Technological Forecasting & Social Change xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Regional foresight and dynamics of smart specialization: A typology of regional diversification patterns

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ARTICLE INFO

Article history:
Received 8 October 2015
Received in revised form 7 June 2016
Accepted 21 June 2016
Available online xxxx

Keywords:
Regional foresight
Foresight
Theory
Smart specialization dynamics
Regional branching
Offshore wind servicing
Smart specialization policy
Renewable energy

ABSTRACT

The concept of smart specialization has attracted great interest and has been adopted widely in European regional and innovation policy. Foresight is an important part of creating smart specialization strategies. However, both the smart specialization concept and foresight have been criticized for lacking an empirical and theoretical foundation that can help guide their application in practice. This paper contributes to the theoretical foundation of smart specialization and regional foresight by drawing on the field of economic geography and elaborating a typology for patterns of smart specialization. We highlight that there are different paths to reaching smart specialization within the same industrial domain. The empirical research focuses on the offshore wind service sector in four regions around the North Sea. The findings corroborate a typology that offers four distinct patterns—diversification, transition, radical foundation, and modernization—all of which can enable the creation of new industrial activities where regions enter an emerging industry based on fundamentally different starting points.

1. Introduction

The concept of smart specialization has come to play a major role in supporting the Europe 2020 jobs and growth agenda. All member states and regions that aspire to receive funding through the EU Cohesion and Structural Funds for the current programming period (2014–2020) are required to develop third-generation Research and Innovation Strategies (RIS3), called 'Research and Innovation Strategies for Smart Specialization'. The RIS3 framework represents the most recent wave of thinking in regional development; the novelty lies in the smart specialization, i.e., the requirement to build on each country and region's strengths, competitive advantages and potential for excellence.

The importance of foresight in smart specialization is established in the RIS3 Guide, which advocates foresight during the development of smart specialization strategies (Foray et al., 2012). Foresight, or future-oriented technology analysis (FTA), has developed in parallel with the development of regional policy ideas. Foresight generally draws from the various traditions of future studies with a pragmatic intent to inform policy making (Martin, 2010; Miles, 2010; Miles, 2008; Miles et al., 2008). Foresight, specifically in the regional policy context, is defined as a systematic, participatory, multidisciplinary, intelligence gathering, and medium-to-long-term vision-building process to capture existing expert intelligence to make it accessible for present decision making, aimed at uncovering possible future paths, and opening them up for debate (e.g., Foray et al., 2012; Hanssen et al., 2009). The evolution and adoption of foresight coincide with the rise of research on and subsequent diffusion of the innovation systems concept (Cariola and Rolfo, 2004). As Martin and Johnston (1999) concisely put it, foresight is, among other things, aimed to 'wire up' an innovation system, meaning that foresight can facilitate setting priorities for research, development and innovation, illuminate available technological options and constraints, and develop new connections among actors. In the context of smart specialization, foresight exercises can be useful in developing RIS3 because they can help identify trends, discontinuities, current constrains, emerging technologies and future opportunities in promising areas of strategic research, thus helping to set research and development agendas (Amanatidou and Guy, 2008; Harper and Georghiou, 2005; Paliokaitė et al., 2015; Piirainen et al., 2016; Rappert, 1999).

Under the umbrella of foresight, the two most relevant sub-literatures are regional and sectoral foresight. Of these two, regional foresight is predominately attached to policy-making processes and is thus increasingly less concerned with accurate anticipation of the future or forecasting and is more used as an objective setting, negotiation and commitment process (Cariola and Rolfo, 2004; Dufva et al., 2015; Hanssen et al., 2009). Technically, these processes might be characterized as generally normative foresight, backcasting, roadmapping, or visionary processes, or, with a more critical outlook, planning processes under the veneer of

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http://dx.doi.org/10.1016/j.techfore.2016.06.027
0040-1625/

foresight. While regional foresight is conducted from a regional perspective, it may include perspectives on innovation systems that have had a large influence in the infancy of foresight research (c.f. Martin and Johnston, 1999; Martin, 2010; Martin, 1995; Miles, 2010). The most specific articulation of this focus is sectoral or innovations system foresight, where the focus is explicitly on anticipating the development and growth of an industry or sector, often with the view of proposing actions to remove 'systems failures' that impede that development (Alkemade et al., 2007; Andersen and Andersen, 2014; Dufva et al., 2015; Weber et al., 2009). Thus, innovation systems analysis has recently been (re-) established in foresight, especially in innovation systems foresight (Andersen and Andersen, 2014), as a basis for understanding the challenges and change dynamics for innovation in a given context (Alkemade et al., 2007; Andersen and Andersen, 2014; Breukers et al., 2014; Keller et al., 2014).

Foresight exercises in regional smart specialization processes have been useful in identifying trends, discontinuities, emerging technologies and future opportunities in promising areas of strategic research (Paliokaitė et al., 2015), but while foresight as such is an established practice, several challenges remain in theory and practice. A key issue for research in foresight is the lack of a sound theory and use thereof (Hideg, 2007; Piirainen and Gonzalez, 2015; Öner, 2010). A related challenge in practice is heavy reliance on participatory processes that greatly depend on the initial set-up of participants and their perceptions. This is highlighted by the fact that six of the top ten foresight methods are based on the solicitation of expert views and opinions (literature reviews, panels, workshops, brainstorming, interviews, and the Delphi method) (Popper, 2008).

One aspect of theory use and development in foresight is focusing on theory, as in understanding how and why a given unit of analysis works and leveraging that understanding to anticipate future development paths (Piirainen and Gonzalez, 2015). Following the call for theory use, the contribution of this paper is that it explores the dynamics related to smart specialization to better understand the patterns of change and growth associated with regional dynamics. A key contribution of this paper is that it demonstrates that using empirical data to understand the diversity of regional development can improve the quality of foresight and, hence, lead to (more-) relevant and sound policy recommendations.

A parallel contribution from this paper is to the literature on smart specialization. According to one of the fathers of the smart specialization concept, Dominique Foray, smart specialization is an example of "policy running ahead of theory" (Foray et al., 2011). It has been argued in particular that the smart specialization concept lacks an understanding of regional economics and innovation (Boschma, 2014). For decades, economic geographers have been engaged in studies of the spatial formation of new industrial paths (Boschma and Lambooy, 1999; Hassink, 2010; Martin and Sunley, 2006; Tödtling and Trippl, 2004). These studies have contributed to an understanding of how new industries develop in particular regions based on pre-existing innovative regional capacities (Boschma and Frenken, 2011; Frenken and Boschma, 2007; Tanner, 2016). The aim of this paper is to enhance the conceptualization of smart specialization by linking the findings from evolutionary economic geography with a real-time analysis of diversification processes in four European regions.

This paper explores how different regions have followed different paths and developed similar industrial capacities in the offshore wind servicing (OWS) sector. These paths help illustrate the diversity of smart specialization dynamics. The specific research question for this paper is: What are the specific patterns of regional development underlying smart specialization in the OWS sector? And how can this understanding strengthen the theoretical base of (regional) foresight processes?

First, we carry out a comparative study of smart specialization dynamics in four regions. The results show how these four regions have entered the same industry based on different sets of capabilities, showing that there exist multiple pathways to the same specialist domain. We use the findings to refine a typology of structural transformation (Foray, 2014). We think this typology of structural change can support policy makers when they are tasked with thinking ahead and building smart specialization policies. Second, we discuss the possibilities and pitfalls by using foresight approaches in developing smart specialization policies.

As our empirical case, we explore the offshore wind service (OWS) industry in four countries surrounding the North Sea, through the lens of a Regions of Knowledge project funded by the European Commission. We base our study on patent data collected for each region, classified into multiple technology areas, all relevant for the development of the OWS industry. This project and multiple others are the result of an increased focus within the European Union on strengthening the development of regional industries to spur on economic growth following the recent recession.

The paper is structured as follows: first, we present the concept of smart specialization and its theoretical background and elaborate on the typology of structural change. Section 3 presents the data and the method by which we have carried out the analysis. In Section 4, we present the findings and illustrate the typology of structural changes. In Section 5, we conclude and discuss the implications of the findings for smart specialization policy making.

2. Theoretical background

Evidence is mounting that the lingering problems in the European economy in the early 2010s cannot be reduced solely to the structural problems of the monetary union or the failure in financial markets (Economic Crisis in Europe: Causes, Consequences and Responses, 2009; Overbeek, 2012); they are also due to changes in industrial production and globalization, implying the need for existing industries or sectors to reinvent themselves (Foster et al., 2013; van Ark et al., 2013). The need for structural change is relevant to all European economies, from relatively low-tech economies that need to develop their innovation capabilities to high-tech economies that struggle with international or global competition.

The European Regional Development Policy, or 'Cohesion Policy', has generally been at least a moderate success (McCann and Ortega-Argilés, 2013a). However the architecture, which remained unchanged from the 1980s to the 2010s, is currently undergoing a significant change under the most recent programming period (2014–2020) to strike a balance between an institutional focus and a focus on economic geography (McCann and Ortega-Argilés, 2013a, 2013b). The need for structural change has led to the creation of the smart specialization concept, which essentially seeks to support the European Cohesion target by encouraging regions to identify their relative strengths and leverage them, while avoiding imitation or duplication and head-on competition with other regions (Foray et al., 2011; McCann and Ortega-Argilés, 2013a).

Regional smart specialization is one of the initiatives of the EU2020 strategy, particularly the 'Innovation Union' Flagship Initiative. The concept of smart specialization was put forward by an expert group of academics called Knowledge for Growth (K4G) that was established by the Commissioner for Research, Janez Potočnik, to help reinvigorate the Lisbon Strategy (McCann and Ortega-Argilés, 2013b). The concept was first introduced in 2008 and has rapidly been adopted at the highest level of policy within the EU. It is now one of the key elements of the EU2020 strategy.

Despite the broad adoption and application, according to critics, the concept of smart specialization has been implemented without sufficient theoretical or empirical understanding of the concept (c.f. Boschma, 2014; Foray et al., 2011). Consequently, the current implementation of smart specialization seems to be characterized by wishful thinking and hopes for what the future can bring. One of the specific gaps in the research is insight into the complex institutional coordination failures (Grillitsch,

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2016) that result in poor economic development in various regions. Another, which this paper takes up, is the diversity of smart specialization dynamics. Therefore, the aim is to open up the black box of 'smart specialization' by discussing the diversity of diversification patterns that can lead to smart specialization. By focusing on the same industry—OWS—and how this industry has appeared in several regions approximately simultaneously by following different routes, we are able to refine a typology of structural economic change suggested by Foray (2014).

Furthermore, as discussed, foresight generally tends to lack a rigorous understanding of the mechanisms of development. The literature of regional foresight is preoccupied with participation and impact, while it remains largely silent on the mechanisms of regional development and associated industrial dynamics (see e.g., Gavigan et al., 2001; Gertler and Wolfe, 2004; Hanssen et al., 2009; Puglisi and Marvin, 2002; Roveda et al., 2004; Uotila and Melkas, 2007).

2.1. Smart specialization dynamics

Following Foray (2014), we distinguish between smart specialization dynamics and smart specialization policy.

Smart specialization dynamics refers to the underlying structural economic changes in a region where local resources and competences develop into new domains that transform the productive structure. According to Foray (2014) structural change is a result of several processes, including entrepreneurial discovery, spillover of different types of knowledge, and entry and agglomeration of firms into a new economic activity. These development processes are in force spontaneously all the time. As such, the theory on the dynamics of smart specialization is conceptually related to endogenous or new growth theory (c.f. Martin and Sunley, 2008; Sengupta, 1998; Solow, 2000).

Smart specialization policies rely on regional (or national) strategies that aim to facilitate dynamics that can lead to the development of new specialty domains, when these do not happen spontaneously. Hence, these policies are designed within different specialty domains and aim to support the preferred dynamics leading to structural change.

Smart specialization dynamics unfold along several characteristic processes, such as entrepreneurial discovery, knowledge spillover, entry and agglomeration and structural change (Foray, 2014). These are processes that have been studied in the field of economic geography for many decades. More recently, the emerging field of evolutionary economic geography has, with the literature on regional branching (Boschma and Frenken, 2011), focused on how new industries emerge in different regional settings. Likewise, the literature on innovation systems has highlighted how the development of innovation systems (such as regions and nations) is cumulative and path dependent (Malerba and Nelson, 2011; Suurs and Hekkert, 2009) and that place-based knowledge dynamics (Lundvall et al., 2002) are important drivers for innovations and, thus, are the fundament for developing new industries.

The entrepreneurial discovery process is: "*(…) the essential phase, the decisive link that allows the system to reorient and renew itself.*" (Foray, 2014). Entrepreneurial discovery precedes the innovation stage and is the phase Utterback (1971) calls idea generation. It is an explorative process where an idea is generated and matched to a technical mean. However, it covers both technical and economic knowledge about feasibility, marketability and profitability (Dosi, 1984). Hence, the entrepreneurial discovery phase is where entrepreneurial, technological and economic knowledge comes together to create a vision of new economic possibilities.

The question is how these new ideas are linked to the regional economy. Following the emerging literature on regional branching in evolutionary economic geography, such new economic activity can have several starting points. It has been shown that the concrete mechanisms for the creation of new regional economic activity are firm diversification (Tanner, 2014), entrepreneurial spinoffs (Boschma and Wenting, 2007; Klepper and Simons, 2000), labor mobility (Neffke et al., 2011) and networks within the region (Agrawal et al., 2006, Breschi and Lissoni, 2009). All of these mechanisms tend to have a local bias. Consequently, the new entrepreneurial idea is linked to the regional economy through pre-existing economic activities.

This process of creation of new economic activity has been labelled regional branching (Frenken and Boschma, 2007). The regional branching thesis, through its focus on understanding the evolutionary developments of regions, provides insight that supports the idea of smart specialization. The regional branching thesis proposes that regions tend to diversify into new industries that are related to the pre-existing industrial base of a region. The logic is that learning and knowledge spillover is more likely to take place among economic activities that are cognitively related (Nooteboom, 2000) than activities that are unrelated. Because knowledge production is a key element in processes of innovation, learning across existing economic activities functions as the base for developing new economic activities at the regional level. Common to the regional branching thesis and the smart specialization concept is their starting points. Both focus on building on the existing knowledge and capabilities of a regional economy to push it in the direction of new or expanded economic activities. Regional branching has been empirically corroborated for the long-term economic evolution of regions in Sweden (Neffke et al., 2011), the emergence of new industries in regions in Spain (Boschma et al., 2013) and the emerging fuel cell industry across regions in Europe (Tanner, 2016).

Entry and agglomeration are also important elements of smart specialization dynamics. Foray (2014) argues that "*While entrepreneurial discovery signifies the opening up of exploitation opportunities, entry constitutes the confirmation that others see this discovery as meaningful.*" Entrants can either be competitors that are forced to respond to an early mover's new innovation in order to stay competitive or firms that enter a new economic activity because of their supplier relationship with a first mover customer. Either way, the entry of similar or complementary firms is important for a regional economy to start specializing in a new activity and to potentially reach agglomeration effects.

2.2. Typology of structural economic change

Following the research questions for this article, this section proposes a typology for the patterns of regional development. There have been several attempts to classify structural changes in regional economies. Boschma and Frenken (2011) distinguish four types of branching through technological relatedness[1] between an emerging industry and pre-existing regional industrial activities. Tanner (2014) leans towards a classical push-pull distinction when she distinguishes between the emergence of new industries based on technological relatedness and market relatedness to existing regional economic activity. In this paper, we elaborate on Foray's (2014) proposal of a typology of structural economic changes that capture changes that the potential success of an entrepreneurial discovery may have on the regional economy. Foray distinguishes four types: transition, modernization, diversification and radical foundation.

1) *Transition* is characterized by an existing sectorial or technological innovation system of manufacturers, suppliers, customers, R&D infrastructure and specialized know-how and engineering capabilities that enter an emerging domain. A transition occurs when an existing industrial domain is capable of renewing itself and creating new markets, for example, when the wind turbine industry enters the offshore sector.

[1] Boschma and Frenken (2011) propose four mechanisms for regional branching through technology transfer: 1) the supply relationship, where innovation on the supply side drives innovation; 2) the interdependency of actors, which drives the search for innovation throughout the region if new innovations are introduced in one part of the system; 3) technological complementarity among industries, enabling the introduction of major new innovations; and 4) interdependencies introduced through common technological origin.

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2) *Modernization* is when a general purpose technology is applied in an existing (often traditional) sector, such as ICT in tourism, various industrial and retail supply chains, and nanotechnologies in the pulp and paper industry. The modernization pattern is not applicable to the cases investigated in this paper, and hence, we will not discuss this in further detail.
3) *Diversification* in a narrow sense is where a new discovery represents synergies or economies of scope between an existing industry and an emerging domain. In this case, an emerging domain builds on related or complementary resources and capabilities and, in contrast to transition patterns, is less directly linked to a core industrial commons. This is the case in the Norwegian offshore industry, where a strong industrial commons around oil and gas explores the possibilities of entering the emerging field of offshore wind servicing.
4) *Radical foundation* is the fourth pattern. According to Foray (2014), in radical foundation, a new domain is founded with no direct link to existing industries. However, recent studies suggest that radical technological development paths also emerge in regions with technologically related capabilities (Tanner, 2016). Radical foundation occurs either based on technologically related knowledge resources (science push) or through market pull mechanisms, for example, through public procurement. The latter is an important factor in creating markets for offshore wind.

Based on the typology proposed by Foray (2014), we propose focusing on two distinct underlying principles behind the process of structural change towards new economic activities. First, we propose distinguishing between structural changes based on extending the existing core industrial activity (as in *transition patterns A* and *C* in Table 1) or based on extending the core activity with complementary industrial activities (as in *diversification pattern B* in Table 1). In this typology, core and complementary are defined in relation to the target industry. Both paths are examples of generating related variety in a regional economy based on different starting points. It is important to stress that regions can enter an emerging industry based on either of the principles (B or C) or a combination thereof (A) (see Table 1).

Another underlying mechanism that can foster the emergence of new industries is the creation of markets (market pull), for instance, through public procurement (e.g., Edler and Georghiou, 2007). Particularly large infrastructure projects such as offshore wind farms present a stable and sufficiently large market that enables regional firms to pursue new economic possibilities that can sustain innovation in the regional economy as a response to a new market creation. Hence, new economic domains may appear as a response to a clearly articulated market demand, such as public procurement or private investment projects. Such development can explain the fourth pattern of structural change, *radical foundation (D)*, where there is no core or complementary industrial activity to spur from (*D* in Table 1).

In sum, this typology condenses the underlying dynamic principles of these different patterns of structural change related to smart specialization. We propose that this understanding can help policy makers and foresight practitioners visualize the multiple roads that can lead to new specialty domains and relate this to their own regional economy.

3. Method and data

The empirical evaluation of the typology builds on data collected during the EU FP7 project European Clusters for Offshore Wind Servicing (ECOWindS, 2012–2015). The project focused on developing OWS in four regions, East Anglia in the United Kingdom, North West Germany, southern Denmark and Møre in Norway (ECOWindS Partners, 2013). OWS is a subset of offshore wind and comprises the Balance of Plant. In practical terms, this means "everything but the wind turbine (ex-works)", the value chain from the factory door, including onshore logistics of components, installation, with operations and maintenance (O&M) (Findeisen, 2014). The project itself is modelled after the European guidelines for creating Regional Smart Specialization Strategies (Foray et al., 2012). As part of this project, four regions were mapped to identify their specialization in OWS around the North Sea. OWS is defined as a distinct subsector within the value chain of wind energy production and supply. This subsector encompasses the process of assembly, installation, operation and maintenance of offshore wind turbines.

We follow the guiding principles of a foresight mapping exercise in our study, akin to the method proposed by Andersen and Andersen (2014) and Hekkert et al. (2011). More specifically, we follow the innovation systems approach to foresight, seeking to apply the innovation systems foresight approach to the study of regional innovation systems. The objective is not to conduct a complete foresight exercise of the regions participating in the EcoWinds project from which our data is collected but rather to utilize the opportunities presented in the project to function as input to the Mapping and Foresighting stages of the foresight process (Andersen and Andersen, 2014). Thus, we perform an innovation systems analysis, mapping the strengths and weaknesses of the different regions included in the EcoWinds project, followed by identification and discussion of the driving factors and trends (Paliokaitė et al., 2015). In this paper, we do not elaborate on the Prioritising and Action Planning phases, as the objective here is not to report on the actual foresight exercise but rather to test the applicability of our empirical method as part of a regional foresight exercise.

The empirical context for this research is the OWS industry around the North Sea. Our empirical study is based on patent data as a surrogate to map regional technological competencies relevant to wind turbines and OWS. Patents are utilized as an indirect indicator of knowledge and competency development within a given region. Patents are a formal method of appropriation for the inventor and, hence, do not capture all available knowledge within a region. Some inventions are not patented, due to lack of novelty, and others are kept as trade secrets. Despite the inherent limitations of patent data, they present a viable source for measuring knowledge within a region and as a proxy for innovation and knowledge flows. In addition, the wind energy industry is generally known for actively patenting, and hence, most inventions with industrial application would be expected to be patented. We ascribe patents to firms based on patent assignee(s) and classify each patent according to data on the geographical location of the assignee(s) found in the address part of the patent. In the case of multiple assignees placed in multiple regions, the knowledge present in the invention is inherently shared among the involved organizations, and hence, the patent is ascribed to multiple regions. We use the OECD

Table 1
Patterns of smart specialization from different starting points for emerging economic activity as a function of relation to existing activities (Foray, 2014).

		Branching from	
		Core industrial activity	No core industrial activity
Branching with	Complementary/related industry	A Transition to a new/emerging industry	B Diversification to a new/emerging industry
	Non-complementary/related industry	C Transition to a new/emerging industry	D Radical foundation

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Regpat database (Maraut et al., 2008), which connects patents submitted to the European Patent Office to regions using NUTS3 regional codes.

Working with technical experts within wind energy and OWS, we identified 7 distinct technology areas relevant to OWS. These technology areas were identified using the International Patent Classification (IPC), allowing the technical experts to pinpoint the relevant technology areas in a number of OWS patents supplied by members of OWS industries. These classifications were applied in an iterative process with the technical experts, and during each round of iteration, both the included IPC codes and identified technology areas were evaluated. The result of this process is 7 distinct technology areas: *Cranes & lifting*, *Foundations*, *Grid connection*, *Jack-up barges*, *Positioning & anchoring*, *Support structure* and *Vessels*. These technology areas are combined with the regional codes (NUTS3) found in the OECD Regpat database, providing the basis for a regional mapping of the technical competencies within OWS.

It is important to note the distinction between patents we deem 'OWS relevant' and patents covering OWS technology. The dataset is based on two separate searches in Regpat. The OWS-relevant patents are classified within one of the 7 technology areas, but they are not necessarily directly applicable to OWS or Wind turbines. These are collected from 1977 to 2000 in an effort to estimate the knowledge present within each region that could form the basis of a new OWS industry. Patents covering OWS technology are classified to the same 7 technology areas as introduced previously but include either an IPC code indicating that the technology patented is applicable to Wind turbines (e.g., IPC code F03D) or text in the title or abstract indicating that the technology is relevant to wind turbines or offshore servicing. The result is a dataset containing 7996 patents relevant to OWS and wind turbines gathered from 1977 to 2010 (for the development of world OWS patents, see Fig. 1), covering the 4 regions that are the subject of the analysis. Of these 7996 patents, 4993 cover OWS-relevant technologies prior to 2000.

These patents are used to measure the knowledge present in the region prior to the introduction of OWS, which started to increase in 2001 (Corbetta, 2014). In total, 933 patents cover OWS technologies from 2001, with the remaining observations covering wind turbine patents from 1977 to 2010. These are included to provide an indicator of the competencies within this industry on which OWS relies. The distribution of OWS and OWS-relevant patents is presented in Table 2.

The distribution of these patents across regions and technology areas within OWS is presented in Table 3. Overall, the 4 regions that are analyzed cover 43% of the worldwide patenting activity in the area, reaching upwards of 60% of the total patents in the *Cranes* technology area. This highlights the important role these 4 regions fulfil, not only for the European market, but also worldwide. Overall, Germany and Denmark are the most active in the OWS industry.

In addition, the number of OWS patents and OWS-relevant patents worldwide are gathered from the period 1977 to 2010. This covers 59,236 patents, which are gathered to gauge the relative concentration of knowledge within the 4 regions in comparison to the global development within OWS. Based on this information, an index for the degree of specialization is calculated for each region and technology (Madsen and Andersen, 2010), comparing the number of patents within a given technology with the world average. Values >1 indicate a higher concentration of patent activity within the region. This index is used to calculate the regional specialization both for related technologies and for OWS technologies, highlighting the technological competencies of each region compared with the global average.

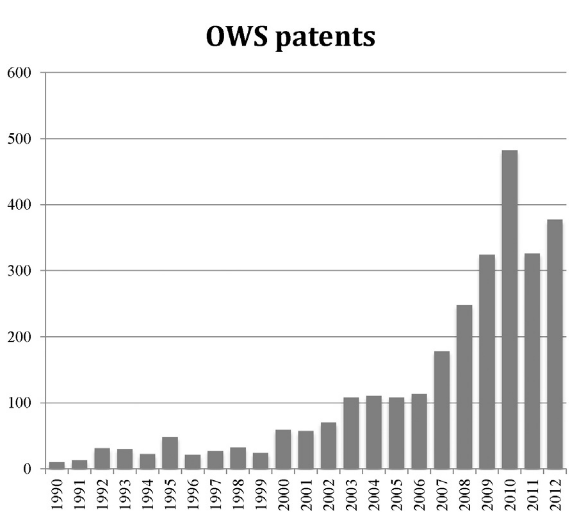

Fig. 1. World development in OWS patents, by year.

4. Findings

In this section, we present the results of the comparative analysis of how each of the four regions has entered the OWS sector. Wind energy is maturing as a reliable and economically sound renewable energy source, and offshore wind is anticipated to be the next expansion of wind energy (e.g., Kaldellis and Kapsali, 2013; Sun et al., 2012). Offshore wind in Europe is driven from the top largely by the Kyoto Protocol and the EU SET Plan and renewable energy targets (e.g., Snyder and Kaiser, 2009). Additionally, because wind energy (onshore) is next to hydropower among the most cost-competitive renewable energy forms, offshore wind is a natural extension, as onshore sites are beginning to become saturated in Europe and other densely populated areas around the world, and offshore wind has a promise of being a superior wind resource (Bilgili et al., 2011; Kaldellis and Kapsali, 2013).

Although the first offshore wind farm was erected in 1991 in Denmark, offshore wind has emerged only during the last five to ten years as a serious commercial alternative, as the installed (nameplate or nominal) capacity in Europe exceeded 1 GW in 2007, with 300 MW or more added every year since (Corbetta, 2014).

A combination of a drive for energy security and environmentalism has driven wind energy in Denmark and Germany before many other EU member states. It is often casually mentioned that the Danish history of wind power starts with the 1970s Oil Crisis, which led to pressure to seek energy independence through renewable sources. By the end of the 1990s, over 10% of Danish electricity was generated by wind power, and by 2012, it was >30% (Danish Energy Agency, 2014). The long history of utility-scale (onshore) wind power generation and its relative importance in the energy mix may explain why Denmark is so prominent in the turbine segment. Also, Germany has a long history with wind energy, and a similar position in the value chain. In fact, over 80% of the world's installed offshore capacity at the time of the writing has been delivered by Vestas Wind Systems and German-owned Siemens Wind Power, located in Denmark (Corbetta, 2014).

Despite the early mover status in Denmark, the domestic market for offshore wind historically has been relatively small in Denmark. At the time of writing, half of Europe's—and, in fact, nearly half the world's—installed offshore wind capacity resides in the UK (Corbetta, 2014; Wieczorek et al., 2013). The UK government has engaged in quite a purposeful niche creation to accelerate renewable energy adoption, with wind energy in particular benefitting (Kern et al., 2015; Kern et al., 2014; Wieczorek et al., 2013). This also explains why the UK is rated as strong in the O&M part of the value chain. In the UK, the history of (offshore) wind is quite different from that of Denmark and Germany, as the emergence of utility-scale renewables has been quite recent and driven by energy policy and international commitments, without the support of domestic original equipment manufacturers (OEMs).

Due to abundant hydropower and fossil energy supplies, Norway has next to no installed capacity at the time of writing. However, Norway and the Møre region have a history of servicing Offshore Oil & Gas operations, which contribute to the capabilities of OWS operations.

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Table 2
OWS patents by region.

	Related technology prior to 2000	Wind turbine technology prior to 2000	(Region) Total patents prior to 2000	OWS technology from 2001	Wind turbine technology from 2001	(Region) Total patents from 2001
DK	126	39	8256	230	544	11,946
DE	3766	112	255,012	522	1183	250,705
GB	851	15	74,474	109	120	49,777
NO	250	3	3837	72	54	4427
Category totals	4993	169	341,579	933	1.901	316,855

Table 3
OWS and wind turbine patents by region.

	Cranes	Foundations	Grid	Jack-up	Positioning	Support structure	Vessels	Total
DE	52	54	282	38	10	166	29	631
DK	24	18	126	9	3	72	17	269
NO	2	13	17	14	0	35	14	95
UK	3	12	44	24	1	38	23	145
Other countries	52	98	785	64	14	384	110	1507
ECOWinds share of world OWS patents	*60.90%*	*49.74%*	*37.40%*	*57.05%*	*50.00%*	*44.75%*	*43.01%*	*43.07%*

Norwegian companies have consequently been actively engaged in OWS operations around the North Sea, particularly in building service vessels of wind farm operators, OEMs and OWS service providers.

To illustrate the regional actors' own perceptions of their strengths along the OWS value chain, Fig. 2 displays a quantified (self-) assessment of the regional competences based on a stock-taking of resources.[2] The regions with the most installed capacity focus on the chain from assembly to O&M. Manufacturing and planning are strongest in Denmark and Germany, as the world's largest offshore wind turbine suppliers reside in Denmark, one being a Danish enterprise and the other a German-owned Danish-German enterprise. It is also evident that the strength of the chain from installation to O&M correlates with installed capacity, with the UK and Denmark being the strongest.

Table 4 summarizes the findings from the patent analysis showing the regional specialization degrees for related technologies and for OWS technologies. This highlights the technological competencies of each region in comparison with the global average. Values > 1 indicate a higher concentration of patent activity within the region. The four regions show different profiles, highlighting that while each region has achieved strong competencies within OWS, these are based on different knowledge bases.

In the following, we analyze these patterns in more detail. For each region, we show the regional patenting profile within OWS and wind turbine patents as well as the regional strengths (see Figs. 3–10).

As discussed, Denmark is a leader in turbine technologies, and thus, the regional patenting profile is very sharply focused on wind turbine technology. Fig. 4 shows the regional strengths in Denmark in related technologies prior to 2000 and in OWS after 2000. Denmark has managed to develop very strong positions in OWS technologies (with specialization degrees ranging from 7.2 to 21.5) after 2000, despite Denmark only having limited specialized skills within related OWS technologies prior to 2000. Table 4 shows how Denmark's strengths in related competences prior to 2000 are close to the world average (between 0.5 and 1.18). Nevertheless, these figures indicate that Denmark has had related competences to build on, and hence, we argue that the structural change we see in Denmark combines competences from the core industrial domain (wind turbines) and complementary OWS assets, which marks *transition (A)*.

Norway's patenting profile is dominated by vessels, jack-up barges and positioning and anchoring; see Fig. 5. Fig. 6 shows how Norway has been able to develop strong positions within most of the OWS technologies (except for positioning and anchoring) in the years after 2000. This development is based on Norway's strong patenting activity in related technology areas prior to 2000, particularly vessels, jack-up barges, foundations, positioning and anchoring, cranes and support structures, which all show specialization degrees above 1. It is likely that the experience from offshore construction in relation to the offshore oil and gas industry that has driven Norwegian development. In this regard, Norwegian development has followed the structural change of *diversification (B)* based on complementary industrial activities.

The UK also has a different patenting profile from the other regions; see Fig. 7. The focus is balanced among foundations, supports, positioning, and vessels, but there is a major focus on grid connections. The grid focus may be in part explained with the strong presence of Prysmian Group and Nexans, two of the leading providers of cables for offshore wind farms (c.f. Jacobsson and Karltorp, 2013; Wieczorek et al., 2013). Similarly, the related technologies have expanded much in the same way as in Denmark. However, prior to 2000, the UK did not have any particular strength in any of the OWS technologies, although the numbers show that related competences were present in the region (see Table 4). Since 2000, the UK has developed regional strengths in jack-up barges and vessels, as well as foundations and supports (specialization degrees > 1) (Fig. 8). This profile is consistent with a large installed capacity of offshore wind and points towards a market-driven *radical foundation (D)*.

Finally, the German patenting profile, see Fig. 9, is very sharply focused on grid connection and positioning on the one hand and wind turbines on the other. Fig. 10 reveals that Germany had some specialty in cranes and lifting as the only related technology area prior to 2000, and has developed moderate strengths in all of the OWS technologies post-2000, except in vessels. We hypothesize that this is due to a generally strong and varied industrial base, and the specific effect of offshore wind is therefore difficult to trace. Nevertheless, the structural change that has taken place in Germany can be ascribed to a combination of related skills and skills in the core industrial domain of wind turbines in a pattern of *transition (A)*.

One of the key findings is that the four regions indeed have different profiles in terms of knowledge assets, capabilities and capacity in different parts of the OWS value chain. The analysis has revealed quite distinct profiles among the regions, which reflect the history of the region in terms of the wind industry in general and OWS in particular.

Relating the profiles to the typology of structural change, it is evident that the regions build on different combinations of core and complementary economic activities (see Table 5) as well as market mechanisms

[2] The self-assessment was conducted by regional cluster organizations during the mapping of regional competence profiles and is based on the documentation of tangible and intangible regional resources and expert interviews (for details, see Findeisen, 2014).

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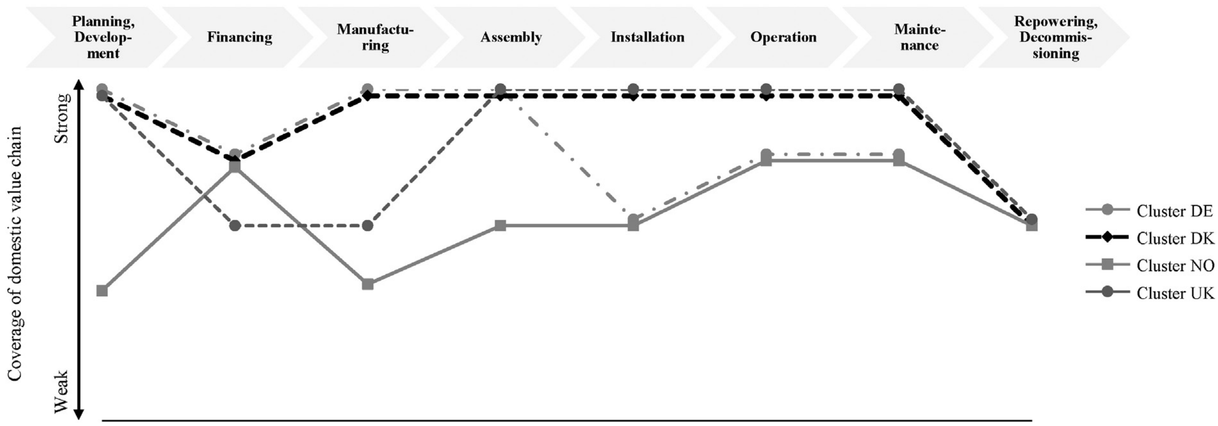

Fig. 2. Coverage of OWS value chain in the four regions (Findeisen, 2014).

demanding the development of new economic activity. The case for a *radical foundation* of the OWS sector is the strongest in the UK. The case for *diversification*, in turn, is the strongest in Norway, where the technologies are based on existing complementary knowledge assets built up in the offshore oil and gas industry, whereas Denmark and Germany exhibit *transition* patterns, where the emerging OWS sector is developed based on a combination of core and complementary industrial activity.

Overall, this analysis illustrates concisely that while there is a rich history behind the observed regional differences, the measurable differences in patenting capture those phenomena. If we compare these findings against the short history of offshore wind, the different competences are linked to the history and path of development in terms of the adoption of wind energy and the development of industry and related policies. We can hypothesize that the early interest in and gradual scaling of wind power in general and component manufacturing overall has shaped Danish and German paths differently than the UK, where offshore wind has scaled up more rapidly, and Norway, which has been dominated by offshore oil and gas industry.

5. Discussion

The empirical analysis essentially corroborates the theoretical propositions about the four patterns of regional dynamics underlying smart specialization. This has implications both for smart specialization and foresight, particularly regional foresight. The contribution to the literature on smart specialization and foresight is the empirically corroborated typology of diversification patterns that can be used as an analytical framework for both analysis and anticipation, as discussed in the following section.

The contribution of this research on dynamics of smart specialization and regional branching is that we have identified and empirically evaluated four distinct patterns of smart specialization. This framework of patterns offers a theoretically and empirically sound 'template' for understanding the pathways of smart specialization.

Based on the findings, we argue that smart specialization hinges on two pivots: 1) leveraging existing resources, both tangible and intangible, towards new markets and applications, and developing new resources to reinforce the new path within enterprises and their networks, and 2) providing suitable framework conditions for the new industry to build on and develop. Within the framework of smart specialization policy, the focus of public institutions' actions is on the framework conditions, but the literature generally acknowledges that for interventions to be effective, they need to recognize the regional assets as well as the specific weaknesses in the framework conditions that hinder the innovation (Asheim et al., 2011; Bergek, 2014; Boschma, 2014).

One of the challenges in the smart specialization strategy process is the difficulty of acknowledging and anticipating the possible alternative development paths based on the strengths and weaknesses of the innovation system. The typology helps provide a framework for analyzing the necessary conditions for regional branching towards a given industry. This exploration of dynamics informs the analysis of regional competences and planning for action. The smart specialization policy (RIS3) involves facilitating dynamics that can lead to changes in the regional production structure and thus (smart) specialization. Following that, we propose that a better understanding of the principles behind regional branching processes contributes to reducing the difficulties policy makers face when developing RIS3 strategies.

Going forward, Foray (2014) argues that smart specialization requires moving from 'horizontal' policies aiming at general framework conditions to 'vertical' policies targeting specific fields or technologies. This means moving from general recommendations on improving human capital, creating incubators, and setting up tech-transfer facilities to selecting specific projects within emerging domains. Here, the typology offers tools, because when a target industry is chosen, the typology

Table 4
Degree of regional specialization within OWS, prior to & after 2000.

Degree of specialization	Cranes	Foundations	Grid	Jack-up	Positioning	Support structure	Vessels
Regional specialization within related technologies, after 2000							
DK	21.54	11.02	11.99	7.21	12.79	12.37	10.51
DE	2.22	1.58	1.28	1.45	2.03	1.36	0.85
UK	0.65	1.76	1.01	4.61	1.02	1.57	3.41
NO	4.84	21.48	4.37	30.27	0.00	16.22	23.37
Regional specialization within OWS technologies, prior to 2000							
DK	0.94	1.18	0.53	0.98	0.46	1.06	0.80
DE	1.11	0.82	0.69	0.48	0.69	0.71	0.42
UK	0.38	0.98	0.35	0.69	0.47	0.72	0.70
NO	1.66	2.17	0.21	6.81	2.20	1.02	15.96

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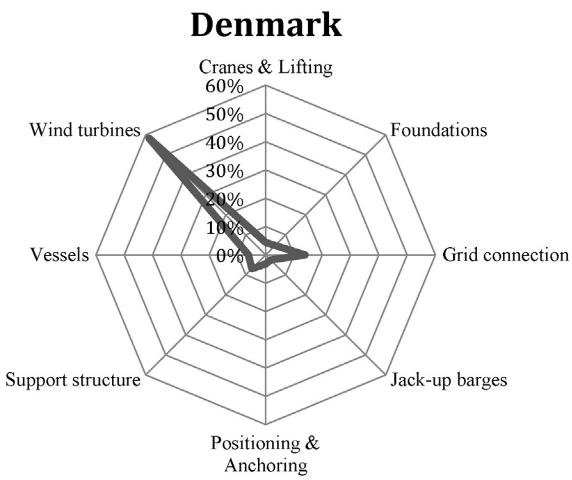

Fig. 3. Regional patenting profile, Denmark.

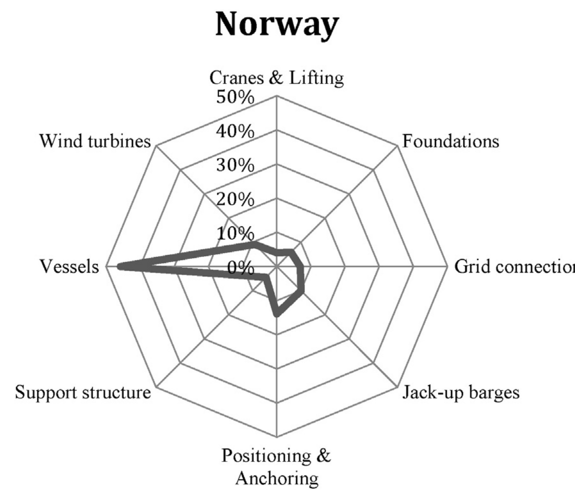

Fig. 5. Regional patenting profile, Norway.

provides an analytical framework for the examination of regional activities, assets and their complementarities, as well as analysis of the likely diversification patterns, which in turn enables the design of instruments.

We can take the case of offshore wind and OWS as an example. The general weaknesses include fragmented and unstable policies and regulatory frameworks, as well as costs and the associated high risks (e.g., Andersen et al., 2015; Stolpe et al., 2014; Wieczorek et al., 2012). As recorded elsewhere, the paradox of OWS and offshore wind in general is that the market is not more developed in Denmark and Germany, where the component manufacturing value chains are arguably the strongest (Wieczorek et al., 2015; Wieczorek et al., 2013). It is likely that the size of the market and relative lack of effort to build a niche for offshore wind and, by extension, offshore wind services have influenced the trajectories. Assuming a degree of risk averseness, the most likely pattern of transition would be based on strong core activities, possibly with complementary activities (*transitions A–C*). The likelihood of the other patterns that require extensive investment in developing assets likely hinges on the stability of framework conditions and the market.

In this sense, the case of the UK illustrates that, while rare, a *radical foundation (D)* of industry is possible given a stable political framework and sufficient public and private investments (Foxon et al., 2005; Kern et al., 2015; Kern et al., 2014). Kern et al. (2014) describe the creation of 'protective space' by renewable energy quotas, subsidies, and feed-in tariffs that created a demand for offshore wind energy and, by extension, OWS and thus supported investment in technology and infrastructure. It has been argued that active 'system building' from public organizations has contributed to the growth of the offshore system in the UK by forming the institutional framework and by acting as mediators or facilitators (Kern et al., 2015). The case in Norway is similar, except that the path is driven by a strong complementary industry that is diversifying to a new market that is opening especially in the nearby UK waters.

These cases also suggest that the role of 'demand-side instruments' (Edler and Georghiou, 2007; Georghiou et al., 2013) may be important in facilitating smart specialization. Demand-side policy instruments, such as those discussed above, are one possible tool for creating and shielding spaces for emerging technologies and for bolstering market creation by essentially creating 'artificial' demand. This demand enables one to enter a market, refine the technology and processes, and reach economies of scale while being sheltered from competition by (incumbent) substitute technologies.

The contribution to foresight is based similarly on the typology of diversification patterns, as the framework can be used for analysis of the present as well as anticipation of possible future development paths. The paper contributes to both methodological and theoretical aspects for foresight.

The paper contributes specifically to the theory of innovation system foresight (ISF) based on the patterns of industrial change and understanding of the evolution of innovation systems (Andersen and Andersen,

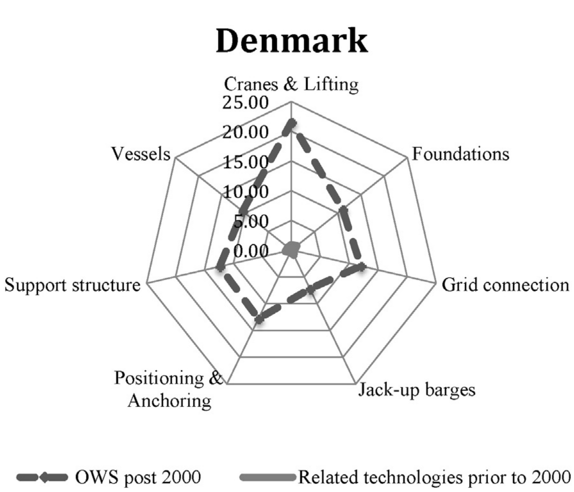

Fig. 4. Regional strengths, Denmark.

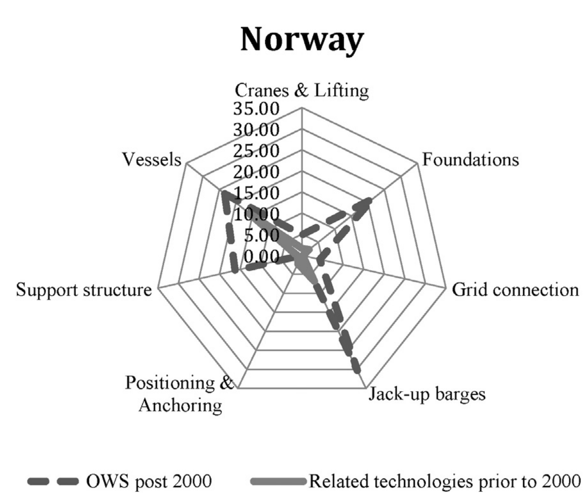

Fig. 6. Regional strengths, Norway.

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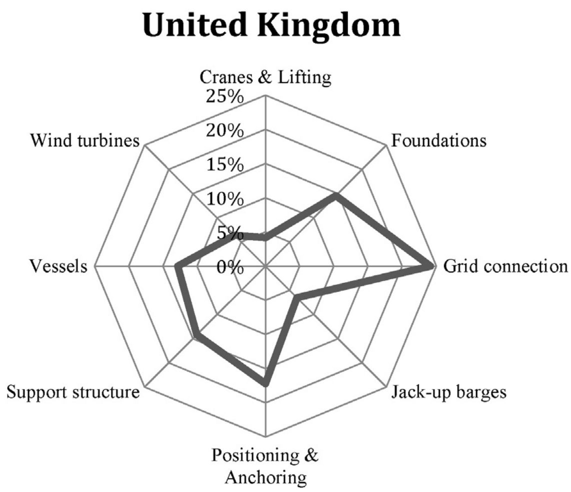

Fig. 7. Regional patenting profile, United Kingdom.

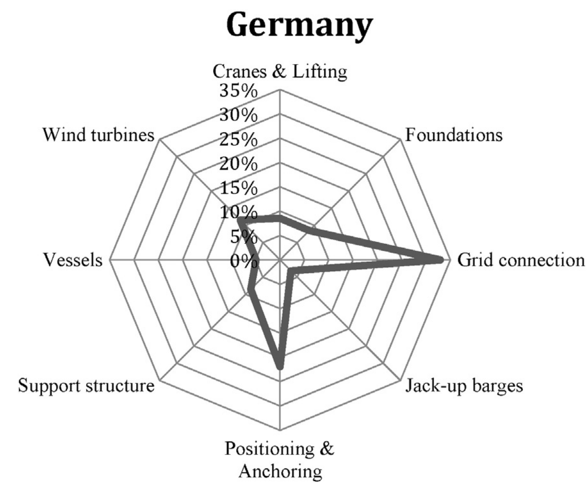

Fig. 9. Regional patenting profile, Germany.

2014). ISF is based on certain theoretical assumptions on the development of innovation systems. It is assumed that an innovation system is constructed from a network of actors, institutions, and certain key processes called the functions of innovation systems (Alkemade et al., 2007; Bergek et al., 2008). The projections towards the future in ISF follow the logic of diagnosing the state of the innovation system and anticipating the unfolding development through the lens of innovation systems and their functions. The typology presented in this paper provides a theoretical contribution to ISF by proposing an explanation for regional branching in terms of the identified development patterns. That is to say, the typology is a theoretical construct that characterizes regional development and can be used to analyze and anticipate regional branching within smart specialization and other foresight processes. In terms of theoretical aspects of foresight, in the recently-used terms, this research represents 'theorizing within foresight', i.e., developing and applying domain-specific theoretical understanding that enables theoretically and empirically sound conjectures about the future (Piirainen and Gonzalez, 2015).

Methodologically, the typology offers a new analytical framework for anticipating plausible developments based on the analysis of available resources and competences and functions of the innovation system. Related to the methodology of ISF, innovation systems foresight starts from mapping the innovation system and analysis, and it proceeds to foresighting (Andersen and Andersen, 2014). The analysis of smart specialization dynamics straddles the mapping and analysis of the innovation system context and foresighting, as in analyzing the establishment of trends and drivers of development.

At the level of a foresight process, the practical application of the typology for foresight specifically can be viewed from two opposing perspectives in the traditions of explorative or normative foresight. First, in the normative tradition, a vision and goals are selected for, e.g., a region, early in the process. The subsequent analysis of options and paths to achieve that vision can be based on the proposed typology to analyze the possible branching paths from the present to the goal state to inform the planning of actions. Second, in the explorative tradition, an analysis of regional knowledge bases and industry structure can be used to anticipate the development of new industries based on identifying the combinations of strong core industrial activities and complementary assets that, for example, can be used to formulate scenarios for regional branching according to the typology. The identified patterns offer an analytical framework schema to examine the possible paths of *modernization*, *transition*, *diversification*, and *radical foundation*, identifying the path of least resistance for regional branching within the framework conditions, market demand, and other incentives, as analysed in ISF. Furthermore, the analysis contributes to planning actions and instruments in relation to the chosen goals for the development of the system.

Finally, we offer two reflections on the limitations of the research and suggestions for further study. First, our analysis has focused on

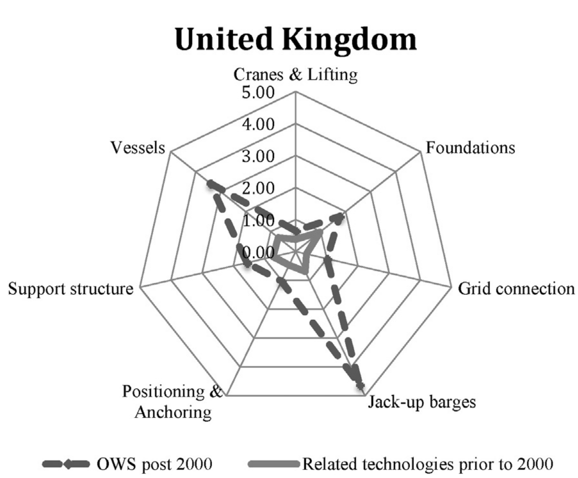

Fig. 8. Regional strengths, United Kingdom.

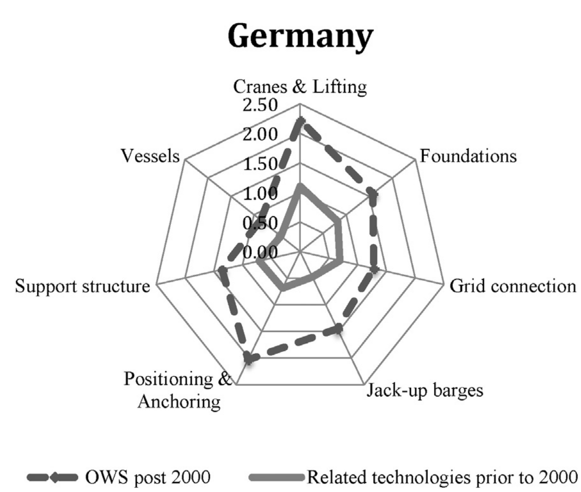

Fig. 10. Regional strengths, Germany.

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Table 5
Starting points for the emerging OWS sector.

		Branching from	
		Core industrial activity	No core industrial activity
Branching with	Complementary/related industry	Denmark Germany	Norway
	No complementary/related industry		UK

the industry level, taking the development in the regions as wholes. It follows that there are three main limitations to the study. We have not analyzed the firm-level dynamics within or across regions specifically. Similarly, we have not specifically investigated the interplay among industrial dynamics, the time of entry to a given market/technology niche, or the life-cycle phase of market/technology. Finally, we have not mapped the specific framework conditions and various inducement and blocking mechanisms to the regional industrial dynamics to make conclusive statements about which combination of specific framework conditions and/or policy instruments go hand-in-hand with particular patterns of regional branching.

These limitations suggest further investigation into the micro-foundations of the regional dynamics. At the firm level, the time of entry and industry asset position bear significance when it comes to the difference between *Diversification* and *Transition* patterns. The situation is analogous for *diversification (B)* and radical *foundation (D)*, as again, the common factor is position to core industrial activity or lack thereof, but the pivot is whether there is an industry to branch with or whether it is the branching region creating it. As discussed in the literature related to first mover advantage, perceptions of risk and relative asset position have a great influence on risk taking and innovation at the firm level (Hoppe and Lehmann-Grube, 2001; Piirainen et al., 2014; Suarez and Lanzolla, 2007; Tellis and Golder, 1996). On the other hand, there is the pending question of how exactly the observed regional branching has been shaped by various national and regional framework conditions and inducement and blocking mechanisms and whether it has happened because of or despite policy interventions.

Second, in this instance, we have used patents as a surrogate measure for knowledge creation and industrial change. The general weakness with patent data is that, depending on the industry, patents capture a variable portion of innovation activities. In the context of smart specialization and foresight, other applicable measures that also signal where the regional actors are headed could be R&D investments, a number of research, development, innovation, and other development projects, or new product launches, possibly in some combination, coded by a technology or competence area.

6. Conclusion

This paper set out to explore dynamics of smart specialization through a contemporary case from the emerging Offshore Wind Service (OWS) industry around the North Sea in order to elaborate the typology of structural change patterns suggested by Foray (2014). To answer the research question, we suggest four different paths based on two drivers: the existence of a complementary industry and position in relation to core business activities. The paths are named *Transition (A)* from the existing core base with complementary industry, *Transition (C)* from core business to new industry without complementary activities, *diversification (B)* outside core business with complementary industry, and *radical foundation (D)* of a new industry without previous core business or complementary industry.

The findings presented above show some evidence of regional branching, i.e., that related and relevant industries spur the growth of new ones. The empirical analysis of the OWS industry around the North Sea finds that the regions have different starting points and have followed different trajectories (Denmark and Germany's turbine manufacturing-based *transition*, the UK's *radical foundation* based on rapid increase in installed capacity and Norway's *diversification* based on offshore oil and gas).

What we can derive from this exploratory investigation in terms of the dynamics of smart specialization is that, as proposed, the dynamics rely on different principles of relatedness to pre-existing regional economic activities, while also being driven by other incentives. However, the emergence of OWS has been partly a top-down process driven by energy policy, which can mean that the emergence of the industry and associated capabilities is likely affected by 'pull' mechanisms in all of the investigated regions. This also indicates that sectoral policies and instruments outside industrial and innovation policy play a crucial role in smart specialization. To go beyond the present findings, further work is needed to corroborate this research in different contexts to provide a better understanding of the dynamics of regional smart specialization, particularly regarding industry creation in the context of other industries and in relation to industry maturity and phase of development.

The significance of these findings for foresight literature and practice is that the typology of smart specialization dynamics provides an analytic framework for regional development that enables theoretically and empirically sound anticipation of industrial dynamics. The typology can be used to lay out plausible development paths based on the analysis of regional capabilities. These findings can be used in explorative foresight to anticipate development patterns or in normative foresight to map the current state and probable developments and to design interventions to change the system.

Acknowledgements

The authors acknowledge the ECOWindS partners' extensive contribution to data collection and aggregation. This research has been partly funded by the European Commission under the 7th Framework Programme for Research and Innovation under grant no. 320042, and the Danish Council for Strategic Research / Innovation Fund Denmark through EIS - Strategic Research Alliance for Energy Innovation Systems and their Dynamics.

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Please cite this article as: Piirainen, K.A., et al., Regional foresight and dynamics of smart specialization: A typology of regional diversification patterns, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.06.027