

How Purchasing and Supply Management Practices Affect Key Success Factors: The Case of the Offshore-Wind Supply Chain

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ABSTRACT

Purpose—In reference to the offshore-wind industry, this study shows that innovative purchasing and supply management practices can increase not only firm- but also industry-level performance. This article also includes a description of the offshore-wind supply chain, which remains under studied in academic literature, despite increasing global development of offshore-wind farms.

Design/Methodology/Approach—Offshore-wind farm projects employ more and larger turbines, which greatly increase the complexity of the supply chain. Innovative purchasing and supply management practices, designed to tackle this growing complexity, could help companies achieve the key success factors that define this industry. The evidence comes from real-world, offshore-wind farm projects, with the London Array farm as a principal example.

Findings—Innovative purchasing and supply management practices include decisions to make or buy, contract forms and local-to-global sourcing. These practices affect the key success factors of the industry by increasing competition, capabilities, and control.

Originality/value—Purchasing and supply management practices could affect industry-level performance. This article is among the first ones to provide an analysis of the offshore-wind supply chain and its evolution.

Keywords—capabilities; competition; contracts; control; global sourcing; local sourcing; make-or-buy; renewable energy; vertical integration; supply chain.

Article Type—Conceptual paper

1. Introduction

The effective use of global sourcing can help companies achieve superior firm performance (Lindgreen *et al.*, 2009; Lindgreen *et al.*, 2013). We consider how innovative purchasing and supply management practices might increase industry-level performance too, with a focus on the offshore-wind industry. Offshore-wind offers a promising renewable form of energy, such that the industry has experienced constant growth in recent years (GWEC, 2013). In efforts to improve energy generation capabilities, firms have built more and larger turbines, a trend that has repercussions for the offshore-wind market, its technology, and the complexity of the supply chain. With a supply chain-level analysis, we identify the innovative use of three purchasing and supply management practices—make-or-buy decisions, contract forms, and local-to-global sourcing decisions—that can address supply chain complexity. On the basis of key success factor theory (De Vasconcellos E Sá and Hambrick, 1989), we propose a conceptual framework in which innovative purchasing and supply management practices represent the strengths that firms acquire to achieve key success factors for the industry. With real-world, industrial evidence from recent offshore-wind farm projects, including the London Array farm, we identify three key success factors in the offshore-wind industry: competition, capabilities, and control.

We contribute to managerial practice by offering a clear direction to companies operating in the offshore-wind industry for innovating their purchasing and supply management practices and thereby increase performance. In terms of our academic contribution, we offer the first academic study of the offshore-wind supply chain and its underlying mechanics. Furthermore, we confirm that purchasing and supply management practices have both firm-level and industry-level relevance. In investigating the offshore-wind industry, we reveal various opportunities for purchasing and supply management practices, as outlined by Schoenherr *et al.* (2011), such as identifying the dynamics that lead

to global sourcing, analyzing the effect of supply management on competition, investigating effective ways to develop supplier capabilities, and identifying mitigation measures for supply chain risks.

We contribute to theory by proposing a conceptual framework, tailored for the offshore-wind industry, in which purchasing and supply management practices can increase not only firm- but also industry-level performance. A limitation of our conceptual framework is that the purchasing and supplies management practices and success factors we identified are specific to the offshore-wind industry.

In the next section, we detail some relevant literature, before we describe the offshore-wind industry and its supply chain, using the London Array farm as a principal example. From this description, we propose a conceptual framework that links innovative purchasing and supply management practices with key success factors. In addition to comparing our results with extant findings, we conclude with some opportunities for further research.

2. Theoretical background

Previous studies, drawing on resource-based theory, suggest that purchasing and supply management practices enhance firm-level performance (Lawson *et al.*, 2009). Zimmerman and Foerstl (2014), by conducting an extensive analysis of previous literature, indicate a strong support for the positive relationship among purchasing and supply management practices and firm performance. We argue that innovative purchasing and supply management practices can increase not only firm but also industry-level performance. We use the key success factor theory to motivate our conceptual framework and its application to the offshore-wind industry (Figure 1). De Vasconcellos E Sá and Hambrick (1989) suggest that key success factors in an industry derive from its underlying characteristics, the context of its

market, and the technology available. They theorize that firms whose strengths match the key success factors of their industry achieve better performance. The authors use a broad definition of strengths, including knowledge and capability types, with purchasing classified among the latter. We argue that the growth of offshore-wind developments requires new technological advances and affects the market but also increases the complexity of the supply chain, as we detail in Paragraph 3.2. To respond to such changes, companies operating in this industry should adapt by innovating their purchasing and supply management practices. In our conceptual framework, innovative purchasing and supply management practices constitute strengths, from key success factor theory. By reviewing previous and current projects in Paragraph 3.3, we argue that they are consistently associated with make-or-buy decisions, contract forms and local-to-global sourcing decisions. These innovative purchasing and supply management practices match industrial-level key success factors and allow companies to achieve high performance. From our industrial evidence, described in Paragraph 3.4, we identify competition, capabilities, and control as key success factors for the offshore-wind industry.

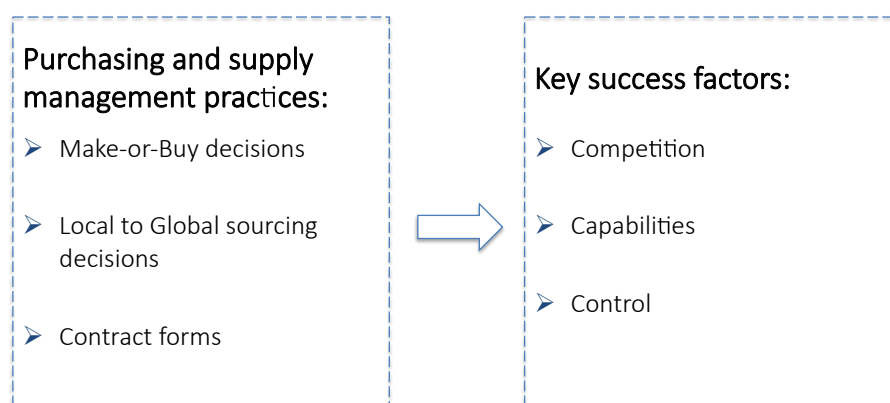


Figure 1: Conceptual framework for the offshore-wind industry.

In here, we review studies closely associated with our conceptual framework and its central purchasing and supply management practices, namely, make-or-buy decisions, contract forms, and local-to-global sourcing. For each purchasing and supply management practice, we emphasize evidence from previous studies regarding the effects of the key success factors in our conceptual framework, namely, competition, capabilities, and control.

Make-or-buy decisions pertain to whether a company performs a process in-house or outsources it to a third-party supplier. Vertically integrated assemblers adopt a make strategy for component fabrication. In a two-tier setting, Corbett and Karmarkar (2001) analyze the relationship between vertical integration and competition in a serial supply chain with deterministic demand and find that integrating successive oligopolists reduces total profits; because despite their avoidance of double marginalization, the benefits do not outweigh upstream competition. Furthermore, between integrated and nonintegrated firms, integrated chains perform better. Argyres (1996) explores how supplier capabilities affect outsourcing but contests the prediction from transaction cost economics (TCE) that firms outsource if the external transaction costs are lower than the internal ones (Riordan and Williamson, 1985). Argyres (1996) claims instead that firms outsource when they possess capabilities inferior to potential suppliers, such that their production efforts would lead to the same results as those of suppliers but at a higher cost, reflecting a capability-based view. He concludes that firms bear higher costs only in the short term, when they develop capabilities in-house. Novak and Stern (2009) cite control as a driver of vertical integration. When developing a new product, the choice to build a component in-house increases the probability that other components get built in-house too, which increases the level of vertical integration (Novak and Stern, 2009). This behavior is particularly prominent when firms manufacture complex products and aim to increase their control over manufacturing processes.

Contract forms refer to the conditions of delivery of products or services. By signing contracts, buyers and suppliers agree on the price, quality, and time of delivery of products or services; they also determine how to share risks if a disruption occurs. Cachon and Kök (2010) analyze a serial supply chain with many suppliers and one buyer, examining a case in which firms adopt sophisticated contracts, such as quantity discounts and two-part tariffs. These contracts allow suppliers to coordinate the supply chain and maximize their overall profits. However, such contracts also force suppliers to compete more aggressively, which lowers their profits. Contract literature traditionally differentiates detailed and court-enforceable transactional contracts, such as those analyzed by Cachon and Kök (2010), from relational, more informal agreements between suppliers and buyers. Taylor and Plambeck (2007) note that relational contracts can be extremely effective in the earlier stages of new product development, when the design is ill-defined and demand forecasts are uncertain. In this context, suppliers and buyers rarely can write transactional contracts that appropriately specify the supplier's investment in the capabilities to manufacture the needed components. Lindgreen *et al.* (2013) also provide empirical evidence that firms that adopt relational contracts and a high level of integration generally outperform others. The high level of integration increases knowledge transfer between suppliers and buyers, allowing firms to develop superior capabilities. Previous literature also focuses on how contracts might increase the level of control on the supply chain. For example, Li and Kouvelis (1999) argue that suppliers should take increasing responsibility for supply chain processes through risk-sharing mechanisms, such as buyback, revenue-sharing, and quantity-flexibility contracts that bind suppliers to share the risks of volatile demand with buyers (Chopra and Meindl, 2010). Buyback contracts allow buyers to return unsold products to suppliers; revenue-sharing contracts give suppliers the right to charge buyers a low price for the items and share a fraction of the buyers' revenues; and quantity-flexibility contracts allow buyers to update

their orders after observing demand. In addition, delayed-payment contracts in high-uncertainty projects can bind suppliers to sharing their operational risks with buyers (Kwon *et al.*, 2010), because buyers pay suppliers only after the completion of contracted tasks.

Finally, *sourcing* covers the processes of identifying, selecting, evaluating, and engaging with suppliers. Firms operating with suppliers, mostly in the same country where the product or service is delivered, use a local sourcing process. Others rely on global suppliers. When suppliers are scarce, buyers often lack any choice between local and global sourcing strategies; they simply sign long-term agreements with available suppliers and turn to single sourcing (Bozarth *et al.*, 1998). Local sourcing and industrial clusters in particular have proven effective for enhancing suppliers' capabilities and skills, because of the proximity between suppliers and buyers (Tunisini *et al.*, 2011). Holweg *et al.* (2011) argue that firms are less likely to adopt a global sourcing model in the presence of uncertain demand, high customer service, high costs of expediting shipments, or more complex product manufacturing. Micheli *et al.* (2014) also note that global sourcing risks could negatively affect firms' performance, in terms of quality and time in particular. A closely associated strategy is offshoring, in which firms move their manufacturing to another country, due to its proximity to the final market or potential labor cost savings. However, such firms also must consider whether the government of the production country will bind them to purchase components locally or invest in the country's economy (Bozarth *et al.*, 1998).

3. Industrial application

In this section, we describe the industry application of our conceptual framework. First, we introduce the methodology of this study. Next, we describe the offshore-wind industry and its supply chain. Then, we present the results of our analysis in relation to purchasing and supply management practices and key success factors for the offshore-wind industry.

3.1. Methodology

We employ real-world, industrial evidence from recent offshore-wind farm projects, and from the London Array farm in particular to understand the role of purchasing and supply management practices in support key success factors for the offshore-wind industry. We use secondary data available from reputable web sources selected with the help of practitioners working in the offshore-wind industry. Because of the exploratory nature of this research project, secondary data have been deemed suitable to improve our understanding on the offshore-wind industry and its supply chain and to develop the conceptual framework in Figure 1. We use the data from the London Array farm for the findings on the offshore-wind industry and its supply chain (paragraph 3.2). We use the data from many offshore-wind farm projects for the findings on the purchasing and supply management practices and the key success factors of the industry (paragraphs 3.3 and 3.4).

3.2. Offshore-wind industry and supply chain

To provide a detailed description of the offshore-wind industry and its supply chain, as well as argue that the growth of existing developments has increased the complexity of this supply chain, we use the London Array farm as a principal industrial example. The London Array is in the outer Thames estuary; its 175 turbines make it one of the largest offshore-wind farms currently in operation (London Array, 2012). This 630 MW development can supply the equivalent of 480,000 households a year, which is ideal for a major consumption center such as London (London Array, 2012). Its proximity to the city also avoids the need for long transmission lines, which reduces installation investments and energy dispersions. The London Array covers 90 km² (London Array, 2012), such that it would be impossible to build onshore, especially near the city, because of the lack of land availability and acceptance concerns among the local population. Another advantage of offshore-wind plants, compared

with onshore versions, is that sea winds are stronger and more stable, leading to better energy generation. In this sense, offshore wind is one of the most promising renewable energy technologies, and Europe, China and the United States all plan to invest heavily in new farms (Figure 2).

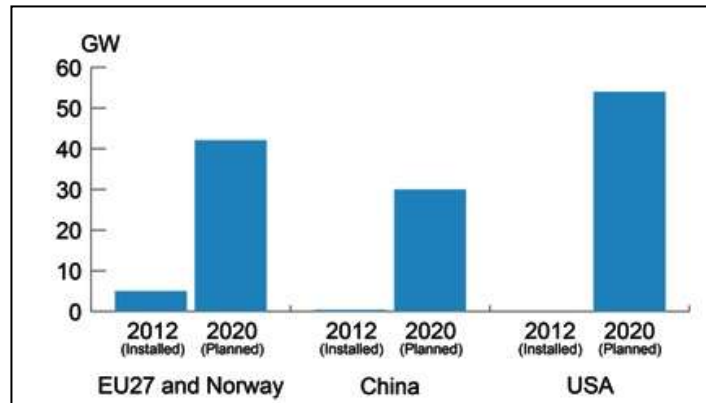


Figure 2: Global offshore wind development

Source: Based on EC (2010), AWEA (2012) and GWEC (2013).

Currently though, most operating projects are in Europe, in line with the EU legislative framework that sets targets for member states to increase the energy produced from renewable sources (Figure 3). The North Sea is home to several projects, because of its strong and stable winds and shallow waters, which are suitable for installing turbine foundations.

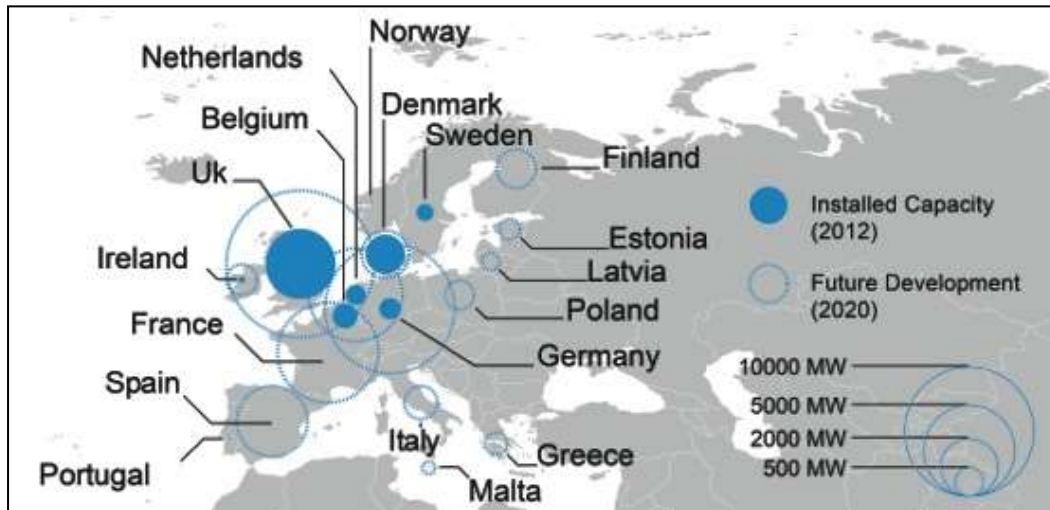


Figure 3: European offshore wind development

Source: Based on EC (2010).

The offshore wind power generated globally will be likely to increase dramatically in coming years, because of both the construction of many new farms and their improved capacity (Roland Berger, 2013). Capacity improvements stem from the use of larger turbines and more installed turbines per plant, with the goal of achieving economies of scale and gaining efficiency in energy generation. However, the transition to larger offshore wind farms also requires changes to the supply chain, so that it can cope with projects that are more challenging, from both logistical and organizational points of view.

We provide a purposely-simplified introduction to this complex supply chain, which may involve more than 40 firms. Here, we list only the principal supply chain roles, excluding tier-two and tier-three suppliers. Therefore, we describe the offshore wind supply chain by three principal phases: supply, construction, and management (Figure 4). In the London Array project, supply and construction took four years to complete.

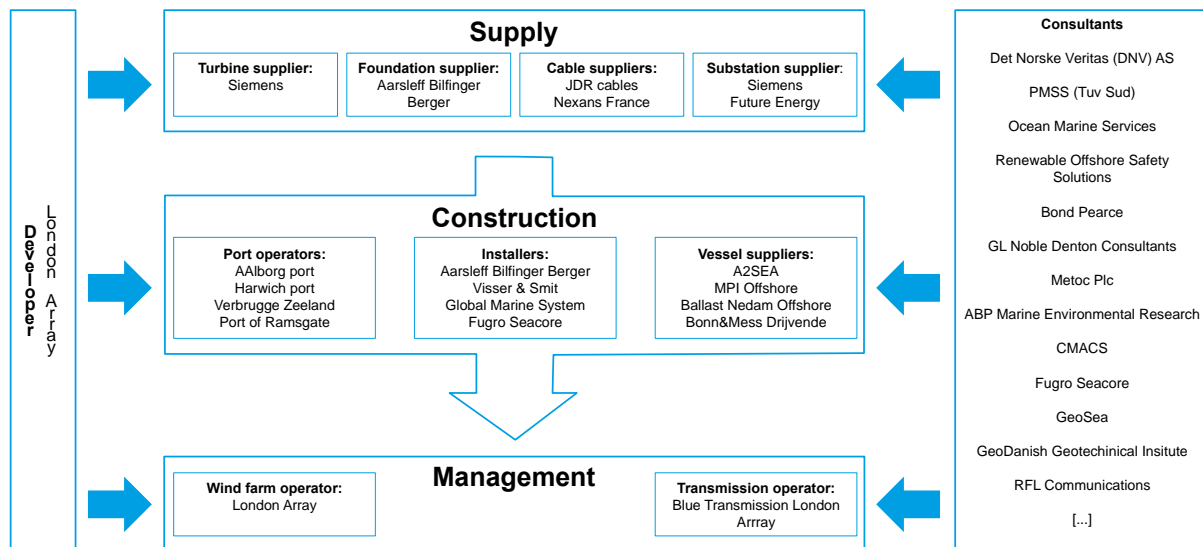


Figure 4: Offshore wind supply chain for the London Array project

Source: Based on BVG (2009) and 4Coffshore (2014a).

The developer and consultants support all three phases. The developer is the project manager for the offshore wind farm, which sometimes coincides with the owner or operator of the plant. Consultants offer environmental, technical, and financial advice. In addition, the firms involved in the first phase are responsible for the supply of offshore wind farm components, such as turbines, foundations, cables, and substations (Figure 5). Turbine suppliers, or their second-tier partners, produce the blades, hub, nacelle, and tower for each turbine; these components account for most of the capital spending by an offshore wind farm. Three blades connect to the rotor hub, whose rotation generates energy in the nacelle, which houses the mechanical and power units. The blades, hub, and nacelle sit atop the tower, whose great height is designed to capture stable upper winds. Suppliers also provide foundations to anchor the turbines to the seabed and substructures that connect the towers and foundations. The transition is part of the substructure; it also provides employee access through vessels. To illustrate the huge size of turbines, in the London Array, the blades and towers are 58.5 m and 87 m long, respectively (London Array, 2012), while the transition piece is 27 m long,

and mono-piles that measure 68 m long serve as foundations (Aarsleff, 2012). Furthermore, cable suppliers produce array and export cables. Array cables connect the turbines with an offshore substation; export cables connect the offshore substation to an onshore substation, whence power gets distributed to the national grid. Substation suppliers provide substations, which convert the voltage of the energy generated.

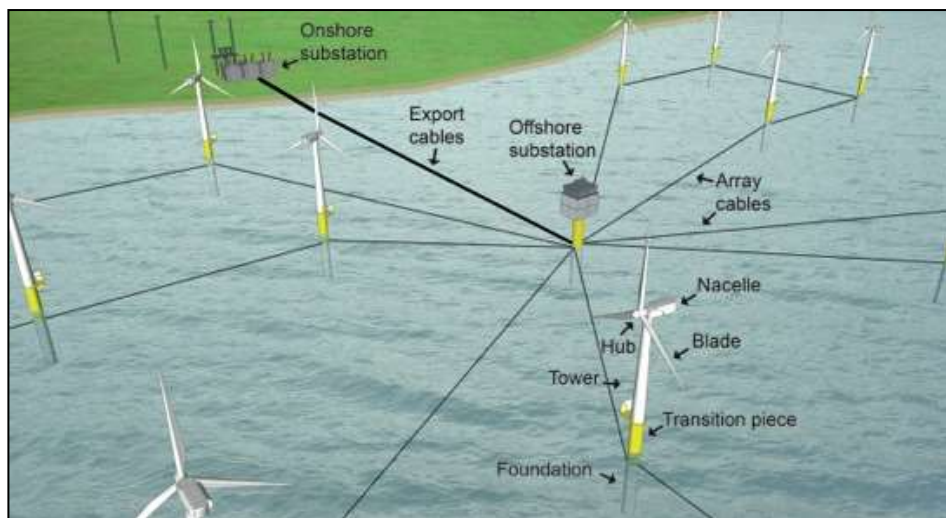


Figure 5: Offshore-wind farm and its components

Source: Based on Crown Estate (2013).

Port operators, installers and vessel suppliers constitute the principal actors involved in the construction phase, which includes assembly, installation, and commissioning of the offshore-wind farm. Ports perform various roles in the construction phase. In the London Array for example, the Aalborg and Harwich ports serve exclusively to load components on ships, the Vlissingen port provides a staging area for components, and the Ramsgate port also features the final assembly of the components (Aarsleff, 2012). Vessel suppliers are responsible for providing ships, usually custom built, to transfer crew employed in installation and maintenance activities. Installers provide a highly skilled workforce and equipment to perform installation activities at the port and offshore. The wind farm and

transmission operators are the principal companies involved in managing the farm. The wind farm operator takes responsibility for day-by-day management of the plant, including maintenance operations. In some projects, it coincides with the developer (as in the London Array) or the owner. Energy regulations in some countries, including the UK, mandate that the substations and cables are maintained and managed by a different company, that is, the transmission operator.

These three phases are not strictly sequential but rather overlap, because of the long duration of such projects and resource availability concerns. The supply of components and the construction of the plant both take several years and require substantial capital, which means that money stays tied up for a long time before the plant starts to produce any energy or financial return. Time compression strategies, such as parallel manufacturing processes and installation work, can reduce the time needed for the plant to become operational. In the London Array, some clusters of turbines were commissioned to become operational even as other clusters were still being installed (London Array, 2012). The main resource availability problems for the offshore-wind supply chain are vessel availability, capacity of staging areas and suppliers' capacity. These bottlenecks lead companies to gather resources as they become available; a strategy that often causes overlap in supply chain activities. Although such tactics can enhance time compression and resource use, they make the supply chain activities even more complex, demanding greater flow synchronization to manage operations properly.

The new, larger plants thus not only transform the market and technology associated with the offshore-wind industry but also increase the complexity of the supply chain. Larger plants expand the number of companies involved in the project and require more coordination. They also exacerbate the capacity problems already present in the industry and require more frequent uses of activity overlapping strategies, leading to more challenging coordination efforts.

3.3. *Purchasing and supply management practices*

Although current projects in the offshore-wind supply chain include various purchasing and supply management practices, we identify three particularly innovative practices that can address the increased complexity of supply chains resulting from growing wind farms. We examine each in turn, illustrating them with industrial examples.

In terms of *make-or-buy decisions*, offshore-wind supply chains exhibit a high degree of vertical integration. In the London Array, Siemens built all the turbines in-house, including all their components, except for the steel plates used in the towers (4Coffshore, 2014a). Vertical integration involves not only the supply phase but also construction and installation. An extreme example is BARD, which supplies and installs turbines, foundations and the offshore substation for its offshore-wind farm, which it has developed, managed, and owned. Two principal reasons underlie the high degree of vertical integration in this industry. Until recently, few firms had any offshore wind-specific expertise, so they had to adopt several roles in the supply chain. Suppliers in the industry also tend to build components in-house and avoid outsourcing, in an effort to protect the intellectual property featured in their technical solutions. As larger-scale projects emerge, the supply chain necessarily must include more firms. We argue that this trend should be associated with more outsourcing. This purchasing and supply management practice also should decrease the level of vertical integration in the industry. For example, the turbine supplier Senvion already outsources the manufacturing of most of its components, retaining only the intellectual property of the turbine design. The evolution of contract forms toward more collaborative relationships also may help increase outsourcing in the industry.

In investigating the *contract forms*, we focus particularly on how risk and responsibilities get shared across various firms. In projects developed between 2005 and 2010, the owner often is also the developer and the operator, as Dong is for the Burbo Bank

wind farm, a 90 MW plant (4Coffshore, 2014b). In a similar contract structure, the owner might delegate development to a third party, and then act as the operator when construction is completed. For the 60 MW plant Scroby Sands, E.ON is the owner and operator, and Vestas is the developer (4Coffshore, 2014c). When the size and complexity of such projects grow, the owner likely cannot bear all the operational risks associated with supply chain activities, such as possible disruptions in the synchronization of logistical flows, potential failures of the many components included in the turbines or bad weather that affects plant construction. The innovative purchasing and supply management practices associated with contract forms thus should feature models that clearly identify responsibilities and operational risks before the project starts, such that they get shared across various supply chain partners. The allocation of responsibilities to partners could rely on private agreements, such as those for the 500 MW plant Greater Gabbard (4Coffshore, 2014d), or tenders, as apply to the London Array. As the number of firms involved in the supply chain increases though, it becomes more difficult to assign every risk or duty to each firm, especially because the allocation must take place well before the project starts. Firms' collaborative relationships also could help reallocate responsibilities as a means to manage disruptions during the development project.

For local-to-global sourcing decisions, we recommend that firms employ more local sourcing strategies. In the London Array, most of the turbine and foundation components were manufactured in Denmark and Germany, then shipped by sea to the port of Harwich, where they were loaded on installation vessels (Aarsleff, 2012). Sourcing from well-established suppliers in continental Europe remains the norm for UK offshore-wind projects. Yet this strategy increases logistical challenges, which could be further aggravated by the growing size of the plants and turbines. New sourcing models also need to be identified, because when China and the United States start constructing offshore-wind farms more actively, shipping components from continental Europe might not be feasible. Firms in the

industry already are assessing the potential for building heavier components, such as blades, nacelles, foundations, and substructures, closer to the construction sites of planned UK offshore-wind farms. The latter two components in particular do not require long-term, industry-specific background for producers, so UK companies potentially could manufacture them. BiFab, an oil and gas firm based in Scotland, thus started supplying substructures for offshore-wind farm projects. When possible, suppliers should build their production facilities near a port, which notably simplifies the material flows, because the first-tier suppliers directly feed the components to the principal assembly site in port, as happens in the purposefully built automotive factory, Smartville. Material flows could be streamlined further by component modularization, another development that already is widespread in the automotive industry. The agglomeration of firms involved in all three supply chain phases then could promote the development of a knowledge cluster or offshore-wind super cluster, which might serve as a center of excellence for job training and technology development. Examples of existing super clusters include the ports of Bremerhaven, Germany, and Esbjerg, Denmark.

3.4. Key success factors

Industrial evidence suggests three key success factors for the offshore-wind industry; we describe these factors and argue that their low current level suggests the need for improvement. Using innovative purchasing and supply management practices offers a viable means to increase their level. We use industrial examples to support these statements.

The *competition level* in the offshore-wind supply chain is low, especially for turbine suppliers and vessel suppliers. The very few turbine suppliers include Areva, Senvion, Siemens and Vestas. Vessel suppliers are limited to a few specialized Chinese and South Korean shipyards. Market concentration is high, because of the substantial investments in

research and development that are required to enter the market. Moreover, turbine suppliers have created barriers to entry in their efforts to protect their intellectual property, such as technical solutions, whether by maintaining the production of turbine components in-house or asking second-tier suppliers to sign exclusivity agreements. The limited availability of suppliers effectively creates capacity problems, such that turbine and vessel suppliers operating with backlogs create bottlenecks in the supply chain. The many new UK projects mean a steep increase in demand, and incumbent suppliers cannot simply ramp up their output to meet it. Instead, the industry requires more competition, with new participants of all categories. The lack of competition also exposes the supply chain to risks. With so few suppliers, it is impossible to accomplish dual sourcing strategies that might mitigate the potential for disruptions. However, offshore-wind purchasing and supply management practices could help increase the level of competition in the industry. For example, transforming contracts from central to more distributed models would require firms to develop flexible relationships, which often leads them to drop exclusivity clauses. As the degree of vertical integration decreases and exclusivity agreements disappear, more opportunities arise for market entrants. When sourcing strategies use production facilities closer to the construction sites, more local firms likely become involved in the supply chain. A supercluster also could help them develop more advanced capabilities to support the industry. Finally, simpler, more standardized components might lower the initial investments in research and development required of companies that hope to enter the market as second-tier suppliers.

Various *capabilities* also are required from firms operating in the offshore-wind supply chain, from renewable energy expertise to knowledge of the marine environment. A high skill level is required. In the supply phase, firms must conform to precise standards of quality. In the construction and operation phases, they need to comply with strict health and

safety requirements. It is not easy to find firms that can meet all these criteria. Offshore-wind supply chain members and national governments already seek to develop the capabilities of firms and people; turbine suppliers could implement similar supplier development programs. National governments offer support for training in the offshore-wind industry, because of its excellent job creation potential (CEBR, 2012). As the level of vertical integration decreases and sourcing strategies move production closer to the offshore-wind farm, first-tier suppliers must take active roles in developing the capabilities of their second-tier suppliers. In terms of contract forms, the introduction of long-term purchase agreements could be instrumental for serious supplier development. Knowledge-intensive super clusters also might contribute meaningfully to the training and development programs of organizations and people interested in entering the industry.

The third key success factor is *control*. Because of the complexity of offshore-wind projects, the risks in the supply chain are manifold, including logistical disruptions, component failures, and inclement weather. Beyond these operational risks, coordination and demand risks create substantial uncertainty in the supply chain. As the number of the firms involved in the supply chain increases, coordination risks cannot be underestimated either. Demand is lumpy and difficult to forecast. With the decision to invest in an offshore-wind farm, turbine suppliers immediately receive requests to supply many units, averaging around 200 in recent projects. Yet the final investment decision does not necessarily coincide with the start of the project. Even with development consent, uncertainty often remains about the start date of the project. Delays associated with the start of the project contribute to further demand uncertainty. Vertically integrated firms should bear demand risks that are consistent with the activities they perform; as the degree of vertical integration decreases, firms thus suffer less from demand variability. Nor does decreasing vertical integration necessarily entail losing control of the supply chain, if the risks and responsibility are shared across

companies through more mature uses of contracts. Finally, local sourcing increases physical proximity, which should be beneficial in reducing coordination risks and facilitating mitigation strategy planning to deal with operational risks.

We have shown how purchasing and supply management practices can influence competition, capabilities and control—the key success factors in the offshore-wind industry. However, many professionals might add a fourth factor: cost. Offshore-wind supply chains are expensive to run, because of their complexity. However, the maturity of the industry and its technologies make increasing competition, capabilities and control a priority. Cost reduction will depend largely on achieving these prior success factors. In particular, increased competition requires suppliers to lower their prices and become more profitable. Increased capabilities should advance technologies and processes that help the firms make their operations more efficient. Higher level of control more avoids glitches and disruptions and reduces their detrimental effects on supply chain costs.

4. Discussion

In this section, we compare our findings with the results in previous literature. For example, our argument related to *make-or-buy decisions*, namely, that firms should decrease their level of vertical integration, is consistent with Corbett and Karmarkar's (2001) finding that the integration of successive oligopolists in a serial supply chain reduces profits. We also propose that manufacturers should be less protective of their intellectual property and share their knowledge with suppliers to increase capabilities. As suggested by Argyres (1996), the supply chain will bear higher costs in the short run, but once suppliers have developed enough capabilities, costs decrease. Moreover, similar to Novak and Stern (2009), we find that product complexity leads firms to build many components in-house, to increase their control over the processes.

With regard to *contract forms*, we have suggested that companies should develop more collaborative relationships. Previous literature agrees. Cachon and Kök (2010) note that transactional contracts, even if sophisticated, often deteriorate the profits of suppliers, and Taylor and Plambeck (2007) and Lindgreen *et al.* (2013) both recommend using relational, informal contracts. Although contracts thus should be based on collaborative relationships, the supply chain members also need to identify the risks arising in the project clearly, together with risk-sharing mechanisms to mitigate those risks. This observation is coherent with previous studies that suggest embedding risk-sharing mechanisms within contracts (Li and Kouvelis, 1999; Chopra and Meindl, 2010; Kwon *et al.*, 2010).

Finally, in relation to *local-to-global sourcing decisions*, we have emphasized that scarce suppliers limit firms' choices of local and global sourcing strategies; they tend to be forced to adopt a single sourcing strategy, a finding that resonates with Bozarth *et al.* (1998). However, we posit that a local sourcing model, in which suppliers and manufacturers locate their facilities near an installation port, could significantly enhance transfer capabilities from manufacturer to supplier. Tunisini *et al.* (2011) come to a similar conclusion. Firms should consider such an adoption carefully though, because it would require them to comply with the legal requirements of the region or the country in which the port is located (Bozarth *et al.*, 1998). Finally, we argue that local sourcing reduces supply chain risks and makes it easier to adopt contingency tactics in response to disruptions. This finding is coherent with Holweg *et al.* (2011) and Micheli *et al.* (2014), who advise against global sourcing in the presence of high supply chain risks. In Table I, we present a summary of our findings and their consistency to previous literature.

Findings for companies operating in offshore wind	Consistency with previous literature
• Companies should decrease their level of vertical integration.	• Consistent with Corbett and Karmarkar (2001).
• Companies should invest in enhancing the capabilities of their suppliers.	• Consistent with Argyres (1996).
• Companies should develop more collaborative relationships.	• Consistent with Taylor and Plambeck (2007) and Lindgreen <i>et al.</i> (2013).
• Companies should employ risk-sharing mechanisms within contracts.	• Consistent with Li and Kouvelis (1999), Chopra and Meindl (2010) and Kwon <i>et al.</i> (2010).
• Companies employing local sourcing models could transfer capabilities to their suppliers more easily.	• Consistent with Tunisini <i>et al.</i> (2011).
• Companies employing local sourcing models could adopt contingency tactics in response to disruptions more easily.	• Consistent with Holweg <i>et al.</i> (2011) and Micheli <i>et al.</i> (2014).

Table I: Summary of our findings and their consistency to previous literature.

5. Further research

This exploratory study identifies several areas for further academic research. We outline three, associated with each key success factor for the industry. First, academics might advance the debate about competition by developing bottleneck analyses specific to an industry, to identify which supply chain phases and activities benefit most from increased competition. Researchers also might study the role of competition in the supply chain through equilibrium analyses, such as by considering how the market varies in its degree of vertical integration and presence of exclusivity agreements. Second, research should address the process by which companies develop capabilities, and offshore wind-specific capabilities in particular. Such investigations also might identify appropriate models for transferring skills across companies. Third, we call for studies that derive decision support systems that can manage the supply chain risks that affect the offshore-wind industry. Identifying appropriate

risk-sharing models among companies represents an open and interesting question for contract-related research.

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