued employment in a single workplace and region for a minimum of two years. This allows for the use of fixed effects to absorb bias from multiple sources of stationary heterogeneity, helping address concerns about sorting and other selectivity issues (Combes et al., 2008; Kemeny, 2012; Lewis and Peri, 2014). Variation in social capital and trust allows us to consider how the relationship between diversity and wages varies across different regional contexts.

The primary data source used in this study is the Norwegian Linked Employer-Employee Data (LEED). These data provide comprehensive information describing workers matched to their work establishments, available between 2001 and 2011. LEED includes information on workers' place of birth and captures our measure of their productivity: total annual earnings. Aggregating these data, we construct measures of regional and workplace immigrant diversity and observe wage changes over time within job spells. Closely following the existing literature on crafting indicators of social capital, we draw on multiple questions in the Norwegian Monitor Survey data (over the period 1990 to 2011) to construct the region-specific institu-

tional measures: bonding and bridging social capital, as well as the two types of trust.

Our empirical results show that informal institutions, proxied by regional social bonding, bridging and trust, matter for the beneficial effects of diversity in the context of Norway. Our results are mostly consistent with theory and largely in line with our hypotheses. In particular, we find that the benefits of regional diversity are higher in regions with lower levels of social bonding. High levels of trust in foreign individuals are associated with enhanced benefits of diversity, as expected. Similarly, regions with higher levels of trust in local government appear to have a significant positive association with diversity spillovers. Only our estimates examining bridging social capital do not confirm the hypotheses. Together these measures expand and refine our understanding of the dimensions of regional context that matter in shaping the diversity-productivity relationship.

The paper is structured into five further sections. This introduction is followed by an engagement of the relevant literature on the local economics of immigrant diversity and regional informal institutions. In section 3, we present contextual information on Norwegian immigration and regional variation in social capital and trust. Section 4 describes the empirical approach and data used in this paper. Section 5 presents the results. The conclusions and some indications for future research are presented in section 6.

2 Diversity, Productivity, and Regional Context

Across economic geography, regional studies, and urban economics, there is a growing literature interested in the localized spillovers from immigrant diversity (e.g., Kemeny, 2014), a distinctive conversation within a much larger literature on the economic impacts of immigrants. This area of research largely focuses on the idea that interactions among people with diverse perspectives and heuristics can help identify more possible solutions to any complex problem (Hong and Page, 2001) and generate more new and innovative ideas (Aiken and Hage, 1971). Superior problem solving and novel approaches should contribute positively to productivity. With heuristics and perspectives shaped partly by demographic characteristics (Nisbett et al., 1980; Clearwater et al., 1991; Thomas and Ely, 1996; Page, 2008), birthplace diversity, generated by increasing and multiplying immigration flows, should theoretically have at least latent positive spillovers for local economies. Empirical studies with a range of approaches and in varied contexts, while not universally in agreement (Bakens et al., 2013; Longhi, 2013; Elias and Paradies, 2016), provide ample observations of a positive and statistically significant relationship between immigrant diversity and productivity (Ottaviano and Peri, 2006; Nathan, 2011,0;

Suedekum et al., 2014; Kemeny, 2012; Bellini et al., 2013; Lee, 2014; Trax et al., 2015; Nijkamp et al., 2015; Alesina et al., 2016; Kemeny and Cooke, 2018; Cooke and Kemeny, 2017; Delgado Gómez-Flors and Alguacil, 2018; Roupakias and Dimou, 2018).

Human interaction, however, is not costless. All else equal, interacting with people who are different from you is likely more costly than interacting with those with whom you are similar or share a similar social context. This idea – that fractionalization might actually be costly – finds support by development economists at the national scale (Alesina and Drazen, 1991; Easterly and Levine, 1997; Rodrik, 1999; Alesina and La Ferrara, 2005; Montalvo and Reynal-Querol, 2005), as well as subnational scales (Poterba, 1997; Alesina et al., 1999; Goldin and Katz, 1999; Pennant, 2005). Just as there is variation in the costliness of interactions, there is also variation in the contexts in which that interaction occurs. This suggests that the institutional context – formal or informal – should shape the transaction costs among people. Where interactions among different people are less costly, the benefits of diversity should be more apparent.

Institutions are an important factor in determining learning capacity (Morgan, 2007) and play an important role in shaping economic performance (North, 1990, 2012; Acemoglu and Robinson, 2012; Rodríguez-Pose, 2013) and innovation (Crescenzi et al., 2013; Nathan and Lee, 2013). Institutions are widely thought of as a system of formal and informal rules and norms facilitating interaction among actors, within the national or regional scale, and in doing so, they regulate the cost of interactions in an economy (North, 1990). Acemoglu and Robinson (2012) argue for the importance of inclusive institutions in particular, defining these as ones that structure and draw people into creative and entrepreneurial opportunities. If these economic activities are the ones that stand to benefit the most from immigrant diversity (Cooke and Kemeny, 2017), then institutions that provide opportunities for interactions across difference should amplify diversity spillovers.

Though there can be regional variation in formal institutions, often captured by laws or regulation, many of these are set at the national level; thus, informal institutions are of particular importance at the regional scale. Informal institutions, also known as 'soft' or 'community' institutions, can include norms, interpersonal contacts and relationships, and networks, all of which can show substantial local and regional variation (Rodríguez-Pose and Storper, 2006). Both theory and evidence support the importance of informal institutions in shaping regional economies (Rodríguez-Pose, 1999; Rodríguez-Pose and Di Cataldo, 2014; Morgan, 2007; Feldman and Storper, 2018).

While clearly important to regional economies, these informal institutions can be challenging to pin down, with considerable debate over definitions and opera-

tionalization (Rodríguez-Pose and Storper, 2006). We find the literature on social capital and trust to be of particular use for our purposes. Putnam (2000b) defines social capital as those features of social organizations, such as trust, norms, and networks that can improve the efficiency of society by facilitating coordinated action (p.167), and enable people to act collectively (Woolcock et al., 2001, p.226). Trust among actors reduces information and cost of interactions (Fukuyama, 1995) and may encourage involvement in the local community enabling collective action through cooperation, solidarity, and public-spiritedness (Putnam, 2000b). These features are associated with what is often called a high level of social capital and make it easier to mobilize local resources. But social capital itself can have multiple dimensions, not all conducive to the smoothing of interactions as imagined above (Coleman, 1988). Homogeneous and tightly knitted communities or networks may have strong social capital within their communities, but can be less exposed to new information and less prone to create new ideas and perspectives (North, 1990). To distinguish these aspects of social capital, and their different potential economic implications, the literature has proposed a distinction between bonding and bridging dimensions of social capital (Knack and Keefer, 1997). On the one side, bridging social capital creates trust and interaction between individuals from different backgrounds, highlighting what is often referred to as 'cross-cutting ties'. On the other side, bonding social capital, focusing on 'intra-group ties', can be defined as strong links and connections between individuals or groups with the same background (Granovetter, 1973).

Following Malecki (2012), we expect social capital to vary at the regional scale in ways that affect trajectories of economic development. Social bridging or a more open culture may help individuals learn from those nearby, taking advantage of the "buzz" possible in regions around the exchange of ideas with others, facilitating the development of new knowledge and creative innovation (Storper and Venables, 2004; Asheim et al., 2007). Florida et al. (2010) goes as far as to argue that tolerant and open cities can attract creative workers that likely bring new knowledge that can create economic advantages. Specific to the implications for immigrant diversity, high bridging social capital in a region should reduce the costs of interacting across differences, facilitating more interactions, which is key to the main theorized mechanism underlying the productivity spillovers of diversity. Following this, we propose that trust and bridging social capital are crucial for the spillover effects of immigrant diversity in a region because they function as a bridge between individuals with different perspectives. By making the local region more interconnected and coordinated, a higher level of trust and the presence of bridging-type social capital are expected to enable the combination of different values, knowledge, and capabilities that underlie the productivity spillovers from diversity. The opposite

applies in the case of bonding social capital. We argue that bonding social capital should be detrimental to the ability of regions to adopt new perspectives from newcomers. Inward-looking groups strongly embedded in a region should reduce the opportunities for interaction across difference and dampen the reception of different perspectives. This should hamper diversity spillovers. Turning to regional variations in trust, we argue that high levels of trust in foreign-born individuals should facilitate more interaction with immigrants. Additionally, we conjecture that high levels of trust in public goverment should reduce transactions costs across all individuals as well. Motivated by these arguments, this article tests the following four hypotheses:

1. Spillovers from immigrant diversity on worker productivity should be higher in regions with higher levels of trust in foreign individuals.

2. Spillovers from immigrant diversity on worker productivity should be higher in regions with higher level of trust in their government.

3. Spillovers from immigrant diversity on worker productivity should be lower in regions that feature higher levels of social bonding.

4. Spillovers from immigrant diversity on worker productivity should be higher in regions that feature higher levels of social bridging.

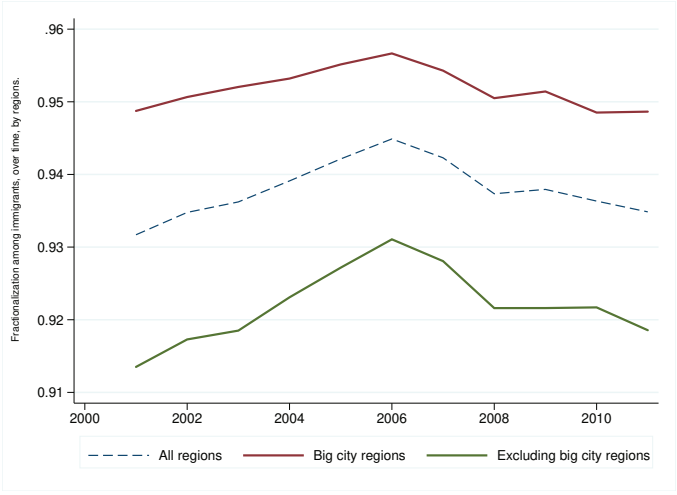
There are only a few studies we are aware of that address related topics at a subnational scale. The closest studies to the current one are two studies in the United State context (Kemeny, 2012; Kemeny and Cooke, 2017). The latter of these studies demonstrates that inclusive institutions matter for the benefits of immigrant diversity and that it matters more for native-born workers than others. We contribute to this research by: offering an empirical example from a context quite different from the United States; and by providing novel information on how different aspects of informal institutions may shape the diversity-productivity relationship. Specifically, we do so by examining regional differences in bonding versus bridging social capital, and two different aspects of trust. The measures of trust, and particularly the explict measure of reported trust in foreigners, provide a clear and direct measure of regional context pertaining to immigrant diversity outcomes that has not been done in earlier research.

3 Norway - a likely case?

3.1 Diversity and productivity

Norway, like other western countries, has had a growing immigrant population over the past decades. In 2018, 14 percent of the total population are immigrants or the Norwegian-born children of immigrants. While in other countries, big city regions are often the major sites of increased diversity, this is not the case in Norway. In the observed time period, diversity increased in all regions, as shown in Figure 1. The peripheral regions[1] contribute substantially to this increase at the beginning of the time period, while at the end of the time period, the changes in fractionalization among immigrants are more similar between the cities and other regions.

Figure 1: Birthplace fractionalization among immigrants in Norway over time, by All Regions, Big City Regions and Peripheral Regions, 2001-2011.

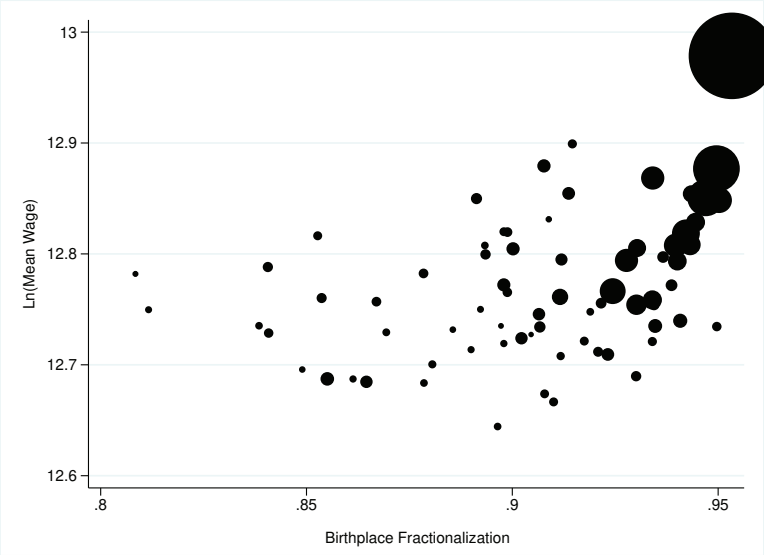


Regions that feature greater immigrant heterogeneity also have workers with higher average annual wages, visible in the simple bivariate correlation in Figure 2. This is a pattern consistent with other countries like the US (Kemeny and Cooke, 2018). However unlike the US, the Norwegian labor market is characterized by strong trade unions power, operating with a rather strict annual wage setting for their members. Under this system of collective bargaining, wages are set annually through a combination of central and local negotiations, with the result that annual wages might not fully represent productivity at the individual level. This labor

[1]We define peripheral regions as regions that are not regarded as 'Big City Regions'. Norway has four 'Big City Regions'; Oslo, Bergen, Trondheim, and Stavanger and therefore 74 regions are regarded as 'Peripheral Regions'.

market feature raises some concerns for our use of individual wages as a proxy for productivity. Two factors should help mitigate major concerns about this. First, there is a general trend in Nordic countries for that the employeer-employee relationship to be more decentralized and individualized (Westlund, 2006). Second, productivity increases from diversity realized by firms should be recognized by the bargaining units, and thus should be generally reflected in rising wages, even if the relationship to individual productivity is somewhat loose. Thus, we argue that individual wages changes within job spells are an operational proxy for productivity in this context. At the same time, these processes might slow the responsiveness of wages to diversity-generated productivity changes, hence we run our models with lagged measures of diversity as a robustness check.

Figure 2: Economic regional average wages and birthplace fractionalization weighted by regional size, 2001- 2011.



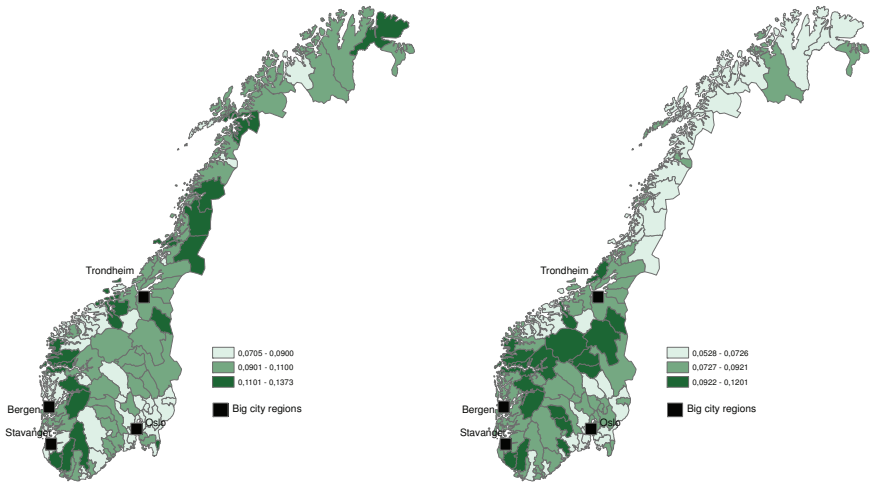
Note: Points on the scatter plot reflect average economic region values for wages and diversity, 2001 to 2011.

3.2 Social Capital and Trust: Norway

Norway, similar to other Nordic countries, is known for its strong institutional setting and its comprehensive welfare system (Westlund, 2006; Mehlum and Torvik, 2006). Furthermore, Norway has a robust national identity and Norwegians typically express high levels of trust in general. But its geography and history have also

shaped differentiated regional identities. Regions across the country are relatively isolated from one another by distance and rugged terrain, contributing to the construction of strong local identities within regions (Fitjar and Rodríguez-Pose, 2011). As in other countries (Rodríguez-Pose and Di Cataldo, 2014), some of this regional variation is visible in measures of social capital and trust across the country. Built on data from the Norwegian Monitor Survey, Figures 3 and 4 underline one of the key motivations for this paper by showing cross-regional differences in social bonding, social bridging, and trust. While the differences in bonding social capital (a) do not suggest a clear spatial pattern, particularly not between big cities and peripheral regions, there do appear to be higher levels of bridging social capital (b) located in areas in the peripheral regions concentrated in the middle of Norway.

Figure 3: Cross-Regional Differences in Social Bonding and Bridging, 1990-2011, average index, in Norway.



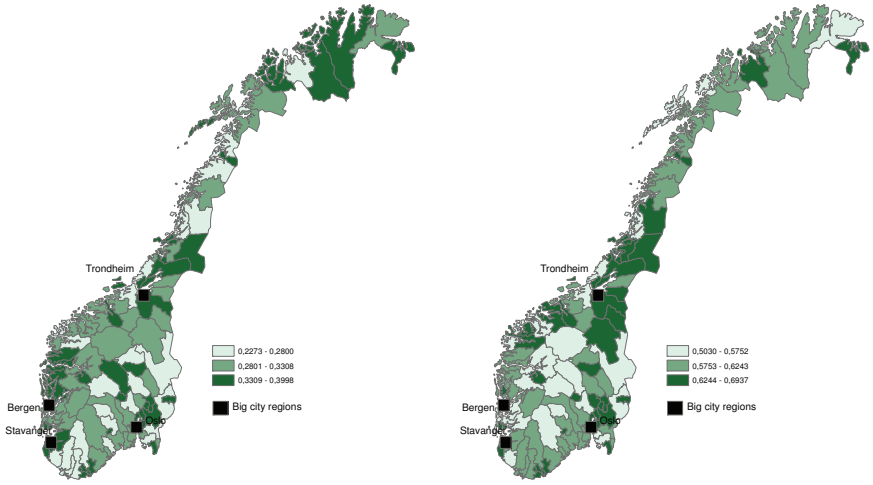
(a) Bonding Social Capital (b) Bridging Social Capital

Note: Bonding and bridging social capital are defined as decribe in section 4.4. Data source: Authors' elaboration on Norwegian Monitor Survey data, 1990-2011.

Building on the same data, we find cross-regional differences in trust in public government and trust in foreign individuals. Regions with high levels of trust might

be considered as sharing same features with regions with high level of social bridging. Indeed, we find a positive correlation between these two measures of trust and the bridging social capital measure. Also visible in Table 1 is the correlation between the two measures of trust: regions with high trust in goverment also are more likely to exhibit high levels of trust in foreign-born individuals. In line with expectations, the correlations between both measures of trust and bonding social capital are negative. Note that there is no significant correlation between bonding and bridging social capital. These features – increasing immigrant populations, diversity in all regions as shown in Figure 1, and the regional variation in social capital and trust as shown in Figures 3 and 4 – make Norway an interesting case for studing how regional context matters for the economic benefits of diversity.

Figure 4: Cross-regional differences in trust, 1990-2011, average index, in Norway



(a) Trust in Foreign-Born Individuals (b) Trust in Public Government

Note: Both trust variables are defined as describe in section 4.4. Data source: Authors' elaboration on Norwwgian Monitor survey data, 1990-2011.

Table 1: Correlation between Social Capital and Trust measures.

		(1)	(2)	(3)	(4)
Bonding Social Capital	(1)	1.000			
Bridging Social Capital	(2)	-0.012	1.000		
Trust in Foreign-Born Individuals	(3)	-0.338*	0.375*	1.000	
Trust in Public Government	(4)	-0.460*	0.407*	0.637*	1.000

Note: * significant at 1 percent level.

4 Empirical Approach and Data

To identify the relationship between immigrant diversity and productivity, we examine how individual workers' wages respond to changes in the diversity that surrounds them. We follow Kemeny and Cooke (2018) (also, Moretti, 2004; Gibbons et al., 2013) to focus our attention on wage changes that occur within job spells, during which individuals that remain in a single workplace and thus region for at least two years. With these workers fixed in place, variation comes from the panel structure of our data, and more specifically from changes in immigrant diversity around these workers – in both their regions and workplaces. We estimate the following equation:

$$ln(w)_{ipjt} = D'_{pjt-1} + d'_{pjt-1} + X'_{ipjt} + E'_{pjt} + C'_{jt} + \mu_{it} + eta_t + \nu_{ipjt} \qquad (1)$$

where, $ln(w)$ represents the log annual wages of an individual worker i in establishment p located in region j at time t; $D'_{pjt-1} = (d_{jt-1}, s_{jt-1})$ is a vector consisting of d_{jt-1}, regional-specific immigrant diversity at time $t-1$ and s_{jt-1} regional immigrant share; d'_{pjt_1} is a vector consisting of d_{pjt-1}, diversity at the level of the firm and s_{pjt-1}, immigrant share at the level of the firm; X' represents time-varying measures of worker-specific characteristics; E' describes a vector of dynamic employer characteristics, such as firm size and share of college educated workers; and C' indicates typical time-varying characteristics of a worker's region, such as population size and share of college educated employees. The fixed effect, μ_{ipj}, is important in our approach. Because we analyze workers only within job spells, this term absorbs the influence of unobserved permanent characteristics of each individual worker, as well as the establishment where they work, and the regional economy in which they live. η_t represents unobserved time-specific shocks that exert uniform impacts across all individuals, such as business cycles; and ν_{ipjt} is the standard error term.

Applying the fixed effects estimator, equation (1) explores how an individual's wages relate to changes her region's and workplace's level of immigrant diversity, while accounting for several other likely influences on wage changes but which are

relatively static but hard to observe at scale[2].

As a point of departure, we estimate equation (1) for all regions of the country together, which helps illuminate the general relationship between immigrant diversity and productivity. However, to gain purchase on our hypotheses, that the regional context should shape this relationship, we estimate equation (1) separately for workers in regions with different levels of bonding social capital, bridging social capital, and the two different types of trust. The next section describes our data, analytical sample, and the construction of our measures of diversity, trust, and social bonding and bridging capital.

4.1 Data

Our primary data source is Norwegian register data for individuals and firms, linked together into an employer-employee (LEED) data set. Our data cover all inhabitants in Norway over the age of 16 who are employed in private establishments located in Norway. The annual data span the period 2001 to 2011. LEED data provide a range of information about individual workers, such as their place of birth, parents' place of birth, sex, birth year, where they live, how much they work, annual wage, and detailed information about any education acquired in Norway. We also know where individuals work and where their establishment is located[3].

4.2 Analytical Sample

The analytical sample includes a subset of all workers within continuous job spells. From the total LEED-covered set of workers available to us, we identify and keep each person's longest continuous job spell that exceeds two consecutive calendar years. Each worker only appears in one establishment and one region in the panel, even if they have multiple job spells over their observed career. Workers who do not hold a job lasting at least two years will not be included in our analytical sample. We further limit our sample by excluding workers with low wages[4], and those who work part-time. To ensure that our measure of diversity in establishments is informative, we restrict our sample to establishments with at least 10 employees. The resulting sample is 1.26 million individuals and altogether 6.77 million observations. While these restrictions in the analytical sample aid in identifying the relationship

[2]For workers, such unobserved heterogeneity could include ability, intelligence, or motivation. Firm characteristics could include differences in capital intensiveness or persistent product quality. Among regions, relatively persistent differences in specialization or agglomeration could be relevant. The individual fixed effect also absorbs important observable but persistent characteristics, such as gender or relative age differences which, in cross section, would be captured by X'. Note that all such observable individual charactistics available in our data are absorbed by the fixed effect.

[3]We know the address of each establishments location, by postcode. We use this to identify their economic region. Workers are identified to their workplace at the establishment level.

[4]We exclude workers that earn below 100,000 NOK.

of interest, they do require a tradeoff in generalizability; our analysis can say little about the relationship between diversity and wages for people who work part-time, have very low wages, change jobs with high frequency, or who work in very small establishments. Our results need to be looked at with that in mind.

4.3 Building diversity measures

To create regional measures of diversity, we use all workers observed in the LEED data, not just workers in the analytical sample. While the overall share of immigrants in a region or workplace arguably shows one aspect of labor force diversity[5], more complex measures can better capture the non-binary (Norwegian or not) nature of diversity arising from the combination of people from many backgrounds. Drawing on Alesina et al. (2016) and Ozgen et al. (2013), we calculate a fractionalization index among only the foreign-born population. Excluding Norwegians from this calculation avoids constructing a measure closely correlated with the overall share of immigrants. The index is calculated as follows:

$$Fractionalization_{jt} = 1 - \sum_{r=1}^{R} s_{rjt}^2 \tag{2}$$

where s is the of proportion of residents in the region j who were born in country r in time t; and R is the maximum number of countries captured in the region. The index value can range between 0 (where all immigrants originate from the same country) and 1-1/R (there are an equal number of immigrant from each of the R countries). Recent research Docquier et al. (see e.g., 2018) argues for similarly decomposing the diversity index and distinguishing a *Between* and *Within* component of the diversity index. The fractionalization index is constructed analogously at the establishment-level, based on the set of individuals working in each firm during the first quarter of the year[6]. These measures, at the region and establishment-level, provide the key independent variables of interest in our estimates.

4.4 Building Regional Social Capital and Trust Measures

We approach the challenge of proxying informal institutions by constructing multiple measures, each capturing a nuanced aspect of this hard-to-measure construct. We seek to operationalize a widely accepted notion of social capital as "the norms and networks that enable people to act collectively" (Woolcock and Narayan, 2000, p.226). Putnam (2000a) famously unpacks this idea into two categories: bonding,

[5]This is included primarily as a control variable in our models.

[6]In our data we have information where each individual works in the first quarter. Workers who change workplace after the first quarter will be counted in our diversity measures where they worked during the first quarter and be counted in their new workplace the following year.

which captures such norms and networks within groups of similar individuals in a community; and bridging, which indicates these capacities among members of disparate groups. Capturing the bridging and bonding dimension of social capital is far from easy and straightforward. We use data from the Norwegian Monitor Survey from 1990 to 2011, following the approach proposed by Knack and Keefer (1997) and used in recent studies looking at other research questions (see e.g., Cortinovis et al., 2017).

The Norwegian Monitor is survey data collected every second year, based on a sample of inhabitants representative at the regional level. From this data set, we get information about how individuals within a region are involved[7] in different types of associations. We catagorize this involvement based on sets of associations identified in the literature as plausibly indicative of different measures of social capital. We cannot directly observe the associational activities of the individuals in our analytical sample, just as we cannot observe the interactions they may have with people born in different countries from them. Instead, we must assume that at the region level, the share of people involved in associations tied to bridging or bonding social capital will be indicative of the broader informal institutional climate in that location. This institutional climate, or regional context, should shape opportunities for interactions across people from different backgrounds. On the one hand, more people involved in associations which are inclusive of different groups (bridging) should facilitate more interactions among people from different countries. On the other hand, more people involved in associations that are more exclusive and homogeneous (bonding) should encourage interactions among people with similar backgrounds and limit interactions across difference.

Following (Knack and Keefer, 1997) we link the bridging dimension of social capital to associations like culture activities (e.g., art, music, education), youth work, and religion. Professional associations, political parties, and trade unions represent associations related to the bonding-type of social capital. For each set of associations, we calculate the share of people that have interacted in at least one organization belonging to each set, over the total respondents in a region, over the time period 1990 to 2010. We aggregate the mean value over time for each region and this provides our measures for regional social bonding and bridging[8].

Our second set of measures of informal institutions makes use of data describing regional trust in public government and trust in foreign individuals. For each

[7]While other studies often use membership data, we consider whether individuals are directly involved in associations. In the survey, the participants are asked if, during the last year, they have been actively interacting in different types of associations.

[8]The time-varying nature of these regional measures would be novel to the literature as far as we are aware. However, unsurprisingly, we find little variation over time at national and regional levels in these measures, which makes it hard to exploit this variation over time in our models. Instead we draw comparisons between groups of regions with high and low levels of these measures.

region, we calculated the share of people who agreed with the statement 'foreigners come to Norway to benefit our country', over the total number of respondents in a region the year in the survey. This measure is of particular interest since it should most directly capture local attitudes towards immigrants, providing a thermostat for how warmly immigrants are received. Trust in public government should provide a slightly different aspect of local informal institutions: public trust in the fair functioning of local governments could dampen impluses towards hording of opportunities. In a similar manner, we calculated for each region the share of people who answered that they generally trust public government. We generate the mean value of these measures over time to form our measure for trust in foreign individuals and local trust in government.

4.5 Control Variables

In this paper, we use a fixed effect estimation, where we include an individual-establishment-regional fixed effect. That means that unobserved factors at each level should not to bias our estimates of the relationships of interest, as long as those factors are relatively stationary. While the Norwegian LEED data provides much information on individuals and establishment-level, many of these are absorbed by this important fixed effect term. Controls that are time-variant remain in our model, including the workforce size of establishments and regions, as well as the share of college educated employees in both of these levels.

Eq. (2) captures well the diversity among immigrants and prevents this measure from being too highly driven by the overall share of immigrants in each region or establishment (Nijkamp and Poot, 2015). In addition, we also include a measure of the total share of immigrants among total employment in a establishment p and region j. While this does not directly measure diversity as it pertains mostly closely to the underlying theorized mechanisms of particular interest in this paper, it does capture other potentially important impacts of immigrants in the labor force (Ottaviano and Peri, 2012; Lewis and Peri, 2014). The share of immigrants at region$j$ is calculated as follows:

$$Share_{jt} = \sum_{r=1}^{R} s_{rjt}/(1 - s_{rjt}) \tag{3}$$

where s is the of proportion of residents in the region j at time t who were born in country r. The share of immigrants is constructed analogously at the establishment-level.

One important additional regional control is added to account for the potential role of regional demand shocks, which could shift the supply of different types of workers. Local demand shifts might be correlated with changes in diversity, due to

the generally higher geographical mobility of immigrants compared to natives [9]. To measure local demand shocks, we draw on a method developed by Bartik (1991), and widely used in labor and regional economics. The 'Bartik' measure is constructed as follows:

$$Bartik_{jt} = \sum_{l=1}^{L} e_{jlt-1}(lnE_{lt-1} - E_{lt-1}) \tag{4}$$

where Bartikjt captures the growth in log national employment in industry l at time t, and weights this national growth based on the initial local employment e_{jlt-1}. We use data on regional industry structure based on NACE codes at the two-digit level[10].

4.6 Summary Statistics

Table 2 provides summary statistics for the analytical sample used in our basic model. It includes nearly 1.3 million individuals working in nearly 34 thousand establishments. Average earnings are almost 440,000 NOK. The average spell duration is 7.2 years and the average age is just over 42 years. At the establishment level, diversity, measured by the fractionalization index among immigrants is 0.67 on average; and 0.92 at the regional level. The share of immigrants is 9 percent at the establishment and regional level. The average establishment in the sample has 204 employees and the average share of college educated employees is just over 22 percent. The regional share of college educated employees is 20 percent and the average regional size 106 thousand people.

5 Results

This section presents results from models estimating equation (1), describing the relationship between the wages of individual workers and the immigrant diversity that surrounds them. As described in Section 4, results are produced using fixed effects models on an annual panel of workers over their longest job spell during the study period (2001-2011). Each model includes a fixed effect that eliminates bias from stationary unobserved heterogeneity among individuals, their establishment, and their region. Year dummy variables are included to capture shocks that are

[9] Regions may experience an increase in the average wage as a result of a positive economic shock. This could attract migrants, leading to an increase in diversity. In the Norwegian case, this is particularly pertinent for regions specialising in oil extraction, which may become 'boom regions' in periods of rising oil prices. Such reverse causality could result in upwardly biased estimates. One way to tackle this problem is to control for local demand shocks.

[10] Because of the change to NACE rev. 2 in 2007, we convert all NACE codes back to NACE rev. 1, allowing us to apply this index for the whole time period.

Table 2: Summary statistics

Variable	Mean	Standard deviation
Individual characteristics		
Age	42.08	11.53
Annual wage	439,280	285,249
Spell duration	7.20	3.03
Female	0.31	0.46
Establishments measures		
Diversity	0.67	0.33
Share foreign-born	0.97	0.12
Firm size	204	416.5
Share of educated employees	0.22	0.21
Regional measures		
Diversity	0.92	0.03
Share foreign-born	0.10	0.04
Regional size	106,229	116,818
Share of educated employees	0.20	0.07
Individuals	1,262,272	
Establishments	34,707	
Regions	78	
Observations	6,769,648	

uniform across individuals, establishments, and regions, but which vary over time. Standard errors are clustered at the establishment level. We predict changes in a worker's wage as a function of changes in the diversity in their region and workplace. Grouping observations by regions with different levels of social bonding, social bridging, and trust, provides results that shed light on the role of the regional context in shaping the diversity-productivity relationship.

To provide a starting point for how diversity and productivity generally relate in Norway, we begin by presenting estimates for the country as a whole in Table 3. Column 1 of Table 3 presents estimates of a model where diversity measured at the establishment-level is the primary predictor of interest, and where we exclude all regional-level measures. While the coefficient on establishment-level diversity is basically zero, the control variables are all significant and positively related to wages. Fractionalization among foreigners at the establishment level seems to matter little for individual wages in Norway. However, note that workers in establishments featuring a larger annual increase in the share of foreign-born employees see a statisically significant increase in wages.

In Column 2 we add in our controls for regional-level measures for diversity, regional size, and share of college educated employees. In this model, the con-

Table 3: Fixed Effects Estimated of the Relationship between Immigrant Diversity and Log Annual Wages, 2001 - 2011.

	(1)	(2)	(3)
Establishment-level measures			
Diversity	0.001	0.001	0.000
	(0.001)	(0.007)	(0.001)
Share foreign-born	0.016**	0.0001	0.001
	(0.008)	(0.008)	(0.007)
Establishment size*(log)*	0.062***	0.059***	0.059***
	(0.013)	(0.002)	(0.019)
Share of educated employees*(log)*	0.075***	0.072***	0.072***
	(0.064)	(0.011)	(0.011)
Regional-level measures			
Diversity		0.066**	0.048**
		(0.017)	(0.015)
Share foreign-born		0.317***	0.226***
		(0.064)	(0.059)
Regional size*(log)*		0.316***	0.150***
		(0.064)	(0.011)
Share of educated employees*(log)*		0.054*	0.192***
		(0.028)	(0.049)
Observations	6,769,648	6,769,648	6,769,648
Individuals	1,262,457	1,262,457	1,262,457
R^2	0.42	0.42	0.42
Bartik index	No	No	Yes

Note: Standard errors in parentheses, clustered by establishment. Estimated equation is (1). Year and individual and regional fixed effects included in model 1, while year, individual, establishment and regional fixed effects included in model 2 and 3.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

trol variables are all significant and positive related to wages. At the same time, controlling for regional-level measures somewhat diminishes the magnitude of the establishment-level measures, indicating that some of the estimated associations presented in column 1 are instead captured by regional-level measures. In Column 3, we further control for local shocks in labor demand by including our version of the Bartik-index. All control variables at the establishment level remain more or less the same, while variables at the regional-level change. Our key variable of interest, immigrant fractionalization, still remains significant at the 1% level but the magnitude of the coefficient declines somewhat. This indicates that part of the estimated association found in Column (2) is attributable to dynamic regional demand for labor. This suggests the importance of including the Bartik index in rest of our models, which we do. Overall, these results confirm that the economic benefits for workers' wages in regions that feature more heterogenity among their workers also

are found to be present in the context of Norway.

5.1 Estimates of the Regional Role of Trust, and Bonding and Bridging Social Capital

We now turn to our key interest of this paper, estimating the role of regional context in shaping basic diversity-productivity relationship described in Table 3. In Table 4 we look at regional levels of trust in foreign-born individuals. For comparative purposes, we include in the estimates for all workers in our analytical sample in Column 1, (identical to Column 3 in Table 3). For simplicity sake, we do not show the control variables in these tables, though they are included in all the models, and operate consistently across estimations. Column 2 presents results estimated on a subset of workers residing in regions where trust in foreigners is lowest (lowest tercile of the regional trust in foreginers measure). Column 3 includes workers living in regions that fall in the middle tercile, while estimates in Column 4 show results for workers who live in regions in the top tercile, where trust in foreigners is highest. The results show that in regions with high levels of trust in foreign-born individuals, the average worker experiences a statistically significant raise as immigrant diversity increases in their region. Where trust in foreigners is low, however, it appears that rising diversity is negatively associated with wages, though the estimate is not statistically significant at a 5 percent level. This finding is consistent with our expectations and supports the first hypothesis. Note that the establishment-level measure of diversity still remains insignificant and near zero. This largely holds across the different measures, as is apparent in the following tables. In the rest of this paper, we therefore focus on regional diversity and how its estimates shift according to differences in the regional context.

Table 4: Fixed Effect Estimates of the Relationship between Immigrant Diversity and Log Annual Wages by Terciles of Trust in Foreign-born Individuals

	Full	**Trust in Foreign-born**		
	Sample	Low	Medium	High
Establishment-level measures:				
Diversity	0.000	-0.005	-0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Share foreign-born	0.001	-0.024	0.024	0.004
	(0.007)	(0.016)	(0.013)	(0.010)
Regional-level measures:				
Diversity	0.048**	-0.043	0.005	0.078**
	(0.015)	(0.035)	(0.046)	(0.017)
Share foreign-born	0.226***	-0.094	0.238***	0.369***
	(0.056)	(0.093)	(0.123)	(0.078)
Observations	6,769,648	857,456	1,373,050	4,539,140
Individuals	1,262,457	154,140	249,181	859,136
R^2	0.42	0.44	0.45	0.41

Note: Standard errors in parentheses, clustered by establishments. Estimated equation is (1). Year and individual, workplace, regional fixed effects included in each model. Standard controls and local shift in labor demand measured by the Bartik index are all included in each model. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 5 presents similarly structured estimates across regions varying in trust in public government. Put briefly, we find the same pattern that we found in the models for trust in foreign individuals. Workers in regions with a higher level of public trust seem to benefit from diversity, whereas workers in regions with low levels of trust in the government do not, supporting the second hypothesis. Interestingly, in this case, their wages appear to actually be hurt by rising diversity, significant at a 5 percent level.

Table 5: Fixed Effect Estimates of the Relationship between Immigrant Diversity and Log Annual Wages by Terciles of Regional Trust in Goverment

	Full	**Trust in Public Government**		
	Sample	Low	Medium	High
Establishment-level measures:				
Diversity	0.000	0.001	0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Share foreign-born	0.001	-0.022	-0.014	0.013
	(0.007)	(0.015)	(0.012)	(0.012)
Regional-level measures:				
Diversity	0.048**	-0.070*	0.147**	0.066***
	(0.015)	(0.037)	(0.048)	(0.020)
Share foreign-born	0.226***	-0.025	0.832***	0.031
	0.059)	(0.010)	(0.142)	(0.080)
Observations	6,769,648	940,647	4,143,125	3,418,813
Individuals	1,262,457	193,806	883,768	644,482
R^2	0.42	0.45	0.44	0.40

Note: Standard errors in parentheses, clustered by establishment. Estimated equation is (1). Year and individual, workplace, regional fixed effects included in each model. Standard controls and local shift in labor demand measured by a Bartik index are included in each model.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6 presents estimates across different levels of regional social capital, in both its bonding and bridging forms. Focusing first on bonding social capital, it is apparent that while wages in all regions are positively associated with diversity, the only staistically the estimate is for regions with the lowest levels of bonding social capital. This is in line with expectations, supporting the third hypothesis. Estimates across different levels of social bridging indicate a more unexpected story. Looking at our key variable of interest, workers in regions with low levels of bridging social capital experience positive and significant wage increases from rising diversity, while regions that feature high levels of bridging show no such relationship. The main result from the bridging social capital models does not support our hypothesis on how this aspect of regional context should shape diversity spillovers.

Table 6: Fixed Effect Estimates of the Relationship between Immigrant Diversity and Log Annual Wages by Terciles of Bridging and Bonding Social Capital

	Regional-level measures		
	Low	Medium	High
Bonding Social Capital:			
Diversity	0.160*	0.051	0.021
	(0.055)	(0.038)	(0.019)
Share foreign-born	0.456***	0.384*	0.201***
	(0.126)	(0.120)	(0.072)
Observations	4,721,574	1,480,971	567,103
Individuals	888,947	270,641	102,869
R^2	0.41	0.45	0.45
Bridging Social Capital:			
Diversity	0.166*	0.026	0.036
	(0.040)	(0.018)	(0.038)
Share foreign-born	-0.106	0.145*	0.495***
	(0.095)	(0.078)	(0.065)
Observations	1,209,733	4,464,140	1,094,735
Individuals	222.692	838,143	201,622
R^2	0.44	0.41	0.43

Note: Standard errors in parentheses, clustered by establishment. Estimated equation is (1). Year and individual, workplace, regional fixed effects included in each model. Standard controls and local shift in labor demand measured by a Bartik index are included in each model.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

5.2 Share of Immigrants in the Region

As noted before, since the main focus of this paper is on the effects of immigrants that specifically run through diversity, the measure of share of immigrants is largely included as a control variable. However, as noted by Lewis and Peri (2014) in a helpful summary of immigrant economic impacts, these impacts do not only operate through diversity mechanisms. The imperfect substitutabilty of immigrants for native-born workers (Ottaviano and Peri, 2012) in the labor market allows for productivity improvements via improved labor market sorting and occupational upgrading of native born workers. Though the effect size is generally small, the impact of the share of immigrants in a regional labor market is generally found to be positive in the literature Lewis and Peri (2014). In this paper, results show that holding changes in immigrant diversity constant, regional share of foreign born is generally positive and significant across the models in this paper. However, it is interesting to note key exceptions to this general finding that suggest that regional context may also matter for these other avenues of immigrant inpact in labor markets. Ex-

ceptions to the generally positive relationship are in regions where bridging social capital, trust in foreigners, and trust in government are each lowest (Tables 4-6). Curiously though, immigrant share is not significantly associated with wage changes where trust in government is highest (Table 5).

5.3 Robustness Checks

One potential concern relates to the question of whether Norwegian salaries respond to productivity-enhancing diversity at the same time scale as in other national labor markets. Rigid wage setting that is set collectively and changed in some sectors every second year might mean that any diversity-generated economic benefits show up in wages after some lag in time. In a working paper by Haus-Reve et al. (2019), using the same data, this concern is taken into account by running models on a sub-set of workers in sectors where individual wage setting is more prevalent. Those findings show that while the estimated coefficients for diversity at the regional level in this sectoral subset do change in magnitude, the broader pattern persists. In other words, in the sectors of the Norwegian economy where individual earnings are likely most closely associated with individual productivity, the economic benefits from regional diversity follow the same pattern as in other sectors.

In this paper, we provide additional information relating to this same concern by running our models with lagged measures of immigrant diversity and immigrant share. Theory does not provide guidance on what the appropriate lag might be. However, typically in Norway wages and salaries can be renegotiated annually. Any productivity gains realized by employers ought to be recognized by the workers and bargaining negotiators and fought for in the following contract reviews. Thus, one plausible delay in any diversity-driven productivity impacts that show up in individuals' wages would be a one year interval.

Table 7 presents results analogous to the results in the top panel of Table 6, but with one-year lags in diversity and immigrant share at both establishment and regional levels. With a special focus on the regional diversity measure, Column 1 shows that for all regions together, the relationship between fractionalization among immigrants still holds when we lag the measure one period. The next three columns show that across each tercil, the pattern corresponds to Table 6, where low social bonding is associated with positive and significant regional diversity spillovers.

Taken together, and despite the contradictory results from the bridging social capital measure, we find support for the idea that regional context matters for the relationship between immigrant diversity and productivity in Norway. At the broadest level, this is in line with evidence from the US (Kemeny, 2012; Kemeny and Cooke, 2018). However, the findings presented here substantially extend and refine our understanding of the particular elements in the regional context that may matter

Table 7: Fixed Effects Estimated of the Relationship between Immigrant Diversity lagged one year and Log Annual Wages

	Full	**Social Bonding Capital**		
	Sample	Low	Medium	High
Establishment-level measures				
Diversity(t-1)	0.001	0.001	0.000	0.001
	(0.007)	(0.000)	(0.001)	(0.001)
Share foreign-born(t-1)	0.047***	0.032***	0.096***	0.091***
	(0.008)	(0.010)	(0.015)	(0.020)
Regional-level measures				
Diversity(t-1)	0.040**	0.188**	0.012	0.043
	(0.016)	(0.050)	(0.036)	(0.019)
Share foreign-born(t-1)	0.282***	0.503***	0.357***	0.136*
	(0.051)	(0.104)	(0.114)	(0.073)
Observations	6,163,195	4,306,804	1,343,865	512,526
Individuals	1,262,385	888,895	270,622	102,868
R^2	0.40	0.39	0.43	0.44

Note: Standard errors in parentheses, clustered by establishment. Estimated equation is (1). Year, individual, establishment and regional fixed effects, control variables and local shift in labor demand measured by a Bartik index are included in each model.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

for this relationship. On the one hand, trust in both foreign-born individuals and local governments captures elements that enhance diversity spillovers. On the other hand, strong bonding social capital – whatever social benefits it may have for those entwined in its inward-facing connections – has the opposite effect of dampening diversity spillovers. The only puzzling result here is that the measure of bridging social capital appears to operate in the opposite manner as hypothesized.

6 Conclusion

This paper set out to answer the following question: do the effects of immigrant diversity on workers productivity depend on the regional context, measured by trust, and bonding and bridging social capital? Institutions are widely viewed to regulate the cost of interactions and because of regional differences in informal institutions, it makes sense to exploit variation at this level. Our study finds that these aspects of regional institutions do indeed matter and our findings highlight the importance of the regional context. Our results provide support for several of our main hypotheses. Wages changes associated with changing immigrant diversity are greater in regions that feature a low level of social bonding compared to regions with high social bonding. We also find that regional variation in trust in foreign individuals, as well as

trust in the government, conditions the relationship between diversity and wages. Here, in regions with high levels of trust (in either foreigners or the government), wages are positively and significantly associated with immigrant diversity. However, in regions with low levels of trust, the coefficient on regional diversity is negative, though only significant for the government measure. Finally, contrary to expectation, high regional levels of bridging social capital were not associated with larger spillovers, but rather the reverse. The association between wages and diversity was largest in regions with the lowest levels of bridging social capital.

The measure of bridging social capital used in this paper is consistent with other uses of the survey data to capture this intangible regional characteristic (e.g., Knack and Keefer, 1997). However, while aiming to capture the same concept, this construction is different than the bridging measure used in Kemeny and Cooke (2017). That measure was built not from survey data but rather a composit of indicators that included elements such as population-scaled counts of associations and 'third spaces', as well as quantifiable traces of civic engagement in the form of voter turnout and Census response rates. It bears repeating: regional levels of social capital are hard to measure. As such, we interpret our results with some caution, just as we might for other work using alternative measures, such as the composit indicator mentioned above, or others such as blood donation rates.

An important feature of this paper is that it expands and refines our understanding of what elements of the regional context may particularly matter in shaping the diversity-wage relationship. The extant literature focuses largely on triangulating across proxies that might indicate 'bridging' social capital. Here we draw attention explicitly to the other important (and regionally variable) part of social capital: bonding. This inward-focused dimension of social capital may be particularly relevant to consider with the apparent rise of nativist sentiment in many Western countries. The bonding dimension has received no sustained attention that we are aware of in this part of the literature. Additionally, the measures of trust, and particularly the explicit measure of reported trust in foreigners, provide rather clear and direct measure of regional context pertaining to immigrant diversity outcomes. These too are, to the best of our knowledge, so far missing from the regional immigrant diversity literature.

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Paper IV

Does assimilation shape the economic value of immigrant diversity?

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Abstract

A growing literature has shown that greater diversity among immigrants offers material benefits in terms of higher wages and productivity. One limitation of existing work is that it has considered immigrants from a given country to be homogenous. However, immigrants differ in various ways, not least in their level of assimilation. This paper considers how assimilation might shape diversity's economic effects. Intuition suggests two conflicting dynamics. Assimilation could lower barriers immigrants and natives face in interacting with one another, and thus enhance benefits. Alternately, it could reduce heuristic differences between immigrants and native-born workers, dampening spillovers from diversity. We use Linked Employer-Employee Data from Norway to test these ideas. We construct diversity indices at the regional and workplace scale to capture different aspects of assimilation, and observe how these are related to worker productivity, proxied using wages. We find that assimilation dampens externalities from immigrant diversity. Diversity among second-generation or childhood migrants offers smaller benefits than diversity in teenage or adult arrivals. Immigrants' cultural proximity to Norway, and their experience of tertiary education in Norway each also reduce the social return to diversity. While assimilation processes may benefit society in various ways, our findings are consistent with the idea that, by diminishing the heuristic gaps between migrants and native-born, integration reduces the productivity externalities derived from immigrant diversity.

Keywords: Immigration, Diversity, Assimilation, Productivity, Wages

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1 Introduction

Immigration has rendered a large number of Western countries increasingly birthplace-diverse. Researchers seeking to understand its effects on host countries have considered that immigrants could substitute for native workers or they could complement them. One potential source of complementarity is immigrants' and natives' differing heuristics and perspectives. If individuals from different backgrounds conceptualize issues in different ways, theory suggests that interaction among them will improve problem solving and creativity (Hong and Page, 2004). Existing empirical research supports this hypothesis, documenting positive relationships between firm- and region-based immigrant diversity and various economic outcomes, especially worker productivity (e.g., Ottaviano and Peri, 2006; Bakens et al., 2013; Alesina et al., 2016; Kemeny and Cooke, 2018), and innovation (Ozgen et al., 2013; Lee, 2014; Solheim and Fitjar, 2018). However, it logically follows that the economic benefits of diversity are not automatic. If their realization depends on interaction across cultural divides, then benefits should vary with the costs of that interaction (Kemeny, 2014). Recent evidence indicates that the latent benefits of heterogeneity can be entirely choked off in locations where these cost are high (Kemeny and Cooke, 2017).

In a diverse society, one likely factor regulating these interaction costs is immigrants' level of integration into their host society. Accordingly, in many countries, integration is an important policy ambition. Integration or assimilation policies typically aim to educate migrants about the language, culture and laws of their host country, and to enable full participation in their new economy and society.

Using Norway as a setting, this paper investigates whether and how assimilation processes affect the relationship between diversity and worker productivity. Theory offers two contrasting predictions. On the one hand, holding diversity levels constant, one might expect interactions with better-integrated immigrants to produce larger positive externalities, as assimilation has reduced the cost of those interactions. The other possibility is that assimilation itself reduces immigrants' heuristic distinctiveness – the very source of diversity's hypothesized benefits. If this is true, greater integration might actually reduce diversity's social return. To the best of our knowledge, no paper has directly measured the role of assimilation in shaping the economic value of immigrant diversity. Indeed, other than considering variation in immigrants' human capital and other more narrowly 'economic' factors, extant research has considered individuals from a given country to be identical in terms of their potential to generate spillovers. The ambiguity in theoretical predictions and the scant existing empirical evidence motivate the present study.

To test these ideas empirically, we use matched employer-employee data to cap-

ture how Norwegian workers' productivity responds to changes in immigrant diversity in their immediate context, defined separately as diversity within their workplace and their regional economy. The basic approach mimics that of Kemeny and Cooke (2018), in which attention is focused on work spells of individuals who remain in the same workplace and the same region for at least two years. Variation arises from contextual changes around these workers in terms of the birthplace diversity in the region in which they live, as well as in their workplace. The chief benefit of this approach is that it accounts for potential bias from unobserved heterogeneity among individuals, their workplaces and the regions in which they live.

Aside from applying this approach to the Norwegian context, the novelty of this paper rests upon our examination of the role of assimilation in shaping the social return to immigrant diversity. We measure diversity separately for immigrant workers at particular levels of assimilation. Assimilation is a multidimensional process, involving language, culture, identity, and social and economic factors (Alba and Nee, 1997; Brown and Bean, 2006; Jimenez, 2017). This makes measuring assimilation challenging, including dimensions for which we do not have data - some of which may even be impossible to measure at scale. However, several likely contributors to assimilation processes are observable in public registers. This includes the time immigrants have spent in the country, age at arrival, second generation status, attending school in the destination country, and very close cultural proximity between the birthplace and destination country. We leverage each of these observables with the aim of better capturing assimilation's multidimensional nature.

The primary data source used in this study is the Norwegian Linked Employer-Employee data (LEED), which permit us to describe the full population of workers in the private sector on an annual basis between 2001 and 2011. These data include worker-level demographic information, including birthplace. They also permit description of worker productivity, proxied by total annual earnings. The data also include a range of establishment characteristics. We exploit additional information from the Immigration database and National Educational Database (NUDB) in order to build a wide array of assimilation proxies, including length of stay, age at arrival, second-generation status, cultural distance, and tertiary education in Norway.

This paper relates broadly to the growing study of the relationship between immigrant diversity and productivity, and most directly to the few extant studies that consider variables that might relate to assimilation. These provide inconclusive results on the role of assimilation in immigrant diversity spillovers. For instance, excluding childhood arrivals or including second-generation immigrants has no impact on the relationship between diversity and productivity (Alesina et al., 2016; Mőhlmann and Bakens, 2015). Alesina et al. (2016) interprets their findings to mean

that diversity spillovers originate chiefly from first- and not second-generation immigrants, whereas the Mőhlmann and Bakens (2015) interpretation suggests that including diversity from the second generation does not dampen the spillovers. Alesina et al. (2016) provide an additional, if indirect, hint at assimilation's impact, finding that intermediate cultural proximity of immigrants provides the largest spillovers. Assimilation is not the primary focus in any of these papers. Rather, it is a topic touched upon in robustness checks of diversity measure construction, in which assimilation is examined largely without clear theorization. In the case of Alesina et al. (2016), the scale of the analysis is also entirely different. In sum, the small amount of evidence on how assimilation shapes diversity spillovers is somewhat contradictory, and some of it has been generated at a very different scale of analysis. Consequently, we are proceeding largely into unknown territory.

Our findings can be summarized as follows: The results indicate a robust positive association between worker productivity and immigrant diversity in Norwegian regions and workplaces. At the same time, there is consistent evidence that immigrants' integration into Norwegian society reduces the size of these benefits at the regional scale. When the measures of regional diversity exclude more assimilated immigrants – defined in terms of the length of their residency; age at arrival; their experience of the Norwegian educational system; or their second-generation status – the spillovers of migrant diversity on native workers' wages are larger than when these groups are included in the measures. In sum, while immigrant diversity offers economic benefits, immigrants' assimilation into Norwegian culture dampens these spillovers.

2 Literature

2.1 Immigrant Diversity and Productivity

When individuals with diverse perspectives and heuristics interact, they may collectively be better able to solve complex problems (Hong and Page, 2001, 2004). This improved problem solving should be reflected in higher productivity.[1] While individual variation in heuristics and perspectives arises for various reasons, country of birth is widely considered to affect the way people understand the world (Nisbett et al., 1980; Clearwater et al., 1991; Thomas and Ely, 1996; Page, 2008). To the extent that this is true, birthplace diversity, generated by growing and diversifying immigration flows (Özden et al., 2011), could be a source of positive externalities, or spillovers. These spillovers may arise from interactions at various scales, including work teams, organizations, regional economies and even countries.

[1] For more far-reaching theoretical reviews at multiple scales, see Nathan (2014) and Kemeny (2014).

Much of the empirical research on this topic considers the regional scale. While findings are not universally consistent (Bakens et al., 2013; Longhi, 2013; Elias and Paradies, 2016), researchers mainly detect a robust, positive and statistically significant relationship between immigrant diversity and productivity (Ottaviano and Peri, 2006; Nathan, 2011, 2015; Suedekum et al., 2014; Kemeny, 2012; Bellini et al., 2013; Lee, 2014; Trax et al., 2015; Nijkamp et al., 2015; Kemeny and Cooke, 2018; Delgado Gómez-Flors and Alguacil, 2018; Roupakias and Dimou, 2018).

A particular strand of this research has sought to understand why the relationship between diversity and productivity might vary among locations. One reason is that certain work activities or skills may be more likely to generate diversity spillovers (Suedekum et al., 2014; Cooke and Kemeny, 2017). Another reason is that human interaction is not costless, and the costs of interaction might vary across different contexts - whether those are understood as workplaces, regions or countries - with implications for the size of the spillovers from diversity. Attempts to test this idea at the regional scale support the notion that the diversity-productivity relationship depends on these interaction costs (Alesina and La Ferrara, 2005; Kemeny, 2012; Kemeny and Cooke, 2017). These interaction costs are shaped by 'institutions', which are collective and can be formal (Collier, 2000; Easterly, 2001) or informal. In the latter case, they reflect the sum of individual attitudes toward diversity and orientation to the local culture.

This opens the door to the present study, which is the first robust attempt to directly examine immigrants' assimilation and its potential moderating role on the relationship of interest. Assimilation is a sociotemporal dimension of immigration: immigrants begin as 'unassimilated' and in most cases become progressively more integrated into their host country over time. This is a function of both traditional conceptions of immigrants adopting the norms of the host country, but also of changes in the host country in response to increasing diversity and the cultural influence of migrants (Jimenez, 2017). This process of assimilation could affect the association between diversity and productivity in two ways. Assimilation may lower the cost of intercultural interaction, thereby enhancing immigrant diversity spillovers. Or, assimilation might mean that, through narrowing the socioeconomic and cultural distance with the host-country culture, immigrants reduce their cultural distinctiveness. If this also reduces their heuristic distinctiveness, then assimilation could dampen spillovers from immigrant diversity.

Very few studies within the economics of diversity literature have touched on this dynamic; none with the kind of motivating theory described here. Moreover, the suggestions we do get from existing evidence are inconclusive. Largely as robustness tests, two papers have examined the impacts of excluding childhood immigrant arrivals or second generation children of immigrants from their diversity measures, on

the logic that these groups are primarily socialized in the host country so thus are 'too assimilated' to be considerent truly different. In a cross-country study, Alesina et al. (2016) find that excluding childhood arrivals from measures of immigrant diversity does not affect their observed positive relationship between diversity and per capita GDP. They also detect no statistically significant differences when they exclude teenage and young adult arrivals. Similarly, Mőhlmann and Bakens (2015) find no difference in their estimates if they include second generation workers in their diversity measures. Hence, the second generation may still be contributing to diversity spillovers. In contrast, when Alesina et al. (2016) jointly consider recent and previous immigration, they find that immigrant diversity in 1960 is unrelated to current per capita GDP, while current diversity remains positive and significant. They interpret this to suggest that the development benefits of diversity flow from first- and not second-generation immigrants. Finally, Alesina et al. (2016) find that the association between birthplace diversity and per capita GDP appear largest for immigrants originating from countries at intermediate levels of cultural proximity, defined by colonial relationships and languages. Though intriguing, this 'goldilocks' finding of an optimal level of cultural proximity being not too close but not too far away (Fitjar et al., 2016), suggests that the cultural distance is important to the relationship of interest, but ultimately does not help us make clear progress on how assimilation may impact it, since cultural proximity measures lack the dynamic temporal aspect of assimilation processes. Clearly, more work is needed to understand the potential moderating role of assimilation in the relationship between diversity and productivity.

Before discussing how we aim to contribute to the scholarly understanding of this topic, we now briefly discuss processes of immigrant integration.

2.2 Assimilation and Immigrant Integration

Approaches to cultural diversity vary across nations and have changed over time. Arguably two sides of the same coin, segregation and forced assimilation policies have variously targeted indigenous populations, racial minorities, and immigrants. Segregation policies rely on keeping minority and majority communities apart, e.g. in different occupations, schools or neighborhoods (e.g. ghettos). Forced assimilation policies mandate that cultural minorities abandon their own culture and adopt that of the dominant power structure, for instance by outlawing minority language, religion, clothing, or other cultural markers. They have also taken the form of family separation, removing indigenous children from their families and placing them in boarding schools (e.g., Minde, 2005). These policies meshed with mid-20th century theories of immigrant assimilation, which often employed deeply bigoted and ethnocentric framings of multigenerational incorporation processes (see Alba and Nee,

1997). But there have also been important counternarratives to these repressive policies in the form of both individual resistence (Child, 1998; Pilkington, 2002) and collective organizing for equal rights and treatment (e.g., Innis-Jiménez, 2013; Katz, 2011; Tyler, 2016). Less oppressive approaches to encouraging assimilation can be found in efforts like the settlement house movement in the US, with its early focus on easing the poverty and social exclusion of European immigrants in the late 19th and early 20th century (Davis, 1984).

These counternarratives, among others, helped lay the groundwork for a broad rise of liberal ideas and increasing respect for human rights. Segregation and forced assimilation policies were largely replaced with multicultural integration policies in which minorities were encouraged to maintain many aspects of their own culture while also gaining greater access to economic opportunity and political inclusion. With variation across countries and across specific minority populations, these included such policies as protection of minority languages and encouragement of bilingualism, changes in school curricula, affirmative action, formal rights recognition, and dual citizenship (Kymlicka, 2010).

The multicultural shift also implied a recognition that the majority culture will also change with purposeful recognition and inclusion of minority populations. This is reflected in important work in sociology to redefine assimilation and retheorize it to help shed light on the the social dynamics of ethnicity, even outside formal policy. Alba and Nee (1997) write: "As a state-imposed normative program aimed at eradicating minority cultures, assimilation has been justifiably repudiated. But as a social process that occurs spontaneously and often unintentionally in the course of interaction between majority and minority groups, assimilation remains a key concept for the study of intergroup relations" (p. 827). Indeed, while still acknowledging how uneven power relations shape these interactions, Jimenez (2017) theorizes assimilation as a relational process. The changes over time are not unidirectional, but rather involve "back-and-forth adjustments in daily life by both newcomers and established individuals as they come into contact with one another" (p. 11). Just as the process of assimilation is not unidirectional, the trajectory of policy around integration does not flow in one direction. Witness the recent rise in bans on religious headwear in countries like France, Belgium and the Netherlands (Kymlicka, 2010; Vertovec, 2010), and the rise in the US of local ordinances aimed variously at either welcoming and including immigrants communities, or excluding them, including adopting English-only language ordinances (Walker and Leitner, 2011).

2.3 Immigration and Integration in Norway

Traditionally a relatively homogeneous country in ethnic terms (albeit with a minority indigenous Sami population), Norway started receiving larger streams of migrants

mainly from the 1970s. Labour migrants from Pakistan, Turkey and Morocco were among the early arrivals. In the same period, discoveries of crude oil in offshore waters brought high-skilled migrants from Western Europe and North America to work in the multinational oil companies. The migrant population expanded gradually, in size as well as diversity. In 1970, the Norwegian immigrant population consisted of less than 60,000 people, of which more than 80% were European. By 2018, this had grown to more than 900,000 (equivalent to 14% of the population), of which less than half were European (SSB, 2018). In particular, migration rates grew following the 2004 expansion of the European Union, which opened for labour migration from Central and Eastern Europe. The largest foreign-born population is currently from Poland, followed by Lithuania, Sweden, Somalia and Syria.

Norwegian integration policy has largely followed the broader international trends outlined above. Historically, Norway pursued a policy of forced assimilation towards the indigenous Sami population (Minde, 2005). This was initially also the approach taken towards immigrants. However, from the 1980s, integration became an important policy ideal and policy discourse gradually moved from conceptions of a homogeneous society towards ideals of multiculturalism (Hagelund, 2002). Immigration policy has become gradually more restrictive. Alongside other European countries, Norway introduced a temporary ban on immigration in 1975, essentially limiting migration to highly-skilled specialists, as well as asylum-seekers and refugees. However, membership of the European Economic Area created a new opening for labour migration under the terms of the Single Market, which became particularly relevant following the EU expansion. Immigration policy remains a contentious policy issue, in particular as pertains to asylum policy. Norway has had a sizeable anti-immigrant party since the 1970s, and mainstream parties have also become increasingly restrictive on immigration. Consequently, most policy changes in this area seek to limit access for asylum-seekers. This has also been reflected in growing criticism of the multicultural ideals from anti-immigrant movements (Eriksen, 2016), although Norwegian integration policy remains fundamentally anchored in multiculturalism.

2.4 Measuring Assimilation or Integration

Approximating assimilation in quantifiable units is challenging. Assimilation processes are multifaceted, which necessarily means that any single measure will be incomplete. They take place over both short and long time periods. Drawing on research in Silicon Valley in the U.S., Jimenez (2017) writes: "This volley of back-and-forth adjustments starts off with rapid-fire intensity as new arrivals and established individuals first meet, and it gradually moderates over time, often across generations.". This suggests that multiple time scales should be measured. These processes are also relational, and at least partly involve developing a "working con-

sensus around ethnic, racial, and national belonging" and "interpreting the details of daily living"(Jimenez, 2017, p. 10-11). Hence, key aspects will be unobservable at scale. Empirical research aiming to measure assimilation must rely on multiple proxies that together triangulate some aspects of this dynamic social process.

3 Empirical Approach

The first aim of this paper is to measure the spillovers from immigrant diversity on worker productivity in the Norwegian economy. The second aim is to investigate whether and how these processes are moderated by immigrant integration into Norwegian society.

To satisfy these aims, we adapt an approach used by several recent papers that each leverage matched employer-employee data to evaluate the relationship of interest (Trax et al., 2015; Kemeny and Cooke, 2018; Cooke and Kemeny, 2017). Like much of the extant literature, we proxy for productivity using earnings. We limit the dataset to focus on the longest work spell for 'stayers' – individuals that remain in the same workplace and in the same region for at least two consecutive calendar years. These workers are fixed in place, and variation arises from the panel structure of the data. We therefore analyze how workers' earnings respond to changes in the immigrant composition of the region in which they live, as well as in the establishment in which they work. Our basic model is described as follows:

$$ln(w)_{ipjt} = \beta_1 d_{jt} + \beta_2 d_{pjt} + X'_{ipjt} + E'_{pjt} + C'_{jt} + \mu_{ipjt} \tag{1}$$

In this equation, $ln(w)$ is the log annual wage of an individual worker i in establishment p located in region j at time t. The two independent variables of interest are d_{jt} and d_{pjt}, which measure diversity among the immigrant population at the scale of the region and the establishment, respectively. The vectors X', E', and C' capture time-varying characteristics of workers, establishments and regions, respectively. Finally, μ_{ipjt} represents a standard error term. In estimation, we decompose this error term, adapting a two-way fixed effects error components model (Baltagi, 2013), such that:

$$\mu_{ipjt} = \mu_{ipj} + \lambda_t + \upsilon_{ipjt} \tag{2}$$

The first error component represents a key feature of our approach. In a conventional two-way fixed effects model, this term would represent a fixed parameter capturing stationary unobservable individual-level factors. However, owing to our focus on spells of 'stayers', μ_{ipj} absorbs bias not just from individual-level unmeasured characteristics, but also time-invariant unobservables at the workplace and regional scales.

At the individual level, these might include differences in workers' innate ability, intelligence, or motivation. Establishment-specific features could include enduring differences in capital intensiveness or product quality. And at the level of regions, deep-rooted variation in specialization and agglomeration could be relevant, if hard to precisely capture (Kemeny and Storper, 2015). The remainder of the error term is decomposed in the standard manner, with λ_t being a time fixed effect that absorbs bias from unobserved time-specific shocks such as recessions and other business cycle effects. Finally v_{ipjt} represents the remaining stochastic disturbance term. The primary identifying assumption is that pertinent nonstationary unobserved factors ought to be uncorrelated with changes in regional or establishment-level diversity.

Although some studies pair an equation predicting earnings with another predicting rents, following Moretti (2013) and Acemoglu and Zilibotti (2001), we argue that identification does not demand a Roback-style complementary equation predicting rents (Roback, 1982). In regions that contain tradeable sectors, earnings unadjusted for cost-of-living difference will reflect underlying productivity, as such firms are faced with national, and not regional prices. This is a reasonable assumption in the Norwegian case, where interregional cost-of-living differences are in any case relatively moderate, and where wages are partly determined through national negotiations.

Though this argument has been made in more market-oriented economies like the US, it is worth considering the usefulness of earnings as a proxy for productivity in the specific Norwegian context. One potential challenge is that under the Norwegian system of collective bargaining, wages are set annually through a combination of central and local negotiations, resulting in a relatively compressed wage structure that might not fully represent productivity at the individual level. At the same time, these processes are more important in some sectors than others. As a robustness check, we consider a subset of industries in which the relationship between productivity and wages can be expected to be higher, due to competitive pressures or wage-setting procedures.

3.1 Measuring diversity and assimilation

We build annual region- and establishment-specific measures of immigrant diversity in several varieties, each reflecting different aspects of potential immigrant integration. To create these measures, we observe each working-age individual's job spell with each employer and their place of residence. We use this information, in combination with information on country of birth, to estimate measures of immigrant diversity at each scale, based on the set of all workers in the establishment and in the region during a given year. We use a variant of a standard fractionalization index, which we estimate specifically across the non-native population. The frac-

tionalization index is apt as it captures both the breadth of countries from which individuals originate, as well as the relative sizes of these different country groups. Though region-focused researchers have used various measures to describe diversity, the fractionalization index remains by far the most common, and results across different measures tend toward consistency.[2] At the regional scale, our baseline index is calculated as follows:

$$d_{jt} = 1 - \sum_{r=1}^{R} s_{rjt}^2 \tag{3}$$

where s is the proportion of all immigrants in the region j who were born in country r in time t; and R is the maximum number of countries captured in the immigrant population of the region. The index ranges between a low of zero, meaning all immigrants come from a single country, and a maximum diversity value nearing one (more specifically (1-1/R)), reflecting a situation where each immigrant group would occupy the same proportion of the total immigrant population. The index can be thought of as summarizing the probability that two immigrants who meet at random in a particular context were born in two different countries. We exclude native Norwegians from equation (3) because to do otherwise renders the measure very highly correlated with the simple share of all foreign born in the population. This would then conflate effects from overall immigration with effects from diversity, defined in terms of the mix of countries from which immigrants hail. At the same time, we include the simple share of foreign born as a control, to ensure we can separately account for effects that derive from immigration flows on the whole.

Equation (3) presumes that all immigrants from country r are homogenous, contributing equally to the overall measure of diversity. Implicitly, all studies of birthplace diversity make this assumption. However, immigrants vary from one another, in particular in terms of their degree of assimilation into the host society. In this case, their location at the time of birth may not be the only appropriate measure of diversity. Consequently, we proceed to vary the definition of immigrant according to different dimensions of assimilation, in each case excluding more highly assimilated immigrants from the measure in order to examine how this influences the size of the spillovers from diversity. The aim in this regard is to observe how the coefficients for migrant diversity vary across different possible definitions of migrant status. Specifically, we compute variants of equation (3) for specific subsets of less assimilated immigrants. In effect, we exclude highly assimilated immigrants from the diversity measures in order to compare the spillovers from unassimilated workers with those calculated for all foreign-born workers. Based on the review in Section

[2]For a wider discussion of measurement, consult Dawson (2012); Kemeny (2014); Nijkamp and Poot (2015).

2, we consider the following observable characteristics that proxy for differences in assimilation: length of stay; age of arrival; educational background; second generation status; and cultural proximity between the native country and Norway. The Immigration database provides information on time of arrival in Norway. The National Educational Database (NUDB) provides data on immigrants with educational background from Norwegian universities. For second generation status, we assigned individual background to mother's country of birth[3]. For cultural proximity, we exclude immigrants from culturally and linguistically similar neighbouring countries (Sweden, Denmark and Iceland). We assume that immigrants are more likely to have been assimilated if they have stayed in Norway for an extended period, were very young when arriving in the country, are part of the second generation, have studied at a Norwegian university, or were born in a culturally similar society.

3.2 Establishment-level and regional controls

The overall estimation approach accounts for various static unobserved factors, as well as system-wide dynamics such as business cycles. Nonetheless, estimates of equation (1) remain vulnerable to structural changes that affect individuals, workplaces or regions differently. While it is impossible to fully account for all changes that may have non-uniform effects, we address such concerns by controlling for several time-varying factors at the workplace and regional scale. As described in the previous section, we control for the share of foreign-born at both the regional and establishment scale. When, in our diversity measures, we limit attention to immigrants at particular levels of integration, we also adjust proportions of foreign-born to that same subgroup. Additional control variables include establishment employment and regional population, accounting for internal and external economies of scale, respectively. We also measure the share of employees with tertiary education at each of these two scales. Motivated by studies by Moretti (2004) and others, in doing so we aim to capture potential spillovers flowing from the presence of educated individuals, whether as co-workers or neighbors. These variables are drawn from the Norwegian Education Database, which includes details on the educational background of individuals educated at Norwegian universities or who receive a Norwegian student loan.

Finally, we consider the potential role of regional and local demand shocks which could shift the supply of different types of workers. Local demand shifts might be correlated with changes in diversity, due to the generally higher geographical mobility of immigrants compared to natives[4]. To measure local demand shocks,

[3]We only have data on mother's background country.

[4]Regions may experience an increase in the average wage as a result of a positive economic shock. This could attract migrants, leading to an increase in diversity. In the Norwegian case, this

we draw on a method developed by Bartik (1991) and widely used in labor and regional economics (see, for instance Bound and Holzer, 2000). As a means to produce measures of local demand that are unrelated to shifts in local labor supply, the measure applies industry-specific national employment growth rates to local industry employment shares. The 'Bartik' measure is constructed as follows:

$$Bartik_{jt} = \sum_{l=1}^{L} e_{jlt-1}(lnE_{lt-1} - E_{lt-1}) \tag{4}$$

where $Bartik_{jt}$ captures the growth in log national employment in industry l at time t, and the local employment weight to national measure is indicated by E. We use data on regional industry structure based on NACE codes at the two-digit level [5]

4 Data and analytical sample

The analysis uses linked employer-employee data from Norwegian individual and establishment registers. The annual data spans the period 2001 to 2011, and covers all inhabitants in Norway over the age of 16 who are employed in the private sector, and all establishments located in Norway. The registers provide a range of information about individual workers, such as their place and year of birth, mothers' place of birth, sex, educational background, place of residence and employment, employer, working hours, and annual wage. For immigrants, the registers provide information on when they first entered the country, their age and if they have taken any education in Norway. A limitation is that the data do not describe immigrants' educational background outside of Norway. At the establishment level, the registers include information on location, industry and number of employees. Additional establishment-level variables are calculated from the individual registers based on the composition of each establishment.

The analytical sample is limited to 'stayers', i.e. individuals who remain in the same establishment and region for at least two years, in order to minimize sorting effects as much as possible. From the full population of private-sector employees, we identify and keep each worker's longest continuous job spell. Thus, each individual can only appear in one establishment and one region in the panel, even if they have multiple job spells over their observed career that meet the two-year minimum. We further limit the sample by excluding workers registered as working part-time and

is particularly pertinent for regions specialising in oil extraction, which may become 'boom regions' in periods of rising oil prices (Fitjar and Timmermans, 2019). Such reverse causality could result in upwardly biased estimates. One way to tackle this problem is to control for local demand shocks.

[5] Because of the change to NACE rev. 2 in 2007, we convert all NACE codes back to NACE rev. 1, allowing us to apply this index for the whole time period.

earning very low wages[6], in order to focus on full-time employment. We also restrict the sample to establishments with at least 10 employees. The resulting sample includes 6,769,648 observations of 1,262,457 individuals.

4.1 Sample characteristics and control variables

Table 1 provides summary statistics for the analytical sample. The dataset includes nearly 1.3 millions individuals working in almost 35,000 establishments. Average earnings are around 440,000 NOK [7].

Table 1: Summary statistics

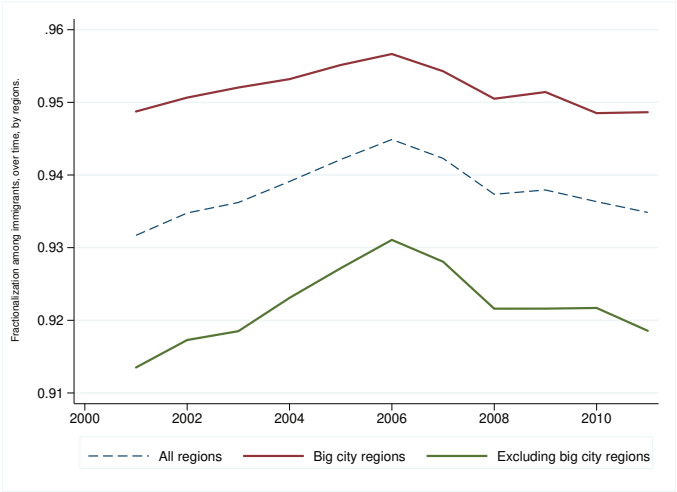
Variable	Mean	Standard deviation
Individual characteristics		
Age	42.08	11.43
Annual wage (NOK)	439,280	285,249
Spell duration in years	7.20	3.03
Establishment measures		
Birthplace fractionalization	0.67	0.33
Share foreign-born	0.10	0.12
Firm size	204	417
Share of educated employees	0.22	0.21
Regional measures		
Birthplace fractionalization	0.92	0.03
Share foreign-born	0.10	0.04
Population	106,229	116,818
Share of educated employees	0.20	0.07
Individuals	1,262,272	
Establishments	34,707	
Regions	78	
Observations	6,769,648	

[6]We exclude earnings that are below 100 000 NOK, as these are unlikely to reflect full-time employment.

[7]440,000 NOK (Norwegian krone) was the equivalent of approximately 51,000 US Dollars in 2011.

Figure 1 shows the fractionalization among immigrants over time in all regions, as well as separately for big city regions[8] and all other regions. Fractionalization is highest in the big city regions throughout the period. However, other regions contribute most to the change in fractionalization in the beginning of the period, while there is a more equal pattern in both types of regions in final part of the period.

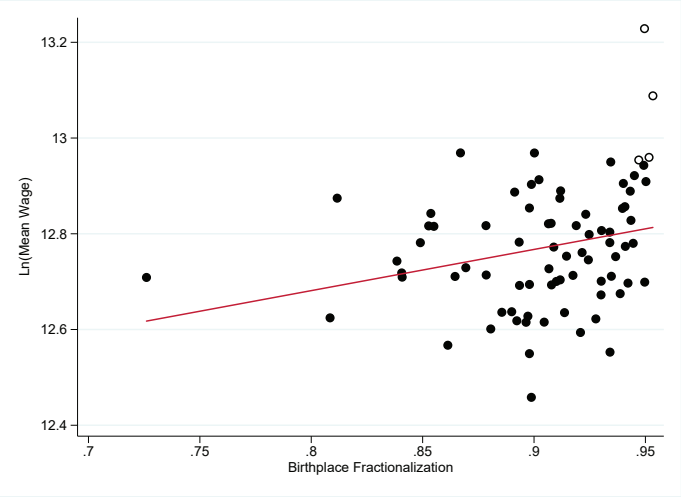
Figure 1: Fractionalization among immigrants, over time



Norway experienced a large growth in immigration over the study period. The share of foreign-born in the dataset grew from 6 percent to 14 percent over the period (see Figure A1 in the appendix). The increase in average wage levels is similar across the regions (see Figure A2 in the appendix). However, on average, the tends to be an association between mean wages and birthplace diversity. Of course, big city regions (shown as non-filled circles in Figure 3) feature a high level of both fractionalization and average wages. However, average wages also tend to be higher in peripheral regions with higher levels of diversity.

[8]Oslo, Bergen, Stavanger and Trondheim

Figure 2: Wages and Birthplace fractionalization, 2001–2011.



Note: Points on the scatterplot reflect regional average values of wages and birthplace fractionalization among immigrants. The solig line reflects the least-squares fitted regression line.

5 Results

In this section, we first examine the overall spillovers from immigrant diversity on productivity for Norwegian workers. Subsequently, we examine how these spillovers are influenced by assimilation processes. We consider various dimensions of assimilation, in each case excluding more highly assimilated workers from the diversity measures in order to examine how the coefficients for spillovers change. Comparing these results with those from the initial analyses provides an indication of how the spillovers from immigrant diversity might vary depending on the assimilation of immigrants into the host society. Finally, we report various robustness checks.

5.1 Overall immigrant diversity spillovers in Norway

Table 2 shows the results for the overall relationship between diversity spillovers and productivity in the Norwegian context estimated using Eq.1. In column 1, we include establishment-level diversity and controls only. The coefficient for establishment-level diversity, measured by birthplace fractionalization, is insignificant[9]. The share of foreign-born is also insignificant. Meanwhile, firm size and share of educated employees are positive and significant, as expected. In column 2, we add region-level measures. As in the previous model, establishment-level measures of diversity and the share of foreign born are insignificantly related to worker wages. Meanwhile, regional birthplace diversity and the regional share of foreign-born are both posi-

[9]Assuming a threshold of 0.05.

tively and significantly linked to wages. These results are broadly consistent with findings from studies of diversity spillovers in other country contexts, although the spillovers from diversity in the Norwegian case flow only from diversity manifested at the regional scale.

Table 2: Overall spillovers from immigrant diversity for Norwegian workers, 2001-2011.

	Dependent variable: log of annual earnings	
	(1)	(2)
Establishment measures		
Diversity	0.001	0.000
	(0.001)	(0.001)
Share foreign-born	0.016	-0.001
	(0.008)	(0.007)
Firm size *(log)*	0.062**	0.059**
	(0.013)	(0.019)
Share of educated employees*(log)*	0.073**	0.072**
	(0.002)	(0.011)
Regional measures		
Diversity		0.048**
		(0.015)
Share foreign-born		0.226**
		(0.056)
Regional size *(log)*		0.150**
		(0.011)
Share of educated employees		0.192**
		(0.049)

Note: All models include year and individual-establishment-region fixed-effects. Standard errors in parentheses, clustered by establishment. Both models includes 6,769,648 observations, 1,262,457 individuals and 34,715 establishments. $R^2 = 0.42$. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

5.2 Diversity spillovers from less assimilated workers

Having confirmed that there are spillovers from regional immigrant diversity also in the Norwegian case, this section addresses the main research question of this paper: How does assimilation of immigrant workers affect these diversity spillovers. Below, we examine various dimensions of the assimilation process in turn: Length of stay, age of arrival, exposure to host country institutions, cultural proximity to native country, and second generation status. Table 3 presents the estimates for the relationship between birthplace diversity by various dimension of the assimilation process. We present coefficients and standard errors only for the key independent

variables of interest - establishment and regional immigrant diversity, measured by birthplace fractionalization. However, each model includes the full battery of control variables discussed in section 4.1. These controls offer consistent predictions across the various models and are in line with expectations. This is also the case for the analyses in the following sections.

Table 3: Diversity spillovers by various dimension of the assimilation process

	Dependent variable: log of annual earnings:	
	Establishment-level	Regional-level
All immigrants	0.001	0.048**
	(0.001)	(0.015)
Length of stay:		
2 or less	0.001**	0.048**
	(0.002)	(0.007)
5 or less	0.007**	0.104***
	(0.001)	(0.012)
10 or less	0.015**	0.090***
	(0.002)	(0.017)
15 or less	0.001***	0.080***
	(0.007)	(0.021)
Exposure to host country institutions:		
Arrived after age 13	0.005	0.124***
	(0.001)	(0.027)
Immigrant not educated in Norway	-0.000	0.254*
	(0.001)	(0.123)
Cultural proximity to native country:		
Excluding neighbouring countries	0.001	0.182***
	(0.001)	(0.029)
First- or second-generation status:		
Including second-generation	0.000	0.001
	(0.001)	(0.021)

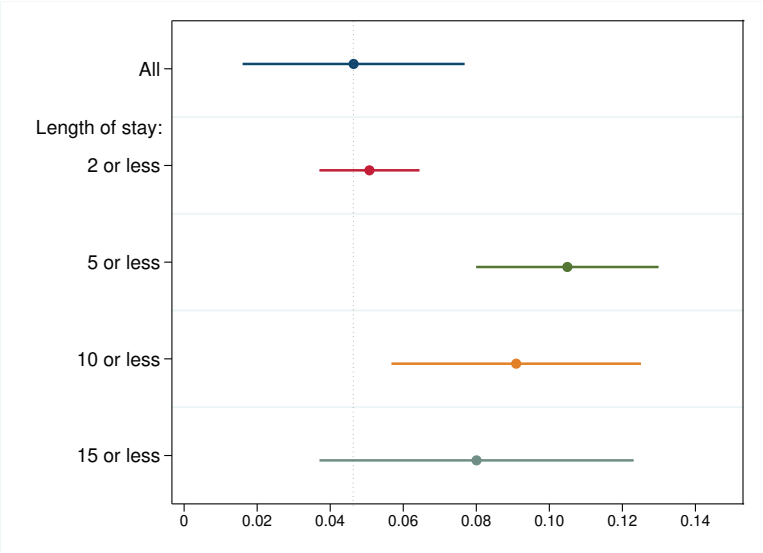
Note: Controls, year- and individual-establishment-region fixed effects, and Bartik-index are included in all models. For all models $R^2 = 0.42$; All models estimated on 6,769,648 observations nested in 1,262,457 individuals. Standard errors in parentheses, clustered by establishment. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.3 Length of stay

In Table 3, the first row report the estimates for our baseline, diversity among all immigrants in Norway. We then report estimates for diversity among immigrants

who have spent up to two, five, ten, and fifteen years in Norway. At the establishment level, there are significant and positive spillovers from diversity as soon as particularly long-term migrants (i.e. those who have lived in Norway for more than 15 years) are excluded from the fractionalization measures. The coefficients increase as migrants become more recent, although these differences in effect size are not statistically significant. At the regional level, the effect sizes also increase as long-term migrants are excluded. Excluding migrants who have lived in Norway for more than 15 years already doubles the effect of regional immigrant diversity. The largest spillovers are found when we include migrants who arrived up to five years ago. When looking only at very recent migrants (less than two years), the spillovers are smaller. Potentially, this reflects higher interaction costs for very recent migrants. Overall, these results seem to indicate a curvilinear effect of the assimilation process on diversity spillovers. The spillovers from diversity tend to grow as migrants become more assimilated to Norwegian cultural codes, but only up to a point (after around 5 years), after which their heuristic diversity from the native population diminishes. Figure 3 plots the coefficients for regional birthplace fractionalization, along with their confidence intervals, for comparison. As the figure shows, birthplace fractionalization among immigrants with up to five years of stay in Norway has a significantly stronger effect than birthplace fractionalization among all foreign-born (i.e. including those with longer spells in the country). It also has a significantly stronger effect than birthplace fractionalization among very recent entrants only.

Figure 3: Estimated cofficients for regional diversity by length of stay



5.3.1 Age of arrival

Table 3 continues by examines another dimension of the assimilation process: the immigrant‘s age when first settling in Norway. Childhood arrivals would be more easily socialized into Norwegian culture then those who arrive at a more mature age. The coefficient for establishment level diversity is positive and significant when we limit the measure of birthplace fractionalization to immigrant arriving in their teens or as adults. At the regional level, the effect of birthplace fractionalization is 2.5 times higher when childhoos arrivals are excluded.

5.3.2 Exposure to host country institutions

Table 3 then presents the impact of exposure to host country institutions, specifically treating immigrants who have enrolled in tertiary education in Norway as assimilated. At the establishment level, the coefficient remains insignificant when excluding migrants not educated in Norway. At the regional level, the effect becomes much stronger when these migrants.

5.3.3 Cultural proximity

Table 3 continues by examines the impact of diversity when excluding immigrants from neighbouring countires, which are culturally and linguistically similar to Noray and where we can therefore expect the assimilation process to go faster (and heuristic diversity to be lower). The effect of fractionalization at the regional level is again much higher when excluding immigrants from neighbouring countries than when considering all foreign-born. For establishment-level diversity, the coefficient is not statistically significant regardless of whether we include or exclude immigrants from neighbouring countries.

5.3.4 Second-generation status

In the last line, in Table 3, the estimated for diversity when including second-generation immigrants. Contray to the above analysis, this measure expands rather then restricts the definition of diversity. Instead of excluding foreign-born which are highliy assimilated, this analysis includes potentially less assimilated native-born in the measure of diversity. Potentially, second-generation migrants could still offer some heuristic diversty relative to the native population. However, the results show that the effect of both regional diveristy diappear when including second generation migrants. This correspond to the results of Alesina et al. (2016), but in contrast with Møhlmann and Bakens (2015).

5.4 Robustness checks

One potential concern in these analyses is that individual wages in Norway do not directly reflect productivity, due to the Norwegian system of collective bargaining. In order to examine this, Table 4 shows the results for subsets of industries where wages can be expected to correspond more closely to individual productivity. These are tradable industries, where international competitive pressures mean that employers cannot afford to pay wages that do not reflect productivity levels, and knowledge-intensive industries (high-technology manufacturing and knowledge-intensive services), where there is a larger tradition of individual wage negotiations. The table reports coefficients for regional diversity only. The results for control variables and for establishment diversity are similar to those for the overall model.

For tradables, the spillovers from diversity are larger than for all industries. The patterns by length of stay follow the same pattern as in the analyses for all industries. For knowledge-intensive industries, the effects are similar to those found for all industries. Overall, this suggests that the results hold also for industries where wages more closely reflect individual productivity.

Table 4: Diversity spillovers by length of stay for various subsets of workers

	Dependent variable: log of annual earnings:		
	Tradeable	High-Tech.	Knowledge Int.
	(1)	(2)	(3)
Length of Stay:			
$\leq$ 2 years	0.075***	0.074*	0.040***
	(0.011)	(0.069)	(0.016)
$\leq$ 5 years	0.209***	0.251*	0.125**
	(0.038)	(0.014)	(0.071)
$\leq$ 10 years	0.204***	0.221*	0.192*
	(0.044)	(0.044)	(0.087)
$\leq$ 15 years	0.165*	0.166*	0.109*
	(0.035)	(0.023)	(0.035)
All	0.087***	0.034	0.052*
	(0.026)	(0.128)	(0.038)

Note: Controls, year- and individual-establishment-region fixed effects. For Column (1) all models $R^2 = 0.41$; All models estimated on 1,421,507 observations nested in 422,152 individuals. For Column (2) all models $R^2 = 0.44$; All models estimated on 93,787 observations nested in 16,462 individuals. For Column (3) all models $R^2 = 0.41$; All models estimated on 2,661,814 observations nested in 565,007 individuals. For Column (4) all models $R^2 = 0.39$; All models estimated on 1,051,751 observations nested in 292,248 individuals. Standard errors in parentheses, clustered by establishment. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A second concern is that the results might be driven by a few big city regions. As

Figure 2 shows, the four largest city regions have the highest average wage levels as well as the highest fractionalization levels (although the changes in fractionalization, which we are analyzing here, have been larger in peripheral regions). To address this, Table 5 presents the results when excluding these four regions from the analysis. While the coefficients are somewhat weaker than in the main analysis, they remain statistically significant and follow the same pattern as in the analysis for all regions.

Table 5: Diversity spillovers by region size

	Dependent variable: log of annual earnings:	
	Excluding big city regions	All
	(1)	(2)
Length of Stay:		
≤2 years	0.039***	0.048**
	(0.007)	(0.007)
≤ 5 years	0.099**	0.104***
	(0.023)	(0.012)
≤ 10 years	0.087*	0.090**
	(0.032)	(0.017)
≤ 15 years	0.074*	0.080***
	(0.023)	(0.021)
All	0.021*	0.048**
	(0.005)	(0.015)

Note: Controls, year- and individual-establishment-region fixed effects. For Column (1) R^2 = 0.41, estimated on 2,661,814 observations nested in 565,007 individuals. For Column (2) R^2 = 0.42, estimated 6,769648 observations nested 1,262457 individuals. Standard errors in parentheses, clustered by establishment. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6 Conclusion

Using data from Norway, this article has examined if the spillovers from migrant diversity are affected by assimilation into the host society. Previous research on spillovers from diversity has assumed that immigrants from any particular country are homogenous. However, migrants' contributions to diversity in a firm or region is a function of their assimilation into society. While assimilation helps migrants to communicate better with the native-born population, highly assimilated migrants may also to a lesser extent be able to offer different perspectives and heuristics. Hence, the heuristic diversity might be lower than what a simple analysis of birthplace diversity would suggest. This paper is the first to consider how this assimilation process shapes the economic spillovers from diversity.

Indeed, we find that assimilation, in a variety of dimensions, dampens the positive spillovers from diversity. The spillovers from diversity are higher when looking only at recent arrivals, with the highest coefficient for arrivals within the last five years (although the spillovers from very recent arrivals are lower, suggesting some assimilation may be helpful in enhancing the spillovers from diversity). The spillovers are also higher when restricting the analysis to teenage or adult arrivals, or when excluding migrants who studied at Norwegian universities. Similarly, the spillovers are higher for migrants from more distant cultures than when including immigrants from other Nordic countries. Finally, the effects disappear completely when considering immigrants who are part of the second-generation.

Overall, the results indicate that assimilation processes may be associated with a reduction in heuristic diversity. These effects seem to outweigh the positive effects of assimilation on reduced communication costs. For any observable measure of assimilation, we find lower spillover effects from immigrants that we can assume to be more highly assimilated into the host society. Of course, this does not imply that policy-makers should forget about integration of migrants. However, it does mean that integration policies need to be aware of the benefits of allowing migrants to also maintain their native culture. Wiping out cultural differences between migrants and the native population means that there is less potential for migrants to make a unique positive contribution to their firms and regions by providing alternative perspectives and new ideas.

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