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Same Sea, Different Ponds: Cross-Sectorial Knowledge Spillovers in the North Sea

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ABSTRACT

Knowledge spillovers are crucial to innovation and upgrading, but it is largely unclear what knowledge spillovers are made of and how they actually happen. The importance of MAR vs. Jacobs externalities is also a debated matter, whereas the concept of "related variety" has recently come to occupy a middle-ground position. However, the relatedness concept is ambiguous in terms of operationalization and emphasises codified knowledge on behalf of other knowledge resources that are important for innovation, particularly if firms cross into new sectors. This paper sheds light on the "black box" concepts of knowledge spillovers and relatedness by exploring cross-sectorial transfers from the mature offshore oil and gas sector into the emerging offshore wind industry. A qualitative research design allows for a more nuanced understanding of the contents of knowledge spillovers and (un)relatedness between sectors.

1 Introduction

Knowledge spillovers are crucial to innovation, but it is largely unclear "what" knowledge spillovers are actually made of and how they happen (Boschma and Frenken 2011, Malerba 2002, Izushi and Aoyama 2006). The nature and level of innovation is related to whether knowledge spillovers are intra-sectorial or cross-sectorial, but the literature is inconsistent on how and why. Whereas the former is associated with agglomeration theory and economic specialisation, the latter is a core ingredient of urbanization theory and economic diversity or variety (Asheim, Boschma and Cooke 2011). Recently, the concept of "related variety" (Frenken and Boschma 2007), and the broader concept of "relatedness" (Cooke 2012b), has come to occupy a middle-ground position in the agglomeration/specialisation-urbanization/diversity debate. The main argument is that it is not variety or specialisation per se that matters in terms of facilitating knowledge spillovers, but related variety. Related variety studies suggest that new industries are more successful when they evolve from the knowledge and resource base of existing industries (Boschma and Frenken 2011). However, there is no consistent way to measure industrial relatedness (see Cainelli and Iacobucci 2012, Erlinghagen and Markard 2012). Relatedness may be defined with regard to several different characteristics such as inputs, outputs and production methods. When relatedness is operationalized for quantitative analysis, complexity must be reduced to fit predefined categories. This implies that both knowledge spillovers and relatedness are "black box" concepts.

This paper uses data based on a qualitative research design to shed some new light on knowledge spillovers and relatedness. We explore the case of the emerging offshore wind (OW) sector, which has its strongest area of growth in the North Sea in Northern Europe (EWEA 2013). We focus on the Norwegian firms who have become involved in OW, of which most are active in the established offshore oil and gas (O&G) sector and related industries such as maritime logistics, and that are attracted by new opportunities to diversify or expand their operations. This has become particularly apparent over the last few years, as the development of OW farms further from shore in deeper waters has created demand for products and services from specialised offshore firms. A report by the European Wind Energy Association (EWEA 2011, 35) states that the increased participation of O&G sector firms in OW "offer the real possibility of the widely discussed cross fertilization of skills and knowledge from the offshore oil and gas sector to come to fruition." Whereas Norway's onshore wind industry is marginal and Norway is the only North Sea country without OW farms, there is a perception that Norway's legacy and resource base from offshore O&G and other maritime sectors gives competitive advantages for taking part in OW (NOU 2012, Douglas Westwood 2010). Both O&G and OW are large-scale, capital-intensive and project-based offshore energy industries, thus requiring many similar inputs and both produce energy as final output. We posit that a key mechanism for knowledge spillovers is firms seeking opportunities in related sectors and in so doing transfer different types of knowledge. This means that knowledge spillovers are not accidental, as often assumed in the literature, but more often the case of strategic efforts. It also means that academics should scout for both enabling and constraining factors involved in these processes. Thus, it is not a priori

given that assets and skills from O&G constitute a suitable basis for firms attempting to take part in OW.

Against this background, the central questions that motivate this paper are: "What knowledge and other resources are transferred when firms from the mature O&G sector firms enter the emerging OW sector, what variety does this contribute to in OW, and what factors enable or hinder cross-sectorial knowledge spillovers?"

By exploring these issues, the paper makes both theoretical and empirical contributions. First, the paper contributes to the understanding of the agency of knowledge spillovers, particularly in the context of cross-sectorial flows into an emerging industry. The paper thus also ties in with the recent debate on related variety based path creation (Fornahl et al. 2012, Martin 2010), especially with regard to new pathways in renewable energy (Simmie 2012) by processes of "transversality" whereby resources are transferred into new/other sectors (Cooke 2011) through cross-sectorial activities of firms that by so doing contribute with new variety and thus provide nourishment for sectorial development and transformation (Nelson and Winter 1982). Moreover, the paper contributes empirically to an enriched understanding of one of the most rapidly developing new "green" industries in Europe. Being a "new renewable" energy industry, it is also a sector which is highly influenced by state policy and regulation, but it is beyond the scope of this paper to explore how this affects knowledge spillovers in depth. Nonetheless, we reflect on this issue in the concluding discussion.

In the theory section that follows we discuss knowledge spillovers and their significance to innovation. Section three presents our methods and data, whilst section four introduces the offshore wind industry and contextualises our empirical findings which are presented and discussed in section five. Section six summarises and concludes the paper.

2 Theorizing knowledge spillovers

A new industry does not appear from scratch, but develops by "the fusion of a new technology with prior antecedent technologies" (Feldman and Lendel 2010, 149). This process brings about innovations not only in technology, but also in markets, business models and supply chains, that combine to form a new industry. Innovation requires knowledge spillovers, the process by which knowledge is transferred or diffuses into a new domain or context and is consequently applied. Despite the enormous attention devoted to knowledge spillovers and its impact on innovation and economic growth, few studies have addressed what spillovers are actually made of and how they happen.

Of particular relevance to this paper are processes of knowledge knowledge spillovers into an emerging industry. Izushi and Aoyama (2006) compared the evolution of the video game industry in Japan, UK and the US, and found that different national contexts provided differentiated and unique basis for cross-sectorial skill transfer and development trajectories, thus explaining the distinct differences between the video game industries in the three countries. Another example is the evolution of the wind energy industry in countries such as Denmark and the US, in which both sectorial antecedents, policy and consequent development trajectories were

highly different (Garud and Karnøe 2003). These examples also remind us that understanding the development of industries requires sensitivity to issues of structure, organization and governance, as this varies both across and within sectors and spatial contexts (Dicken 2011).

2.1 Externalities and relatedness

Knowledge spillovers are generally ascribed to being outcomes of either agglomeration effects, the co-location of inter-related or similar firms within the same sector (Marshall-Arrow-Romer (MAR) (specialisation) externalities), or urbanization effects, the co-location of varied and heterogeneous economic entities and activities (Jacobs (diversity) externalities). In an extensive review of empirical studies on MAR and/or Jacobs externalities, Beaudry and Schiffauerova (2009 334) conclude that there is “substantial academic support for the positive impact of both“, which implies that the unsettled issue of the virtue of MAR vs. Jacobs externalities is not due to lacking theory, but inconsistent evidence.

We consider it unproductive to expect that one kind of spillovers is superior to the other, since they may have different implications for innovation in different industries, different contexts, or in different life cycle stages of industries. Literature suggests that intra-sectorial knowledge spillovers are likely to result in continuous incremental innovation, whereas radical innovations more often stem from cross-sectorial knowledge spillovers (Asheim et al. 2011). The question then is what typifies cross-sectorial knowledge spillovers? The answer from evolutionary economic geographers (cf. Boschma and Frenken 2006, Boschma and Frenken 2011, Neffke, Henning and Boschma 2011) is that knowledge tends to flow between sectors that are related by having similar inputs and/or outputs. Related variety thus points to the idea that novelty is mostly an outcome of knowledge spillovers between sectors with shared and complementary knowledge bases, rather than a result of specialization or diversification. The key argument is that spillovers are more fruitful when they occur between sectors that are neither too cognitive proximate nor too cognitive distant (Nooteboom et al. 2007).

Relatedness (Cooke 2012a) links knowledge spillovers to economic renewal, new paths and regional growth (Asheim et al. 2011), as empirically demonstrated by Boschma, Minondo and Navarro (2012). In a study of regional development in Spain they found that regions diversify or branch (Frenken and Boschma 2007) into new industries that are related to existing ones, and also that resource availability at the regional level triumphs resource availability at the national level for new industry emergence. Empirical evidence for the related variety thesis is robust and mounting (Boschma & Frenken 2011). Existing "related variety" studies are mainly quantitative, in which relatedness tends to be approached from two angles (see Cainelli and Iacobucci 2012, Boschma, Minondo and Navarro 2013). The first is associated with relatedness as conceptualised in cluster or agglomeration theory, where relatedness has to do with similarity of input or shared goods. The other approach is typically based on industrial classification methods, where relatedness is measured according to output. Some also use a mixture of these two approaches. Critics argue that although firms may be "unrelated" according to SIC, they may nevertheless use similar production methods, technologies and modes of organization, and hence have much to learn from each other (Desrochers and Leppälä 2011). To unravel this complexity,

we think that qualitative studies could contribute to enriched understandings of what spillovers are made of, the agency underlying these processes, and the factors enabling and constraining knowledge spillovers between related sectors.

2.2 The content of knowledge spillovers

Cooke (2011) has coined cross-sectorial resource transfers as transversality, which is particularly needed for emerging industries that somehow contribute to sustainable development. Knowledge transfer is mostly conceived simply as the diffusion of existing knowledge, whereas it is part of the innovation process itself, as it becomes part of new solutions and ideas (Glückler 2011). This implies that there may be qualitative changes in knowledge transferred from one context to another, and that knowledge flows are seldom linear (Hansen 2008). It also demands clarification on what is actually meant by "knowledge", which is a broad concept with many meanings. Since this paper is exploratory in nature we choose an open approach. That is, we see knowledge as including technological know-why, operational know-how, organizational capabilities, network relations (know-who), and as embedded in tools, equipment and infrastructure. This conceptualisation means that "spillovers" could have very heterogeneous constituents that may partly change in content, composition and applicability on the way from one sector to another.

The spillover mechanisms most frequently referred to in the literature are entrepreneurial spinoffs, firm diversification, labor mobility and social networking, but how these mechanisms work is relatively unexplored (Erlinghagen and Markard 2012, Cooke 2012a). Desrochers and Leppälä (2011), who study how entrepreneurs in new sectors transfer knowledge and resources, identify adaptation, application and collaboration as three main generic knowledge spill-over mechanisms. Pinch & Henry (1999), who studied the "Motorsport Valley" in Britain, identified staff turnover, information leakage through shared suppliers, firm entries and exits, informal collaboration and what has later been referred to as "buzz" (Bathelt et al. 2004) as key ways in which knowledge is disseminated. Although we find these categorizations useful, they essentially favours embodied and embrained types of knowledge, i.e. knowledge that resides with individuals. This points to the classic distinction between codified vs. tacit knowledge, and over-emphasis on particular "knowledge workers", which distracts attention from other forms of knowledge, processes and actors. They also mostly say something about how knowledge spills over, and less about what spillover ingredients. Given our understanding of knowledge as a broad-type resource, we need to study not only the flow of people or patents, but also how equipment, standards, organizational set-ups (business models, supply chains etc.) move between sectors.

2.3 Actor types and knowledge transfers

When new sectors emerge, different actors will play different roles and make different contributions. The variation in firms' ability and willingness to innovate by exploring new market opportunities is particularly important to consider when studying highly path-dependent and

capital intensive industries such as those of the energy system (Lovio, Mickwitz and Heiskanen 2011) dominated by very large firms. Strategies and capabilities for seizing opportunities in new sectors varies with firms' size, the nature of their products and services, resource base, access to different forms of capital, how innovation processes are organized, their value and supply chain positions as well as prospects in existing markets. Large (incumbent) and small (entrepreneurial) firms are often assumed to provide different types of innovations (Hill and Rothaermel 2003). A common claim is that radical innovations come from new firm start-ups (Acs et al. 2009), exemplified by the important role such firms have played in knowledge-intensive industries such as biotechnology or ICT (Hockerts and Wüstenhagen 2010). Large incumbent firms, on the other hand, tend to initiate new activities relatively close to what they are already doing. They "store" accumulated assets and capabilities that make them a central source of innovation (Christopherson and Clark 2007), and a source of incremental improvements that also add up to major contributions (Baumol 2004). However, there are of course many examples of large firms developing radical innovations (Branscomb and Auerswald 2001, Chandy and Tellis 2000) through corporate entrepreneurship, and large firms importantly also serve as "incubators" for spin-offs which are fundamental to innovation. Many spin-off firms are created by entrepreneurs who use new knowledge produced within a firm in which they are employed (Karlsen 2011), but where development and commercialization opportunities are not present (Bathelt, Feldman and Kogler 2011), and who thus transfer knowledge into a new context.

Table 1 A basic typology of innovation actors and roles

<i>Innovation type</i>	<i>Firm type</i>	<i>Primary spillover type</i>	<i>Role in emerging industry</i>
Radical	Small/new	Cross-sectorial	Specialized
Incremental	Large/established	Intra-sectorial	Diversified

An issue that has received limited attention in the innovation literature is the nature of cross-sectorial innovation dynamics. Technologies and solutions may be established in certain sectors, but constitute radical innovation if applied in a different sector. Erlinghagen and Markard (2012) refer to firms that cross into a different sector from their home sector as "adjacents". When large firms cross into a new sector, an important effect could be that their suppliers follow. Just as piggybacking (larger) lead firms is an important mechanism for internationalisation, it may equally be the main mode for many firms' entry into a new sector. Although knowledge may be learned and lost without much effort and intention, the idea of effortless knowledge transfer is usually misleading (Jensen et al. 2007). Investing in the development of new knowledge implies uncertainty and risk (Acs et al. 2009), which correlates with the cognitive distance between old and new knowledge. Firms invest time and money in networks and partnerships in order to tap into new knowledge sources, particularly when these are geographically and cognitively distant (Nooteboom et al. 2007). Why and how such partnerships and networks are shaped will for instance depend on whether firms aim to refine and

exploit the application of existing technologies or if the agenda is to explore and develop something new.

In mature industries, physical equipment, institutions, business relationships, cognitive routines and so on, have aligned and combined into a robust "regime" (Smith, Stirling and Berkhout 2005). Regimes are effective with regard to business-as-usual, but may have limited space for new solutions. Large mature firms use projects to explore or initiate new activities, both internally and with external collaborators (Frederiksen and Davies 2008). Projects can serve as time-limited "niches" (Schot and Geels 2007) that allow firms to explore how existing resources and capabilities can be exploited in new markets. In large firms with significant internal diversity, projects may enable individuals with different backgrounds to cooperate on novel ideas. We also assume that projects could be a starting point for spin-offs.

In summarising the theoretical section, and returning to the concepts of related variety and cross-sectorial knowledge spillovers, we assume that diversifying firms will tend to explore opportunities in sectors that are similar in the sense that they can make use of existing capabilities. Furthermore, we anticipate that large and small firms will play different roles in terms of the solutions they have to offer and the variety they thus create. We also expect to find that firms do this by way of collaborative organisational set-ups, such as strategic technology alliances and different kinds of exploratory projects.

3 Methodology

Quantitative studies have dominated research on emerging industries (Feldman and Lendel 2010, Beugelsdijk 2007) knowledge spillovers (Desrochers and Leppälä 2011) and related variety. This research strategy serves well to establish relationships, identify network patterns or learn about the extent of knowledge spillover processes (Broekel and Boschma 2011), but it is less helpful in capturing the contents and modes of knowledge spillovers (Beaudry and Schifffauerova 2009, Rigby and Essletzbichler 2002). In order to explore cross-sectorial spillovers, this paper is primarily based on qualitative methods. The Norwegian OW firm population is comprised of *ca.* 150-200 firms (NVE 2012), although it should be noted that the number of firms indirectly involved through sup-supplier linkages is highly uncertain. In the period September 2010 to February 2013 we conducted 73 semi-structured interviews in 64 firms and organisations. Interviewed firms and organisations are listed in Table 2. We also conducted an online survey (December 2010 – January 2011), directed at 325 strategically sampled firms deemed active in OW. Of 147 responding firms (45 % response rate), 94 have OW as a business area, of which 17 of are specialised OW firms and 67 are diversified O&G firms (see Hansen and Steen 2011). For the purposes of this paper, survey results are used to support main points and generalised findings.

Our empirical analysis is focused on the interviewed firms categorized as diversified O&G (N firms = 20) firms and specialized OW (N firms = 11) firms, which are generally large and small respectively. The remaining 32 interviewed firms and organisations include venture seed capital firms, technology (service) providers, researchers/experts on OW relevant

technologies and key informants in OW related organisations and business development agencies. Most firms interviewed have Norwegian ownership, but some are sub divisions of MNC's (e.g. Siemens). The interviews lasted on average for one hour, and covered a broad range of topics, from origins and history of the firm to innovation and market strategies. Most of our informants are CEOs or division managers in charge of OW activities. Interviews were recorded, transcribed and analysed in *Atlas.ti*. As part of our qualitative approach, we also conducted extensive document studies of industry reports, media and firms/organizations websites. Industry events have also been a valuable source of data and provided access to informants.

Table 2 List of interviewed firms/organizations

<i>Firm/organization type</i>	<i>Firms</i>
Diversified O&G sector firms (20, 24 interviews)	Statoil, Kværner Verdal, MasterMarine, Kongsberg Maritime, Nexans, Draca, Aibel, CCB, Grieg Group, Rosenberg, Odjell Drilling, Inocean, Ingenium, Vitec, Kværner Piping Technology, Kværner Jacket Technology, SmartMotor, Dr. Techn. Olav Olsen, Troll (Goodtech), AF Group
Specialized OW firms (11, 13 interviews)	OWEC, Norwind, Sway, Vestavind Offshore, Inwind, Vici Ventus Technology, Vici Ventus Construction, Windcarrier, Seatower, WindSea, Siragrunnen Offshore.
Other firms/organisations (32, 37 interviews)	Wind/renewable energy firms (9), utilities (4), multi-industry supply firms (4), seed/venture capital firms (8), Support organizations/R&D (7)

4 The making of offshore wind

To recapitulate from preceding sections, this paper explores the transfer of knowledge and resources by Norwegian firms from petro-maritime or offshore oil and gas (O&G) industries into the emerging offshore wind (OW) sector. The North Sea has been home to petroleum extraction since the 1950s, and has given rise to a world-leading offshore O&G industry. The world's first OW farms were developed off the coast of Denmark in the early 1990s, but it is during the last few years that growth in OW has excelled. This development is currently above all taking place in the North Sea sectors of UK and Germany. The main drivers are the need for more renewable energy in compliance with EU's 20-20-20 targets, but also energy security, industrial development and "green jobs" (EWEA 2011). With abundant hydropower and a large petroleum export industry, Norway lacks the drivers in most other Northern European countries for investing in domestic energy production from (costly) new renewables. In fact, only one commercial wind farm has gained consent in Norway, but the project was abandoned by the investors at the end of 2012. Certainly, lower profit opportunities may hinder firm diversification from O&G into OW, and the number of Norwegian O&G sector firms that have invested in OW are of course few compared to the ones that have not.

There are good reasons for locating wind farms offshore, such as stronger and more sustained winds than over land, and OW having fewer amenity disadvantages than onshore wind (Wiser et al. 2011). However, the offshore environment is demanding in terms of transport,

logistics and construction technologies. Until recently, OW farms have been developed near shore in shallow waters using conventional onshore turbines fixed on the seabed, but farms are now developed further from shore in deeper waters using purpose-built (larger) offshore turbines (Douglas Westwood 2010). This "further, deeper and larger" trend is expected to continue in the years to come (EWEA 2013). A third "step" would be floating OW farms, potentially developed both far offshore as well as off coasts that lack shallow waters, such as Japan or the US.

The increase in scale and complexity of OW farms has had a significant impact on costs and technological requirements (Söderholm and Pettersson 2011, Weaver 2012) and on the structure of the industry. Whereas actors with experience from wind onshore pioneered OW by making use of ad hoc "marinated" equipment, the sector is now increasingly influenced and shaped by firms from the offshore O&G industry and other maritime sectors. These firms have entered OW not only because they have been able to meet the demand for new competencies, increased capacity and the ability to take on higher capital costs (Markard and Petersen 2009), but also for reasons such as periodic stagnation in traditional markets and exploration of future "green" opportunities (Hansen and Steen 2011, Weaver 2012). Lack of specialized equipment for OW has caused many problems, from fatal accidents to huge budget overruns, and it is widely agreed that the success of the sector will require increased specialisation.

As illustrated in fig. 1, the OW value chain is comprised of three main parts: exploration and planning, development and construction (including procurement and manufacturing), and operation and maintenance. Despite recent specialization, OW is still an immature industry and the benefits of learning and economies of scope are yet to be harvested across more or less the entire value chain (EWEA 2011, Scottish Enterprise 2011). Particular capacity and technology challenges are found in the development and installation, operation and maintenance of in-sea or sub-sea components and equipment. These are areas in which competence, capabilities and assets from the petro-maritime sector could contribute if transferred to OW.

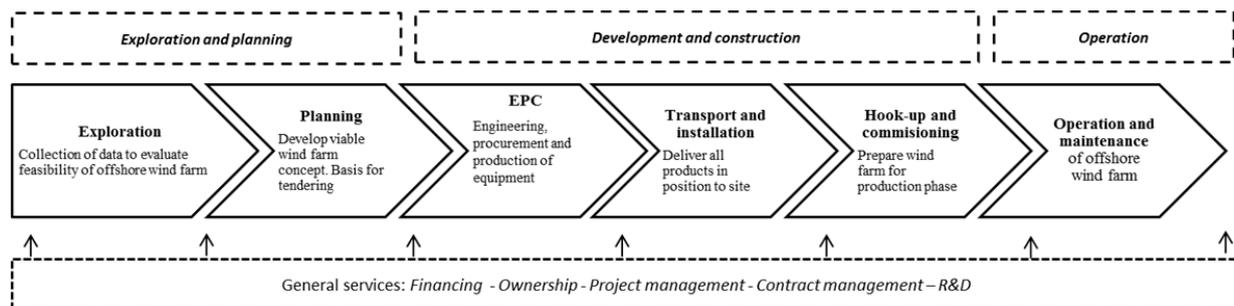


Figure 1 The value chain of offshore wind power

4.1 Cross-sectorial spillovers from offshore O&G to offshore wind

Norway's potential for OW power is vast (NVE 2012), but as of April 2013 only one turbine was installed in Norwegian waters. However, this single turbine, Hywind, which was installed in 2009, is the world's first full scale floating wind turbine (with a 2.3 MW Siemens turbine). Being

the result of a project in major O&G company Statoil, Hywind is, as we shall see, illustrative for knowledge spillovers from offshore O&G to OW, at least in the Norwegian context. Most Norwegian firms involved in the making of OW have the O&G sector as their home market, and who view OW as a supplementary market in which they can utilize existing capabilities and resources. Apart from Statoil, these diversified O&G firms include many large specialized supply firms and a range of sub-suppliers. The following statement from the manager of a large supply firm is illustrative of the general attitude of this category of firms:

Offshore wind represents an opportunity for us and other companies (...) to apply our knowledge, people and vessels in a new way. Not to substitute oil business, but to supplement it.

A main driver for these firms to explore OW has been the volatile demand and cyclical nature of the O&G industry (Hansen & Steen 2011, Steen & Karlsen in press).

The Norwegian firms that are specialized in OW are few and small, but largely stem from the petro-maritime industry. In fact, all 9 specialized OW firms interviewed for this paper were started by entrepreneurial teams in which at least one member had previous working experience from the petro-maritime sector. It is beyond the scope of this paper to explore entrepreneurial motivations in-depth, but it is worth noting that many of these entrepreneurs have several decades of experience from offshore O&G. When OW entrepreneurs with O&G background were asked about motivations, "exciting business development opportunities" in the emerging sector was frequently mentioned.

Table 3 gives an overview of the interviewed firms' positioning in the OW value chain. Although this is a sample of the Norwegian OW firm population, previous studies suggest that the relative balance of firms in the different value chain segments reflects representativity (Hansen and Steen 2011, NVE 2012, Volden et al. 2009). The legacy from offshore O&G is reflected in that most firms are involved in activities related to the design, engineering and fabrication of foundations, sub-sea equipment and solutions, as well transport and installation. Most of the diversified O&G sector firms aim at taking a similar position in the OW value chain as they have in their traditional line of work. It is crucial to note that there is wide consensus amongst managers in the industry that knowledge and solutions from O&G must be adapted to OW, and not transferred as is, in order to be feasible, both technologically and economically. At the time of data collection, many of the Norwegian firms targeting OW had yet to enter the market, and many of these were of the opinion that a small domestic market for developing and verifying new solutions would reduce barriers for accessing markets abroad (Hansen & Steen 2011). This applies to both diversified and specialized firms.

The specialised OW firms aim at activities that are parallel to what the entrepreneurs or founders have previously been involved within other offshore sectors. For instance, all the Norwegian OW foundation suppliers (EPC – subsea), including both diversified and specialised firms, either have O&G foundation structures as a key business area or have been involved in that segment in O&G at some earlier stage. In the following sections we provide a detailed account of some of these firms for illustrative purposes.

Table 3 Overview of interviewed diversified O&G firms and specialized OW firms and their value chain position in OW

Value chain segments	Exploration	Planning	EPC		Transport & installation	Hook-up and commissioning	Operations and maintenance	General services
			Topside	Subsea				
Examples of products or services	Seabed mapping	Consent application FEED studies	Turbine Tower Transformer	Cables Foundations	Ports Logistics Installation	Final testing	Operate Turbine maintenance	Financing R&D
Interviewed diversified O&G firms			Troll (Goodtech), Rosenberg, Aibel	Kværner Verdal, Draca, Nexans, Dr. Techn Olav Olsen, Kværner Jacket Technology, Kværner Piping Technology, Vitec, AF Group	MasterMarine, Ingenium, Inocean, AF Group, CCB, Grieg Group	Odfjell Drilling	Statoil, Statkraft, Kongsberg Maritime	
Interviewed specialized offshore wind firms			SWAY Turbine	OWEC, Vici Ventus C & T, Seatower, SWAY, Windsea,	Inwind, Norwind, Windcarrier,		Vestavind Offshore	

4.2 Foundation solution providers: meshing old and new

Two main implications of the "further, deeper, larger" trend in OW are that new solutions for subsea foundations and methods for installation are required (Snyder and Kaiser 2009). Most of the OW turbines installed to date are fixed on monopoles. Increased depths require other foundation types, of which there are basically three different types: fixed steel structures such as "jackets" and "tripods", fixed concrete gravity based structures (GBS), and floating foundations of steel and/or concrete.

OWEC (specialised OW), and Kværner Verdal (diversified O&G) have applied and transformed jacket foundation technology from O&G to fit OW, and both have entered the OW market with their concepts. OWEC was established in 2001 by two entrepreneurs with several decades experience from jacket design in O&G. Kværner Verdal is a large O&G supply firm specialised in jacket construction that started exploring OW opportunities in the mid-2000s due to (temporary) stagnation in the home market. SOWs Vici Ventus and Seatower have developed new GBS based foundations concepts for OW. Both of these recycle the "Condeep" concept, which was an important foundation solution for O&G installations on the Norwegian Continental Shelf (NCS) from 1975 to 1995. Vici Ventus was established on the basis of a collaborative concept study for electrification of offshore O&G installations involving a utility company, a construction/O&G supply firm and a maritime engineering firm, the latter one of the main developers of the Condeep technology. Seatower was established in 2007 by an entrepreneurial team who formerly worked together in an O&G engineering firm. Following an OW foundation concept study, the team collectively decided to opt for the new market opportunity of OW, and according to the manager the team was also motivated by working to find solutions for sustainable renewable energy. Both Seatower and Vici Ventus' concepts are novel to OW not only as foundation solutions, but also because they implicate a radical change in transportation and installation of turbines, a key issue for cost reduction in OW. According to a Vici Ventus manager, they

saw that installation in offshore wind was done in an extremely complicated way, piles, jackets, interfaces, towers, turbines, etc. all installed using different cranes and vessels. It's a very risky and vulnerable supply chain. Our idea is to develop a foundation that almost runs on its own.

The innovation essentially lies in pre-mounting tower and turbine on the foundation before installation, rather than installing all separate pieces of the grand "meccano set" at sea.

Whereas the firms described in the previous paragraphs have products that fit the needs of current or soon-to-come OW farm projects, other firms focus on developing solutions for floating structures. While the "floating" market is still economically unfeasible, the potential is huge, particularly off the coasts of countries such as Japan and South Korea, where areas for bottom-fixed turbines are limited. Similar to the GBS-concepts, floating foundations allow for radically different installation procedures. Both Statoil's Hywind concept and SWAY's floating tower concepts are based on spar buoy technology from O&G used in maritime industries for decades. SWAY (specialised OW) was established following a concept study by naval architecture firm Inocean (diversified O&G) on electrification of offshore O&G installations. The floating OW foundation concept developed by WindSea (specialised OW) is a semi-submersible platform developed on the basis of extensive experience with FPSO (floating production, storage and offloading) structures and offshore O&G and renewables engineering from mother firms Force and NLI (both O&G supply firms). From Force, Windsea comprises a Norwegian and a Danish branch, and the manager explains that "*our idea was to interbreed the Norwegian offshore competence with the Danish wind competence*", likening it to how the Norwegian offshore O&G industry itself developed as O&G capabilities from abroad and Norwegian maritime experience merged in the 1970s (Sæther, Isaksen and Karlsen 2011).

4.3 The contents and modes of cross-sectorial knowledge transfers

The empirical examples described in the previous section illustrate that the knowledge transferred into OW by diversified O&G sector firms and specialized OW firms is similar and builds on well-established know-how. There is however an important distinction between the two categories in that the specialized firms' products to a greater extent are specifically designed for OW. Generally, they also draw on knowledge and solutions from other sectors. It thus appears that the fusion of new and old solutions, which is at the heart of the processes underlying new industry emergence (Feldman and Lendel 2010), seems to be driven more by specialized than by diversified firms. This is corroborated by the finding that several of the diversifiers that have made OW targeted investments have retained the utilization opportunity in traditional markets in mind. An example is installation vessels that can be used in both sectors, whereas installation vessels developed by specialized OW firms are not particularly fit for O&G installations.

Managers of diversified O&G sector firms generally assert that the ability to reuse existing resources without major switching costs was crucial for opting for the OW market. The mode of entry to the new sector for the diversified firms implies cautious adaptation and relatively limited investments, but diversified firms bring capabilities in the form of experienced personnel, design and engineering know-how, vessels, infrastructure and other material assets to

the OW sector. An example is Aibel, which is one of Norway's largest specialized supply firms, which won a contract for a connection platform for German OW wind farm Dolphin. The platform concept is based on the experience the firm has gained from semi-submersible floating platforms for the O&G sector, although the installation method used in this particular case is different, and according to our informant the firm uses more or less exactly the same in-house material and immaterial resources for carrying out the task. Nonetheless, although the solutions that firms like Aibel bring into OW are not purpose-made, the resources, technologies, routines and modes of organization may be new to the sector. From a technology development perspective such contributions constitute incremental innovations, but if implemented they may exert substantial influence both on choices of technology and operational procedures in the new sector.

Both directly applying and adapting knowledge to the new market are therefore mechanisms (Beaudry and Schiffauerova 2009) at play in the case of spillovers between O&G and OW, both regarding diversified and specialized firms. Incumbents entering a new sector need to develop new capabilities (Helfat and Lieberman 2002), and in the case of offshore O&G firms entering OW, these diversified firms do so mainly by developing in-house resources through various kinds of projects using existing labour and other resources, albeit often in collaboration with other firms with complimentary resources. From an innovation point of view, this mix of developing and combining internal and external knowledge is as expected (Oinas 2006). The use of projects to explore opportunities in a new sector is also typical. These projects allowed for technology, knowledge and user practices to develop "free" from the constraints and demands of "markets" (Essletzbichler 2012, Smith and Raven 2012). The diversified firms generally aim to use the same human and other resources in OW as they use in their "home sector", and many intend to strategically shift between OW and O&G projects, depending on market demand, capacity and outlook. In the case of the diversified O&G sector firms, this can be ascribed to the transfer of value chain positions, as well as hitherto limited OW market penetration. But even those diversifiers that have won relatively sizable contracts for OW farms, involving design, engineering and fabrication work for hundreds of employees, have mainly relied on in-house resources to carry out the task. Interviews (and survey) indicate that hiring new employees with specific OW wind related skills is an important knowledge upgrading strategy some specialized firms, but not for the diversifiers. Also on a more general level, both specialized and diversified firms report that they have limited inputs from external R&D institutions in their innovation, upgrading or learning strategies. Rather than building new knowledge pipelines, the changes in diversified firms' networks thus primarily relate to developing linkages to firms that either provide complimentary assets or somehow ease market access.

From offshore O&G, Norwegian firms have developed experience and equipment that provides the opportunity to engage in OW, particularly in the offshore and subsea parts of the OW value chain. These firms have less to offer with regard to the typical wind sector products such as turbines and towers, where global competition encumbers market entry (Lewis and Wiser 2007). Nonetheless, OW farm owners and developers are keen to see the development of specialised turbines that are larger, more robust and reliable. And the few Norwegian firms that are or have been involved in developing turbines and other topside equipment all claim that

experience from petro-maritime activity is important. For instance, from 2000 to 2009, the firm Scanwind developed a turbine for harsh offshore and near-shore weather conditions. In 2010 Scanwind was acquired by US industry giant GE that, according to the manager of GE in Mid-Norway, “*had been searching the world for offshore turbine technology*” that it could use to compete with global leaders Siemens and Vestas. GE aimed at developing their OW activity in Norway by “*utilizing and transferring experience (...) from GEs offshore O&G division in Norway to offshore wind.*”

This experience from O&G includes a lot more than technological solutions. Many informants compare the current status of OW to the infancy years of the North Sea O&G industry, as illustrated by the following statement from an informant with several decades of experience in petro-maritime activities:

I've never experienced taking part in a new industry like this before (...) the answers are not given. (...) It's very much like O&G was in the 1970s.

As an emerging sector, OW lacks the "stability" of an established socio-technical regime (Lawhon and Murphy 2011). This immaturity represents both opportunities and challenges. Many informants underline that a main problem in OW has been that project developers and contractors have lacked both offshore experience and suitable equipment (cf. Markard and Petersen 2009). According to one manager, the difference between their approach and the "typical approach" by actors with less offshore experience

is that we often start by considering installation and other offshore procedures, then we do engineering and design. Firms lacking offshore experience do it the other way around and get into trouble.

This technological and operative competence related to the maritime environment is regarded as crucial for succeeding in OW. One manager claims that “*offshore and maritime experience is a must! You have to know what it's like out there, in rough weather.*” Competence thus covers how to deal with harsh and often dangerous weather conditions, as well as how to orchestrate and navigate complex supply chains in challenging and risky offshore operations. Linked to this is the transfer of organisational set-ups, particularly in planning and conducting project based activities. This is not to be confused with the more experiment type of projects discussed previously. The offshore O&G industry is project based in the sense that each field and installation forms a small market. This experience is highly emphasized by many of the firm managers:

Our capacity to mobilize resources for large O&G projects can just as well be used for wind. That is our main competence, leading and carrying out projects.

Several managers assert that this *modus operandi* of integrated project and operational planning is a key characteristic of firms used to working offshore, from technical design and engineering to physical operations at sea.

4.4 Different ponds – barriers to knowledge spillovers?

OW is being developed in the North Sea, which many Norwegian petro-maritime firms, regardless of national borders, consider as their "home market". Like O&G, OW is an industry that brings together a highly heterogeneous set of actors with skills and capabilities ranging from

advanced modelling and technical design via fabrication and logistics to navigating vessels at sea. While the previous sections have shown how relatedness between O&G and OW is crucial to understanding this case of transversality (Cooke 2012b), there are some important differences that may hamper cross-sectorial knowledge transfer. The "OW North Sea" is a "different pond" than O&G in terms of actors, governance, risks and profit opportunities. Even global O&G firm Statoil is off its "home turf" when doing OW, as asserted by a manager:

We're a big duck in a small pond in Norway, but we're tiny in the wind industry. We need to find our place and learn who else is in on this.

Of particular importance as a barrier for cross-sectorial knowledge spillovers is that products and services in O&G projects are often custom-made for specific projects, whereas OW, like onshore wind, to a greater extent is characterised by standardization and serial production (EWEA 2009). Although the "serial mode" industrial logic has not yet been successfully implemented in the offshore operations of OW, precisely the value chain segments in which we find most Norwegian firms, the industry is unanimous in calling for further industrial up-scaling, specialization of equipment and standardization of these procedures, since it is seen as key to achieving the overarching aim of reducing both capital and operational expenditure (Brown 2011). It is not a given that firms accustomed to one-off projects are able to organize activities in "serial mode".

However, this tailored vs. standardised dichotomy can be too crude, because the extent of standardisation and the possibility of reaping economies of scale will depend on firms' position in the value chain as well as on how OW farm projects are organized and choice of technological solutions. Many firms in the O&G industry supply standardized products and services, whilst at the same time also have the ability to do detailed engineering for specific projects. The manager of a subsea cable supplier firm, which has been involved in OW since the early 1990s, but has most of its turnover in O&G, says that

our experience is that OW projects are more varied than O&G projects, because each OW project demands a particular type of cable with unique specifications depending on the needs of the client.

An important part of the learning process when firms enter a new sector also has to do with complying with new governance regimes. Standards and health, security and environment (HSE) regulations are an important part of the institutional governance of industries (Nadvi 2008). Whilst many managers stress the importance of transferring well-established HSE regulations and standards from O&G to OW, they also warn against doing so uncritically, as this may contribute to escalating costs. The manager of a diversified firm argues that

we would never accept some of the methods now being used in offshore wind because the risk on people is too high (...) but there must also be a balance between safeguarding people and doing things quicker and simpler.

OW is characterized not only by high financial risk, but one that is different from O&G, particularly because of its (current) reliance on subsidies (Weaver 2012). Generally, we find that firms supplying "standard" or "proven" technology to OW, for instance subsea cables, do not report about specific market entry barriers. As we have seen however, many of the Norwegian

firms entering OW do so with new solutions, and these firms generally struggle to obtain contracts. According to these firms, their challenge is that OW farm developers minimize risk by choosing proven technology, and their main concern is obtaining a first project that can generate references. Rather paradoxically, the budding sector is characterised by conservative technology selection that hampers cost reduction. In other words, limited inflow of knowledge spillovers from other sectors could be a key explanation as to why the development of OW technology is slow despite production capacity deployment is high (EWEA 2013). In this regard, it is also important to note that many of the Norwegian firms argue that a domestic market would (probably) significantly reduce barriers of market entry and knowledge spillovers that would follow.

5 Concluding discussion

This paper has investigated cross-sectorial knowledge and resource transfers from the mature O&G industry into the emerging OW industry in the North Sea, and by doing so attempted to shed some light on the agency of knowledge spillovers. The questions that motivated this paper were: what knowledge and other resources are transferred when firms from the mature O&G sector firms enter the emerging OW sector, what variety does this contribute to in OW, and what factors enable or hinder cross-sectorial knowledge spillovers?

Rather than being the result of MAR (specialized) or Jacobs' (specialized) spillovers, the emerging OW sector is best understood as a "branching" process (Frenken, Izquierdo and Zeppini 2012) from the onshore wind industry in the early 1990s. Subsequent development processes have led to larger and more complex OW farm projects and the inflow of actors and recombination of resources from other sectors, particularly from the offshore O&G industry. O&G and OW have much in common in terms of the resources they demand (cf. Scottish Enterprise 2011). This relatedness (Cooke 2012a) is the key explanation as to why O&G sector firms have diversified into the emerging sector to recycle and extend the usage of existing resources. These "adjacent" firms (Erlinghagen and Markard 2012) (attempt to) transfer value chain position and associated technology into the emerging OW sector. The firms that are specialized towards OW are all small start-up technology providers. As we have demonstrated in this paper, all the specialized OW firms somehow have an O&G background, either from entrepreneurs or in being joint ventures or project spin-offs from established petro-maritime firms. From a theoretical perspective we can conclude that strategic efforts in the form of entrepreneurship and diversification with adaptation of existing knowledge and capabilities figures prominently as knowledge spillover mechanisms.

Both diversified and specialized firms bring variety into OW. As this paper has demonstrated, the "knowledge" that spills over between sectors cannot be reduced to patents or other clearly demarcated (codified) resources, but includes operational experience, organizational capital, routines, institutional aspects as well as technology. In this case study, both small (and mostly new) and large (established) firms had remarkably similar knowledge upgrading strategies. We speculate that this similarity is indicative of a generic approach to "upgrading for

transversality (or diversification)". If true, we could expect that resembling strategies should exist in similar cases, but this is clearly an issue that requires more empirical investigation. The main challenge for the specialized firms, which generally offer more specialized products and services compared to their diversified counterparts, is to gain entry to the emerging sector, even though both categories of firms base their products on "proven solutions".

This leads to the final part of our research agenda, namely barriers to knowledge spillovers. The apparent similarities between offshore O&G and OW imply that technology may be relatively easily adapted and transferred from the mature to the emerging sectors. However, the sectors dispel different investment and institutional contexts that may inhibit adaptation of business models and other aspects of organisation. Existing routines and networks may also hinder both diversification attempts and entrepreneurial ventures.

Based on our analysis, we suggest that the next step in opening the black box of knowledge spillovers includes four main areas of exploration. First, more light need be shed upon knowledge spillover feedback effects between old and new sectors. Second, modes of cross-sectorial knowledge spillovers, i.e. choice of organisation set-ups and potential new forms of cooperation needs more exploration. Third, it would be fruitful to understand how commercial and contractual set-ups influence interactions and dynamics between related sectors. Lastly, the way policies and regulations can both facilitate and hamper cross-sectorial resource flows, particular in highly regulated sectors such as energy, is clearly an understudied and highly important topic that deserves attention. Economic geographers with analytical frameworks sensitive to spatial context can make important contributions in this regard. As a broader theme for economic geography, empirical analysis should be extended by investigating the (co-) evolution of related sectors. As this paper has demonstrated, a sector's evolution may bring its trajectory closer or further from other sectors' trajectories, for instance in knowledge inputs and organizational set-ups, implying shifting degrees and nature of co-sectorial "(un)relatedness".

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