A sustainable Chinese catch-up?

Product quality and interactive learning in the offshore wind industry

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Abstract:

This paper has two main contributions: First, it provides a first-time overview of actors in China's emerging offshore wind industry and details technology sourcing strategies and ownership status. Second, it points out the importance of supplier-manufacturer links for technological learning and product performance in China. The paper finds a lack of attention to product quality amongst offshore wind industry stakeholders, and, as anticipated, time pressure and cost savings were important reasons for this. More surprisingly, the paper finds that the prevailing feedback practices between suppliers and manufacturers were unhelpful in ensuring product quality. This was particularly the case in two instances: when ties between the supplier and purchaser were too close (as was true for companies in the same industry group) and when ties were too shallow (as when turbine manufacturers ‘shopped’ for components, or when suppliers did not care about feedback from manufacturers). Feedback practices in large state-owned enterprises were particularly unfortunate, leading to missed learning opportunities. Unless such relationships are changed and catered for, Chinese firms will likely continue to struggle to catch up with frontier firms.

Keywords: Interactive learning, technological catch-up, China, offshore wind turbine industry, product quality

1. Introduction

As soon as a product is ‘made in China’, product quality appears to become a concern. We have all heard of or experienced toys that have fallen apart or cheap tools that have broken. A transition towards more renewable energy in China will not be achievable if new renewable energy technologies intended to last for 25 years fail after only a few years. As China is now investing in offshore wind energy technologies, quality is imperative in order to ensure the sustainability of development. In this paper, ‘quality’ is taken to mean conformity to established standards. If product quality is compromised to a large enough extent, resources are wasted and renewable energy development may, in the worst case, end up having an altogether negative impact on the environment. This paper therefore investigates the role of quality in China’s efforts to catch up with Europe in offshore wind technology, and provides a novel perspective on how latecomer firms in an emerging industry approach technological capabilities and learning.

Offshore wind is an emerging global industry that is most highly developed in the North Sea. At the end of 2014, Europe had more than 8,000 megawatts (MW) of installed offshore wind power, compared to about 670 MW in China (GWEC, 2015; EWEA, 2015). Since the Chinese offshore wind industry is in its early phase of development, there is considerable uncertainty about its development and direction. Recent literature on China’s onshore wind industry has found that Chinese turbine manufacturers have all largely developed their own design capabilities, predominately through cooperation with foreign actors (Chen et al., 2014a; Gosens and Lu, 2013; Lema et al., 2013; Lewis, 2013; Ru et al., 2012; Silva and Klagge, 2013). There is, however, an established consensus that Chinese turbines perform slightly worse than their European counterparts (Kirkegaard, 2015;Steinfeld and Beltoft, 2014), and that Chinese product quality has been neglected (Gosens and Lu, 2014; He and Chen, 2009; Lewis, 2013; Walz and Delgado, 2012). Can we expect the same of China’s offshore wind industry development?

Discussions of technology transfer and catch-up typically revolve around tensions between 'receivers' and 'providers', and whether transferred technology has been adopted to such an extent that the technology is mastered – meaning that the 'receiver' can innovate independently from foreign assistance and contribute to global technology development (Ernst and Kim, 2002; Kim, 1997; Lewis, 2007). In this paper, technological catch-up is a strategic *ambition* for latecomer firms, whilst the *process* of catching up is dependent on technological learning and the development of technological capabilities within latecomer firms. The process of catching up can be described as a process of reaching an established world standard, in terms of product performance (Kumaraswamy et al., 2012). An important but somewhat neglected aspect of technology mastery is the production of goods that are of acceptable quality. Studies of quality and supply chain management in China tend to be limited to international supply chains, focussing on Chinese suppliers' failure to accord to the requirements and procedures of international buyers (Chen et al., 2014b; Harris, 2009; Midler, 2007; Roth et al., 2008). In these studies, Chinese suppliers are typically perceived to fail due to deficits in regulation, inspection, testing, monitoring or control (ibid.). By understanding product quality as inherent to interactive learning processes, this paper takes another starting point. In this paper, the interaction between Chinese manufacturers and domestic and foreign suppliers is taken to reveal how successfully the firms consider quality and, ultimately, innovate.

Product quality is an elusive topic, as quality is a matter of definition. For instance, if a product is sufficiently cheap, a consumer may opt for it regardless of quality (Wan et al., 2015). In fact, there is no consensus on the definition of quality (Reeves and Bednar, 1994; Yong and Wilkinson, 2002). Quality therefore changes according to the need and criteria at hand, and it can be difficult to measure (Garvin, 1984; Sousa and Voss, 2002). A customer, a manufacturer and a supplier may all have different expectations of product quality (Gehani, 1993). An increasingly popular way of evaluating quality is measuring conformity to an established standard – one that has typically developed in the most advanced companies (Busch, 2011; Garvin, 1984). Indeed, some scholars have noted that quality has moved from being a concept that mainly occupies engineers to a field reserved for managers (Power, 1997). Quality, seen this way, is the result of a process that renders quality measurable, even in cases where it is difficult to measure, so it can be audited by a third party. Power (1997, p.60) therefore concludes that 'there is no quality without quality *assurance*', implying that quality is a form of impression management. In other words, as long as a product conforms to criteria set by someone, typically frontier firms in developed countries, it is of good quality. Hence, as the notions of technological catch-up and product quality both are benchmarks set by frontiers firms, product quality can be taken as a proxy to study technological capabilities. In this paper, I take this working definition as a point of departure and ask whether such product quality criteria set the bar for companies in China, or whether Chinese industry actors understand quality differently. What procedures facilitate or complicate product quality considerations in China's offshore wind industry?

The paper proceeds as follows: Section 2 outlines the theoretical approach, focussing on catch-up, learning and technological capabilities, before section 3 explains the methods used to collect and analyse data. Section 4 gives an overview of the main actors in China's offshore wind industry and summarises their ownership and technology sourcing strategies. Section 5 points to the main challenges in ensuring product quality, and section 6 goes into more detail by examining the relationships between suppliers and customers. Section 7 concludes and provides implications for other industries and for Chinese policy makers.

2. Interactive learning, technological capabilities and quality

The offshore wind industry in Europe is relatively mature, and the emergence of offshore wind technology in China can be understood through analytical lenses that emphasise the learning and interaction that occurs between these regional industries. A variety of theoretical approaches can be used to understand the way in which interactions between frontier and latecomer firms produce learning opportunities in catching-up countries. These approaches, which range from national innovation systems (Lundvall, 2007; Nelson, 2007) to leapfrogging (Lee and Lim, 2001), catch-up (Kim, 1997), global production networks (Ernst and Kim, 2002) and global value chains (Humphrey and Schmitz, 2000), attempt to capture the internationalisation of innovation processes. Further, each approach recognises the interaction between leading and latecomer firms, and the effects of this interaction on both parties. In a globalised economy, we may therefore talk about reflexive learning processes that engender new opportunities for both international and local actors (Hansen, 2009b). In the following, we shall look closer at technological capabilities and learning in latecomer firms in China.

The literature on late industrialisation, catch-up and latecomer firms (e.g. Amsden, 1989; Bell, 2006; Lee and Lim, 2001; Mathews, 2002) grapples with the processes undergone by latecomer firms to acquire the technological capabilities of frontier firms, usually based in more industrially advanced countries. Technological capability is taken to be the 'ability to use technological knowledge efficiently to assimilate, use, adapt and change existing technologies; and to create new technologies, developing new products and processes' (Xiao et al., 2013, p.2). Typical successful catch-up cases include the Korean chaebols (i.e. Samsung, Hyundai and Daewoo), which Kim (1997) describes as having undergone a catch-up process from imitation to innovation. The chaebols, enjoying considerable domestic government support, were able to go from mere manufacturing of frontier firms' products to reverse engineering and eventually design and production of those products. In the process, the chaebols hired foreign consultants, educated people abroad, invested heavily in research and development (R&D) and even set up R&D centres in the most advanced industry-clusters (ibid.).

Kim (1997) identifies four technology transfer mechanisms latecomer companies use to acquire technology from foreign frontier companies. These mechanisms are here referred to as 'learning mechanisms', rather than technology transfer mechanisms, as learning puts the impetus on the 'sourcing' process, rather than the 'transfer' process of technology development (Ernst and Naughton, 2012). Two learning mechanisms relate to whether the latecomer company is actively (e.g. licensing) or passively (e.g. importing machinery) seeking the technology. The two other mechanisms relate to whether learning happens through market mechanisms (e.g. trade or technology licensing) or more informally, such as through technical assistance from abroad (active) or reverse engineering (passive) (Kim, 1997). These mechanisms appear in Figure 1, below.

	Active	**Passive**
Market mediated	Formal mechanisms (1) (Foreign direct investment, licensing, turn-key plants, consultancies)	Formal mechanisms (2) (Commodity trade, standard machinery transfer)
Non-market mediated	Informal mechanisms (3) (Technical assistance of foreign buyer or vendor)	Informal mechanisms (4) (Reverse engineering, trade journals, observation, etc.)

Figure 1: Technological learning in catch-up

Source: Adapted from Kim (1997).

These four learning mechanisms may be characterised as *external* to a latecomer firm, and in order to be successful these must also be combined with sustained and intense *internal* learning efforts, meaning that learning and knowledge sharing within the firm needs to be organised and arranged systematically (Bell and Figueiredo, 2010; Kim, 1997). Externally 'transferred' knowledge is of little use for the latecomer company if the knowledge cannot be absorbed and taken into practice

(Cohen and Levinthal, 1990; Dantas and Bell, 2011; Giuliani and Bell, 2005). In order to absorb knowledge and acquire technological capabilities, firms need to develop both tacit and explicit knowledge (Amsden, 1989; Ernst and Kim, 2002; Gorman, 2002). Jensen et al. (2007) use the concepts STI (science, technology and innovation) and DUI (doing, using and interacting) to distinguish different modes of learning connected with explicit and tacit knowledge respectively. The DUI mode typically produces tacit knowledge – 'know-who' and 'know-how' – while STI gives priority to explicit knowledge – 'know-what' (facts) and 'know-why'. The challenge is not to choose between one and the other, but to combine practical, experience-based (DUI) and scientific research-based (STI) modes of learning, as they are fit to acquire different types of knowledge (Lundvall and Johnson, 1994).

In this paper, learning mechanisms will be part of a wider definition of innovation, wherein interactive learning and collective entrepreneurship are crucial components (Lundvall, 1988), including both experience-based and science-based learning. With this definition, close and persistent contact between users and producers is central to innovation, since a company cannot be expected to have all required knowledge and skills in-house (Kamp et al., 2004; Lundvall, 2010). Communication, interaction and proximity between users and producers are therefore important indicators of the technological learning process (ibid.). A seminal study by Bell and Albu (1999), proposes that latecomer firms are more likely to be successful in acquiring technological capabilities if they in addition to being open to external sources of knowledge also actively seek to cooperate with other firms in the cluster. Evidence from emerging economies shows that as firms enhance their technological capabilities, the surrounding knowledge network benefits positively enabling new and stronger links between users and producers (Giuliani and Bell, 2005; Yoruk, 2011). In other words, in the context of China's offshore wind industry catch-up, gaining insights into learning modes is important in order to emphasise that latecomer firms must engage with both R&D (science-based learning) and trial and error (experience-based learning), and as latecomer companies learn, we should pay attention to their relationships and interactions with surrounding firms in their network.

Technological learning can be hampered by several factors related to the institutions and context in question. Several examples of catch-up focussing on China testify to this (Altenburg et al., 2008; Binz et al., 2012; Gallagher, 2006; Gu and Lundvall, 2006a; Guerin, 2001; Mu and Lee, 2005; Xue and Liang, 2010). These contributions show that there is a great divergence in successful catch-up strategies depending on the industry, the gap between leader and latecomer firm, the level of technological sophistication (high-tech, low-tech), the level and type of commitment from the government and the intellectual property rights protection. For instance, Wang (2006, p.398) proposes that due to institutional constraints such as 'the state's pro-SOE (state-owned enterprise) industrial policy, the state-owned but also local government-controlled financial system and the fragmented industrial structure', Chinese IT firms were unable to develop internal dynamics that facilitated learning and innovation. Similarly, Steinfeld (2004) claims that 'the innovative capacity of Chinese firms and the ability of those firms to upgrade within global supply chains have been impeded by legacies of Chinese reform style, bottlenecks in the institutional reform process, and most recently—of greatest concern for the future—inconsistencies in governmental industrial policy'. So how can we determine a successful catch-up strategy that promotes the 'innovative capacity' of Chinese firms?

Several scholars have pointed out that there is an important difference in catching up in production capability and market share and in innovation capability (see e.g. Bell and Figueiredo 2012; Hansen and Ockwell, 2014; Lee and Lim, 2001). However, as the distinction between production capability and innovation capability can be blurry (Bell and Figueiredo, 2012), it is useful to distinguish between different types of technological capabilities. Although there are several ways to classify technological capabilities, I will use the notions developed by Cai and Tylecote (2008), who divide technological capabilities into those that are ‘static’ and those that are ‘dynamic’. Static capability is the ability to use existing technologies to manufacture a product, whilst dynamic capability involves the adaptation of technologies and procedures into a larger learning and development process. Static capability is typically acquired when a frontier firm has a joint venture with a domestic firm, and in effect manufactures the product locally without much interaction and local learning. This was, for instance, the case with Shanghai Automobiles, who had a joint venture with Volkswagen, but no domestic car company emerged as a result of the cooperation, entirely contrary to the Korean catch-up experience (Liu and Tylecote, 2009). Dynamic capability is acquired through a combination of strategies that aim at being independent from foreign companies, and try to learn through both hands-on experience and R&D. Although the acquisition of dynamic capability is considerably more challenging and risky, we can expect it to be integral to a successful catch-up.

Some research has found that the Chinese institutional set-up favours *static* technological capability. According to Xiao et al. (2013), Chinese state-owned enterprises (SOEs) have strong incentives to favour quick increases in revenue and ‘shiny new products and factories’, typically provided by joint ventures with foreign companies. One reason for this urgency for quick results resides in the government’s SOE policy of rotating top-managers every few years, making short-term revenue more important for each manager’s career (Shi et al., 2014). Hence, companies that do not have a majority ownership from the central government, or ‘outsider’ firms that are not favoured by the central administration, are more likely to practice dynamic capability (Cai and Tylecote, 2008; Xiao et al., 2013). These companies, in turn, face tough competition with companies with high static capability, and have a less certain source of financing than do centrally supported firms (ibid.). Therefore, as we go on to the next section, we may expect Chinese firms to successfully catch up with foreign frontier firms by avoiding too heavy a reliance on quick revenue and by ensuring financing opportunities for their investments. In this sense, company ownership may be telling of how successfully companies acquire dynamic capability.

A successful catch-up in dynamic technological capability also involves an acceptable level of product quality. Knowing that institutions may hinder the ability of Chinese companies to catch up successfully, we may also ask what procedures ensure product quality in China. The difference between static and dynamic capability has implications for product quality. Apart from generating quick revenues for domestic SOEs, joint ventures that generate static capability also have established and accepted criteria for product quality. In some industries (e.g. the automobile, shipbuilding and machine tool industries in Korea) latecomer firms have endured longer periods of sales when their products have been lower quality than frontier firm products (Amsden, 1989; Lee and Lim, 2001). For this reason, a protected domestic market is useful in the early phases of catch-up (Kim, 1997). A latecomer firm must therefore strike a balance between 'accepted' levels of quality and the number of potential buyers, since customers will hesitate to accept lower quality if there is a frontier-firm product, as is often the case in China (Xiao et al., 2013).

Including this point about quality conformity, we can summarise the differences between dynamic and static capability with respect to: 1) the time they require, 2) short-term revenue prospects and 3) conformity to established quality criteria. Compared to static capability, dynamic capability takes more time, has a lower short-term revenue prospect and conforms less to established standards. Hence, we may expect these three considerations to influence the strategies chosen by Chinese firms to acquire technological capability. With this hypothesis as a basis, I will proceed to analyse the learning strategies of firms in China's emerging offshore wind industry.

3. Methodology

This paper is based on qualitative data gathered during an 11-month period of fieldwork in Shanghai, including two months of participant observation with a European certification and advisory agency seeking to enter the offshore wind industry and 43 semi-structured interviews with a total of 56 interviewees from China's emerging offshore wind industry. Most interviews were conducted in Beijing and Shanghai, but several were held in smaller cities along China's coastline, such as Guangzhou, Hangzhou and Nanjing. Information was also collected through participation and observation at the China Wind Power 2011 and 2013 conferences, the Offshore Wind China 2012 and 2013 conferences and the 8th China (Shanghai) International Wind Energy Exhibition and Conference, as well as several workshops on offshore wind, at which I spoke with experts and professionals in the offshore wind industry in China. The interviews focussed on participants' perspectives on offshore wind, challenges – such as quality or management issues – and differences between onshore and offshore wind turbine manufacturing. Taking quality as a proxy for technological learning proved a useful way to get interviewees to talk about the degree of technological mastery. In other words, instead of asking to what degree interviewees felt that they were mastering the technology, I would inquire about challenges in terms of sourcing high-quality components domestically, and whether or not companies in question had to import components. This gave a good impression of the relationships between companies in the offshore wind supply chain. The interview guide was used flexibly, allowing for a change of theme that naturally corresponded with the interviewee's reasoning, and answers were followed up as appropriate.

Below is an overview of the interviewees and their respective stakeholder segments in China's offshore wind industry. The relevant stakeholders are divided into six groups: government, turbine manufacturers, turbine supply chain, 'offshore suppliers', developers and research community. Government stakeholders consisted of officials in local, provincial and central government agencies, including several state-administered industry associations. 'Turbine supply chain' refers to all the components needed to assemble a wind turbine, and 'offshore suppliers' here means all the equipment and services for an offshore wind farm (including the electricity grid), excluding the wind turbines. For the following analysis, insights from the turbine manufacturers, turbine supply chain, offshore suppliers and offshore wind project developers were the most relevant, as these persons made key decisions in terms of investment, quality control, time-usage, supplier relationships and so on. Nevertheless, feedback from all industry segments informed the analysis.

Table 1: Overview of interviewees

Industry segment	**Interviews**	**Number and nationality of interviewees**		
		Chinese	Foreign	Total
Government	**8**	**11**	**1**	**12**
Turbine manufacturer	**7**	**8**	**1**	**9**
Turbine supply chain				
- Gearbox	1	1	0	1
- Pitch and yaw system	1	1	0	1
- Control systems	1	0	1	1
Offshore suppliers				
- Advisory	6	4	3	7
- Certification	6	3	1	4
- Forecasting	1	2	0	2
- Grid	1	1	0	1
- Coating	3	3	0	3
- Cable	1	3	0	3
- Installation and foundation	1	1	0	1
Project developer	**5**	**9**	**0**	**9**
Research (university)	**1**	**2**	**0**	**2**
Total	**43**	**49**	**7**	**56**

On average, each interview lasted 70 minutes, ranging from 15 to 120 minutes. Most interviews lasted around one hour. All interviews were semi-structured, containing 'a sequence of themes to be covered, as well as suggested questions' (Kvale 1996, p.124). Interview candidates were identified through online research, industry association lists and trade statistics and, most importantly, through the snowball method. The underlying reasoning behind selecting particular interview candidates was to be able to map the opinions of central actors in order to paint a representative picture of the challenges and drivers of China's offshore wind industry development. The transcribed interviews were analysed using the computer-assisted software NVIVO. This software was of great assistance in coding and categorising material, allowing for systematic analysis. The interview data were analysed according to principles suggested by 'abductive reasoning', meaning that both field data and existing theory were allowed to influence the researcher, but, ultimately, instead of forcing either the theory or the data into a framework, the researcher left space for his own logical reasoning (Reichertz 2007). The analysis is also inspired by constructivist grounded theory (Charmaz, 2006; Clarke, 2005). Thus, analysis started at the data collection stage, and interview structures changed as I developed a better idea of the topics I wished to pursue in more depth. This enabled a greater focus on topics of interest throughout data collection, and it made coding easier, as all the data had been gathered. Coding took place after all the interview material had been gathered, and before much theoretical search had begun. In this way, the analysis of the data was guided by existing theories and was based on grounded concepts.

I used an interpreter for 16 of the 43 interviews. I employed four different interpreters during the whole stay in China: One mainly in Beijing, two mainly around Shanghai, and one around Guangzhou. Use of an interpreter has both advantages and disadvantages: it allows for flexibility regarding note-taking during interviews, but also heightens the probability of information manipulation in the re-iteration (Scheyvens & Storey 2003). Most of my translators had worked for several years as professional interpreters and had held assignments within the wind industry. Based on the interpreters' experiences and professionalism (e.g. using industry-specific words) and my own basic mastery of Mandarin Chinese, I was assured that the interviews were interpreted as accurately as possible. Although all of the interviews were conducted in English, only two of the interviewees were native English speakers. Use of a foreign language may cause people to unintentionally say things they do not really mean, or may tweak the meaning of what was originally intended. The way this was dealt with was by repeating the question or the meanings when there was any doubt, in order to confirm. I am therefore confident that the following analysis represents the views of the interviewees.

4. China’s offshore wind industry stakeholders and learning opportunities

This section outlines the main stakeholders in China’s offshore wind industry, namely the turbine manufacturers, component suppliers and offshore suppliers. Knowing that onshore wind energy companies were the primary drivers behind Germany’s offshore wind energy industry (Fornahl et al., 2012), we start by looking at the onshore wind companies’ diversification into offshore wind in China. Currently, ten companies have produced operational offshore wind turbines. From Table 2, we see that Sinovel has the most models in operation, and three other companies have two turbine models in operation. In China, there are 117 centrally administered state-owned enterprises (SOEs) that control assets totalling 60 per cent of China’s gross domestic product (Bound et al., 2013), testifying to the immense importance of SOEs to the Chinese economy. In the table, ‘central SOE’ refers to whether the company in question is part of centrally administered SOEs, which are administered by the State Asset Supervision and Administration Commission (SASAC). ‘SOE’ refers to a state-owned enterprise that is not directly administered by SASAC.

Table 2: Chinese offshore wind turbine designs, technology sourcing and affiliation

Company	**Turbine size (MW)**	**Technology acquisition**	**Ownership**	**Parent company’s main industry**
Sinovel	3, 5, 6	Joint design, AMSC-Windtec (3MW) Own design (5 and 6MW)	SOE	Heavy machinery
Goldwind	2.5 / 6	Own design, Vensys	SOE	Wind
CSIC Haizhuang	5	Joint design, Mecal	Central SOE	Shipbuilding

Mingyang	2.5	Joint design, Aerodyn	Private	Power generation equipment
Guodian United	5 / 6	Own design	Central SOE	Power generation / developer
Shanghai Electric	3.6	Joint design, Aerodyn	SOE	Power generation equipment
Dongfang	2.5 / 5.5	Joint design, AMSC-Windtec	Central SOE	Power generation equipment
XEMC Wind	5	Own design, Darwind	SOE	Heavy machinery
Envision	1.5	Own design	Private	Wind
SANY	2	Joint design, Sheyang University of Technology	SOE	Heavy machinery

Sources: Interviews, company webpages, BTM (2012), Gosens and Lu (2014).

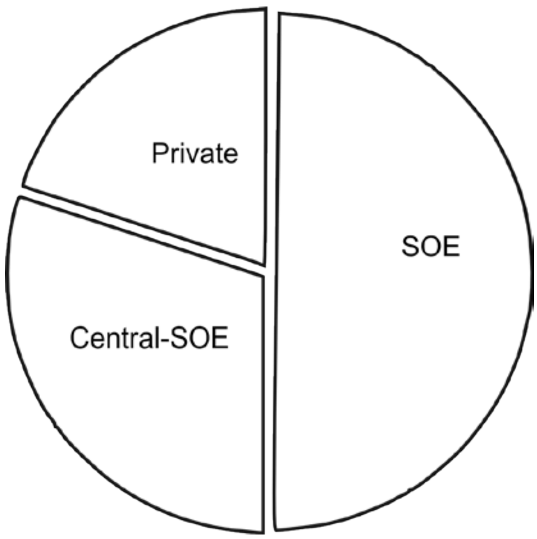

Figure 2: Ownership of offshore wind turbine companies

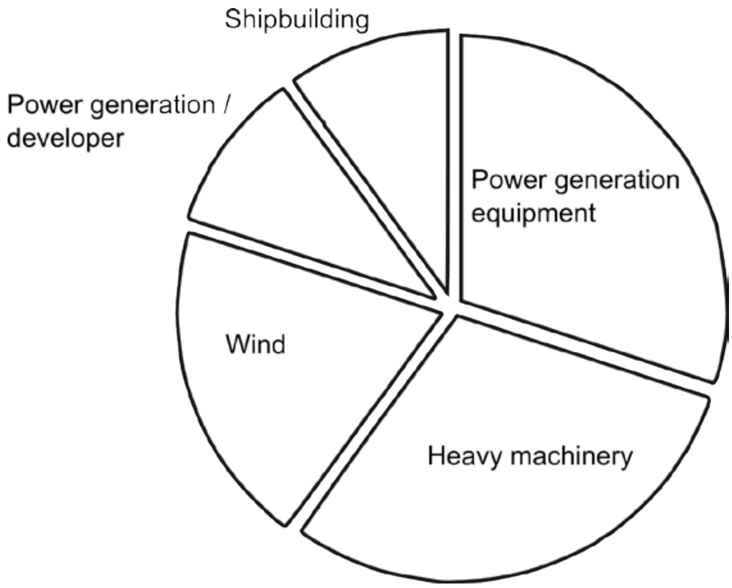

Figure 3: Main industry of offshore wind turbine companies

Three of the companies listed above are part of centrally-owned SOEs, and five are part of SOEs. Only two of the companies, Mingyang and Envision, are privately-owned. In terms of main industry, only two companies, Goldwind and Envision, are purely wind power manufacturers. Sinovel, Shanghai Electric, Dongfang, XEMC Wind, SANY and Mingyang are subsidiaries of large industry groups that have their main industries within power generation equipment or heavy machinery. United Power is a subsidiary of the largest power generation company and developer, Guodian (mother company of Longyuan), and the last company, CSIC-Haizhuang, is a subsidiary of the large shipbuilding group China Shipbuilding Industry Corporation, a group that also produces gearboxes and other key wind turbine components. In terms of technology acquisition, five of the companies have their own designs tested for offshore turbines, whilst the five others jointly design their turbines with foreign (Mecal, Aerodyn and AMSC-Windtec) and domestic (Sheyang University of Technology) collaborators. The process Chinese wind turbine firms went through to acquire these technologies has already been extensively elaborated on by others (e.g. Lewis, 2013; Gosens and Lu, 2013, 2014; Chen et al., 2014a), and we shall not look closely at those strategies here. Rather, I shall examine the supply chain, including what is here termed 'offshore suppliers'.

Looking at the wind turbine supply chain, suppliers of onshore wind turbine components in China typically also supply components for offshore turbines. China's component supply for onshore turbines has a shared supply-base of components, allowing for industrialisation, quick manufacturing and economies of scale (Lema et al., 2013). There are more than 50 blade manufacturers, 100 tower manufacturers and 1000 manufacturers producing other components and parts for the onshore wind industry in China (Kastmann, 2013). In the offshore turbine supply chain in China, many companies increasingly choose to source their components from abroad. For instance, Goldwind decided to increase international component sourcing for their offshore wind turbines to approximately 50 per cent of its needs (Quartz+Co, 2013). Several of the interviewees from large wind turbine manufacturers confirmed this trend for their offshore turbines. This increase in the import of turbine parts can be interpreted as a confirmation that the quality of domestic components is not adequate, and that the European standard is considered the relevant benchmark. I will return to this issue in section 5.

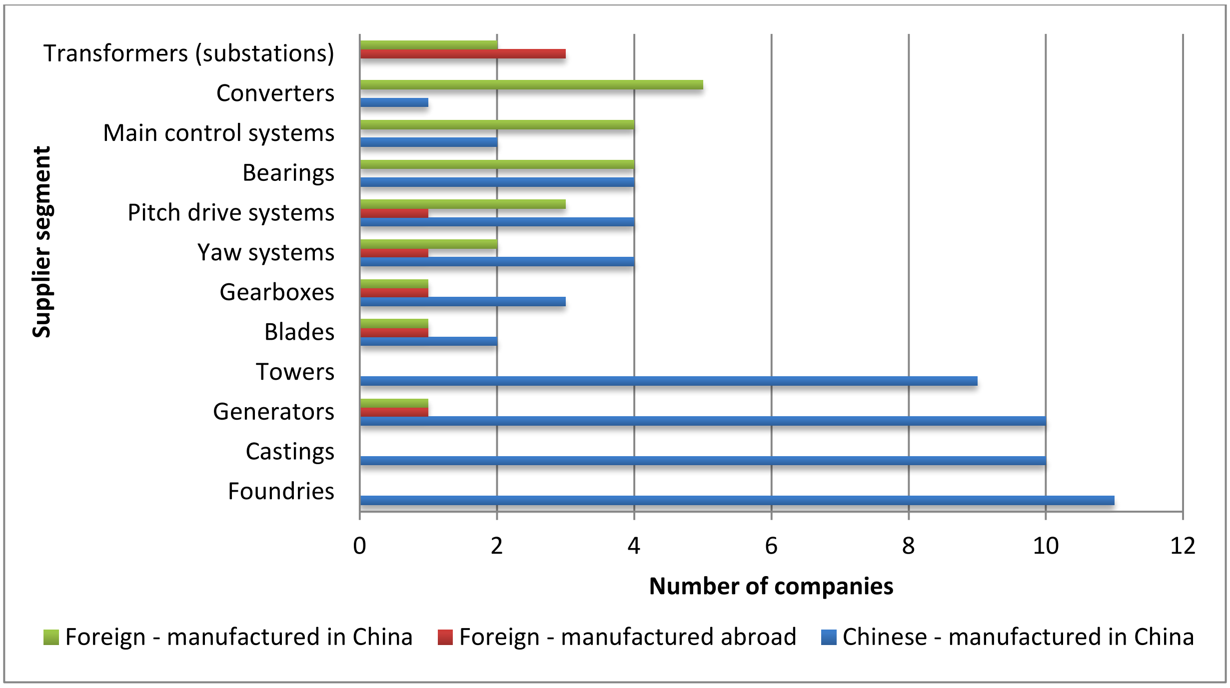

Figure 4: Overview of domestic and foreign suppliers for Chinese offshore wind turbines

Source: BTM (2012), company webpages.

Figure 4 shows the domestic and foreign suppliers for Chinese offshore wind turbines. Until the end of 2012, the total number of suppliers for Chinese offshore wind turbines was 91, indicating that the offshore wind turbine supply chain is quite wide. The figure shows that high-tech and high-precision components such as transformers, converters, control systems and bearings are typically sourced from foreign companies, whilst domestic Chinese companies supply components at the low-value end, such as towers, castings and foundries. The competition in these low-value segments is higher than in the other segments, having on average ten or more suppliers, as opposed to only four blade suppliers (two domestic and two foreign) for Chinese offshore wind turbines. This is consistent with research pointing out that China has thus far been unsuccessful in acquiring high-value technology (Gu and Lundvall, 2006b; Moran, 2011; Tylecote et al., 2010).

If we consider the total cost of an offshore turbine, BTM (2012) calculations show that towers, blades and gearboxes are the most expensive, and make up about 56 per cent of the capital cost. Apart from the towers, which are entirely dominated by Chinese suppliers, there are no clear tendencies as to who typically supplies these more expensive components for Chinese offshore wind turbines. The majority of foreign suppliers actually manufacture their components within China, enabling similar procedures of quality control as those used abroad. The presence of foreign suppliers may, on the one hand, mean that management procedures are also transmitted to Chinese suppliers through informal mechanisms, but it may also mean that knowledge still rests in foreign hands.

In the 'offshore suppliers' segment, the most important players participating in offshore wind projects to the end of 2013 appear in Appendix 1. Large SOEs often enter and invest in new industries in China, with varying degrees of success in terms of acquiring technological competence (Liu and Tylecote, 2009). Ten out of the 17 companies are listed as one of the 117 central SOEs, testifying to the importance of centrally governed (and large) SOEs in this segment. Most of the actors in the offshore segment have a background in the oil and gas, maritime and shipbuilding industries. Today, China is amongst the top shipbuilding nations in the world; there are several ship industry clusters, especially in Jiangsu province (Chen, 2014; Zheng et al., 2013), and China's oil and gas companies are amongst the largest in the world (Andrews-Speed, 2012, Bound et al., 2013).

Shanghai Zhenhua Heavy Industries (ZPMC), for example, grew large based on crane production; the company increasingly produced more components in-house, and expanded into new industries (Plötner and Wang, 2013). In the early phases of China's offshore wind development, their cranes – designed for use on offshore oil and gas structures – were used for installing turbines (BTM, 2012). Moreover, several vessels for offshore wind turbine installation are produced in China, and this can be beneficial for the domestic offshore wind industry. However, when it comes to coating and offshore sub-stations (traditionally an offshore oil and gas business), foreign companies dominate the market. With this overview of the main stakeholders in China's offshore wind industry, I now proceed to examine some of the challenges, considerations and practices for ensuring quality.

5. Time, skill and conformity

Amongst the offshore wind industry stakeholders, the general attitude was that product quality was lower in China. For example, a Chinese employee in a European certification company said that: '[Quality] is a normal problem in China. If the quality were the same as European products, then why can't we sell our turbines to you?' This understanding of European products having superior quality was prominent in the data, and we may therefore broadly say that the European standard was seen as the quality benchmark for Chinese firms.

One way of ensuring that a product conforms to an established standard, and hence reaches accepted quality levels, is to certify the technology. In the list of certifications from a large international certification company, DNV GL (2014), are six Chinese wind turbine manufacturers with type certificates and 12 with design assessments. A type certificate is a certificate for a specific turbine design, and a design assessment (or evaluation) is necessary for a full certificate, but lacks certain important stages related to testing and manufacturing. Both turbine and component manufacturers agreed on the importance of certifying their products. Indeed, some manufacturers viewed an international certificate as true proof of technology mastery, as reported by an interviewee from China General Certification:

> Certification is taken as a symbol that one manufacturer has established their own capability for the design of a wind turbine. It's a kind of symbol, so in the early stage people are following the certification process to acquire knowledge. The kind of knowledge or the know-how of what the procedure should be, what it looks like and to educate their people of what kind of procedure they have to follow.

As the interviewee pointed out, certification procedures also enabled learning through understanding and striving to reach the standards set by frontier firms. However, Chinese manufacturers' main resistance to certificates and design assessments was that they considerably slowed the product commercialisation plan. Since domestic customers did not require certification in the early phases of the onshore wind industry, certification was not regarded as worth the extra time. Getting products quickly to market was considered more important than going through the necessary testing for certification. In other words, the experience these companies needed in terms of operation hours was considered more important than the formal papers.

Manufacturers got around this problem by taking advantage of the industry's general lack of experience with certifications in China. Since the international certification companies, such as DNV GL and TUV, offered simple design assessments as well as more comprehensive type certification, manufacturers were able to fulfil only the quick version without developers noting the difference. The interviewee from China Certification General explained this:

> Some of them [turbine manufacturers] will seek a design evaluation or a prototype certification as defined in IEC standards. These evaluations look quite like the certificate and most of the developers don't recognise the differences between certificates and a design evaluation or a prototype certification. And a design evaluation is much quicker than a full certificate.

Thus, manufacturers were able to short-cut the long process of getting a full certificate from international companies. In practice, their turbines would go through testing after being sold, rather than being tested by certification agencies. In this way, the turbine manufacturers saved time and got the 'right' international documentation that helped them sell turbines on the domestic market. In this case, we may say that quality conformity was unimportant in terms of actual procedures, but made a difference in terms of 'face value' that sped up the commercialisation of the turbines and gave companies with these certificates and edge. In this process, there was a negotiation between speed and commercialisation that had consequences for the final product.

Quality was a concern in the industry, and many interviewees voiced that component suppliers did not manufacture according to European standards. One episode that was referred to by several of the foundation suppliers I spoke with was the ZPMC delivery of foundations to the UK offshore wind project Greater Gabbard in 2010. After the foundations were delivered, there were reports of quality problems relating to poor welds that needed repair (Reina, 2012). These poor welds created a bad reputation not only for ZPMC, but also for other Chinese suppliers. For instance, the interviewee from the small shipyard said that they had been bidding for a project in Denmark, but neither they nor ZPMC had won the bid, ‘possibly because of the bad reputation from the Greater Gabbard’. This bad reputation could potentially persist even if product quality were to correspond to the highest standards, making it more difficult for the Chinese industry to catch up with frontier firms. Frontier firms also recognised that the reputation of Chinese companies was sometimes worse than the actual state of matters. For example, one foreign supplier of control systems confessed that many Chinese turbine manufacturers wanted a foreign control system because it was associated with quality – not necessarily because the quality was actually better. Thus, the reputation of bad quality must be taken into account as a possible factor that made opinions about quality more negative than the actual conformity to standards.

Nevertheless, reports of poor welding were also a topic in other interviews. When asked why this had occurred, some referred to low wages, some to poor training and some to short deadlines that had made some companies hire unskilled labour in times of rapid increases in demand. It appears, therefore, that the possibility and sometimes dire need to save money for Chinese suppliers directly affected the quality of their final products. This was also emphasised by component suppliers at all of the wind conferences I attended during my stays in China. Roth et al. (2008, p.28) claim that Chinese suppliers are obsessed with keeping costs low, which ‘helps to explain Chinese companies’ swapping out of approved ingredients for cheaper substitutes or skimping on proper handling’. In the offshore wind industry, a story from a European coating firm in China stood out: ‘Some of our clients want the most expensive and high-tech coating on the outside of the turbine, where it can be seen, but on the inside they will choose the cheapest one to save money’.

Moreover, the time pressure suppliers were under to construct projects gave them less time to adapt. As one supplier representative put it: ‘To adopt the parameters and the design is normally not very difficult, but the problem is that very often they [the customers] give us very little time for the design and for the production.’

Somewhat expectedly, therefore, the most frequent issues related to poor product quality were associated with cost-cutting – by offering low wages to workers or wanting to get products done in a short amount of time – and a bad reputation that was difficult to overcome.

6. Too close or too shallow? Relationships and quality

There were, however, other compelling practices that may have hampered a concern for product quality. These were revealed in observation of the wind turbine component suppliers. Wind turbine blades were amongst the most expensive wind turbine components, and, as Figure 4 showed, there were several domestic Chinese blade producers. As it turned out, Chinese-produced blades had quality issues, as stated by the interviewee from China General Certification:

> They just buy some design from Europe, in order to manufacture their blades, but the procedures, I think personally, are not quite well followed. So some of the blades have potential risks and today, after they have been in use for some years, there are more failures from the blades.

Several interviewees also expressed that there was a quality difference between products produced by domestic suppliers and those built by foreign suppliers in China. For instance, a foreign professional performing inspection at several wind turbine component suppliers said that:

> My impression is that the foreign suppliers manufacturing here have greater control of the quality. For instance, I was inspecting a Taiwanese supplier and the conditions were perfect. And I have also inspected several Chinese suppliers here and I have several times detected problems with their procedures for quality control.

The difference, according to this inspector, mainly related to failed quality control procedures.

However, the interviewee continued to point out a potential reason for the difference:

> One company I was visiting did not even seem interested in improving the points I mentioned, and I suspect the reason for that was their very good relations with their customer, the turbine manufacturer Siemens.

The interviewee explained that the company in question was supplying components for an offshore turbine produced by Siemens. The interviewee noticed that the person sent from Siemens to audit the component supplier had very good relations with the managers and that they frequently met socially. The importance of good relations has been demonstrated in other cases in China (Hansen, 2009b; Peng and Luo, 2000; Shi et al., 2014), and in the wind industry in particular (e.g. Kirkegaard, 2015; Korsnes, 2014; Søndergaard, 2015). In the offshore wind industry, good personal relations may have been more important than delivery of a perfect component. Hence, the close 'friendship' between supplier and manufacturer may have inhibited information exchange between them.

Other examples of failed communication due to close ties occurred when suppliers and buyers were part of the same industry group. Suppliers within the same group, as the following case with United Power and Longyuan shows, were able to deliver products that did not perform as well as competing products without repercussions. The developer Longyuan has the most experience with onshore and offshore wind energy in China. Their subsidiary, Guodian United Power, was, by the end of 2013, the third largest turbine manufacturer in terms of cumulative turbine installations, and had a 10 per cent market share in both onshore and offshore installations (WWEA, 2014). The poor performance of United Power turbines was a topic in several interviews, and there was a general consensus that the performance was not on par with other Chinese turbines. Longyuan had been the largest customer of United Power, and this had likely led to less feedback for turbine improvements. As an interviewee from the Chinese certification agency put it: 'Longyuan have to buy the turbines from United Power; so I think this will give United Power less encouragement to improve their technology. They're not much driven by the market performance.'

A wind industry consultant commented that United Power's main problem was that they were 'manifestly incapable of understanding what an external client needs. They are selling almost exclusively to their own group, and they haven't been able to break out and sell to other groups.' An interviewee from a gearbox manufacturer explained the situation in this way: 'In China it is like this. If it can sell then it is good enough. If it cannot sell, then we will start to think, "What's the problem?" and then try to improve. As long as we can sell, we cannot always see what the problem is.' The problem was, therefore, that United Power was able to continue to sell their turbines to Longyuan despite their turbines' underperformance. Longyuan patiently supported United Power and, in this way, United Power grew quickly. However, United Power failed to convince other customers that their product was robust – something that was likely due to their very close ties with only one customer, their mother company. An interviewee from a competing wind turbine manufacturer explained the unfortunate relationship in this way: 'it can be compared to having a son; you want to support him regardless if he is talented or not.' In other words, the unchanging support from a state-owned company was useful in enabling them to acquire technology and hence grow to become a big turbine manufacturer, but was useless in ensuring a continual improvement in product performance and inter-firm learning, and hence catching up. Ironically, close ties were important for the success and growth of the company, but these same close links also hindered the improvement of quality. Having the technology and the right connections was therefore not the same as making the technology work.

International entrants and domestic companies manage their supply chains differently, and this may also help explain the underperformance of Chinese firms in terms of quality. Hansen (2009a) argues that domestic companies in China simply choose another supplier if a component does not accord to expectations, whilst international entrants typically cultivate a relationship and develop a component based on mutual feedback. Steinfeld (2004) also shows how Chinese firms integrate 'shallowly' in the supply chain. Looking at the offshore wind supply chain, we saw this distinction particularly between companies with larger and richer owners. For the more expensive components, small companies did thorough research on which supplier to choose to reduce risk related to quality and faults. As a manager of a smaller wind turbine project developer put it:

> There are two types of bearings: one type is inside the turbine and it is very easy to replace. The other type is for the gearbox and the main frame, and it costs a lot of money, a lot of engineers and a lot of time to change it. This is the one we typically import.

This developer chose to import the expensive components in order to ensure quality. The larger developers, on the other hand, appeared less attached to suppliers outside their own group. A representative from a large SOE developer expressed it as follows:

> Maybe there would be a problem with a bearing, but, never mind, I will buy another kind of bearing from another producer. It's OK. Maybe I will lose a little money, but it is never big money. We can afford it. It is not a problem.

Having ample access to financing, large project developers had more slack in terms of suppliers, and did not necessarily mind trying local suppliers. Should the quality of a component not be adequate, they would simply try another supplier. This means that, in terms of local supply chain development, the large, state-owned developers actually gave local suppliers a chance. The problem was only that they did not follow up in terms of feedback and co-development if products were not as expected; hence, the relationship between supplier and manufacturer was 'shallow'. This is also supported by research from China's onshore wind industry. Lema et al. (2013) show that, in contrast to Europe, where many turbine manufacturers produce the majority of components in-house, the Chinese onshore wind turbine supply chain has a large number of manufacturers and a highly competitive environment. This competitive environment drives down prices, but also keeps relationships between suppliers and purchasers short-term (ibid.). Developing a product takes time, and, as the case of Denmark's wind industry showed, feedback between suppliers and manufacturers is crucial for cultivating relationships and convincing customers of the quality of a product (Garud and Karnøe, 2003). In other words, SOEs could have been supportive of domestic suppliers, but instead were 'shopping' for new components and failed to build the necessary competences through mutual feedback and collaboration.

Another aspect of these shallow ties pertained to supplier background. Several component suppliers were large multi-industry companies with experience in related industries. These large companies were sometimes not interested in including feedback from their customers in the early stages. A representative from China General Certification explained the problem:

> If we take the gearbox manufacturers for example; they don't have much experience about wind dynamics in the early stage, since they typically provide gearboxes for ships or other industries. The wind industry is a smaller industry, as they see it, so they will use the existing experience to manufacture the gearbox for the wind industry, and they don't care much about the opinion in wind industry at the early stage.

These large multi-industry conglomerates regarded the wind industry as small and inexperienced, and felt that they knew everything they needed to know about gearboxes. However, this lack of feedback between supplier and buyer could cause several problems relating to turbine performance and optimisation. This was pointed out by a European advisory agency that had been hired as an independent third party arbiter in a dispute over where the responsibility of failing gearboxes should be placed. Including this last point on shallow, but rather arrogant, relationships between suppliers and manufacturers, Table 3 summarises the different types of relationships and the types of firms in which they occurred.

Table 3: Supplier-manufacturer relationships, and where they occurred

	Close	Shallow
No firm-specificity	'Friendship'	
Large-SOE	'Duty'	'Shopping' 'Arrogance'

In summary, we may conclude that a lack of feedback between suppliers and manufacturers was a reason why products did not perform optimally. These relationships varied between being too close or too shallow, and had different consequences depending on the types of firm supplying components and manufacturing. Table 3 provides an overview of the way in which company ownership could influence user and producer relationships, and ultimately product quality. Too close friendships that 'blinded' the manufacturer could occur within any type of supplier–manufacturer relation in China. However, relationships between suppliers and manufacturers within large SOEs were identified as being particularly prone to either too close or too shallow links that could stifle learning processes, because this may have happened through all four of the identified mechanisms. In addition to the 'friendship' type, they may have also had close links that were characterised by 'duty', wherein they had no choice but to buy from a specific supplier. Shallow ties may have also occurred if the manufacturer practiced component 'shopping' or the supplier 'arrogantly' believed it held sufficient knowledge about the product. Firms in China should be cautioned against having too close or too shallow relationships. In effect, these are missed learning opportunities wherein quality might be improved if practices were to be different.

7. Conclusion: Technological learning and quality considerations

Summarising the findings in sections 4, 5 and 6, we can say that as China is catching up in offshore wind technology, several concerns complicate product quality and technological learning. Section 4 showed that joint ventures and technology licensing from Western firms were frequent strategies used to acquire technology in the offshore wind industry. Section 5 then identified some 'usual suspects', such as time, revenue and reputation concerns, that complicated processes that would have ensured product quality. Time constraints were also an important reason why certification was seen as mostly a symbolic and impractical process. Therefore, in the offshore wind industry, quality conformity was unimportant in terms of actual procedures, but made a difference in terms of 'face value'. Chinese firms saw the European standard as a quality benchmark, and turbine manufacturers opted for ‘quasi-certificates’ with a foreign stamp that were satisfactory for the project developers and that would give them an edge on the domestic market. For the domestic Chinese industry, foreign certificates were not as important as turbine installation. This may be interpreted as a strategy of learning through experience rather than waiting for the slower certification procedure. We may therefore say that Chinese offshore wind companies were open to external knowledge in terms of technology sourcing strategies, and were also interested in making sure that experience-based learning happened through trial and error.

The core contribution of this paper is that it shows how links between suppliers and purchasers in China’s offshore wind industry were unhelpful in ensuring technological learning, and hence product quality. Section 6 showed how these links could be too close or too shallow. In the former case, the relationship between the large state-owned enterprise Longyuan and its subsidiary turbine manufacturer Guodian United Power was used to illustrate ties that were so close that feedback was not used to improve product performance; Guodian United Power was the untalented son that received unrelenting support. On the other end of the spectrum, shallow ties led to ‘supplier shopping’ and a communication block, leaving scant possibility for the improvement and optimisation of components. The advantages of close and shallow ties were that local companies were contracted. However, learning opportunities were missed in both cases: where ties were too close, there was a sense of duty or friendship characterised by too much patience, and where ties were too shallow, supplier shopping or arrogance was characterised by a lack of patience. We may therefore conclude that better feedback between supplier and demander could enhance learning processes and, ultimately, product quality.

By breaking down the way in which close and shallow ties influence learning within state-owned enterprises (SOEs) and enterprises more generally in China, this paper provides a novel insight into the way in which state ownership influences the acquisition of dynamic technological capability. In effect, companies may invest all the time, money and engineers they want on R&D but considerations of supplier–manufacturer feedback may still hamper learning processes. This means that although Chinese offshore wind firms appear to be relatively open to external sources of knowledge, they fail in building sound learning networks that include active cooperation with other firms. A policy implication for the Chinese government in this respect is that incentives for technological learning not only should be directed at sourcing strategies (e.g. licences or joint ventures) or internal R&D, but should also be directed at achieving a healthy cooperation between firms within the cluster in question. In this process of technological learning, policy makers should be cautioned against believing that close and sustained interaction automatically will bear fruits: relations may indeed become so close that learning is hampered. In other words, a form of 'optimal' proximity must be found in order for interactive learning to occur. This is especially important in China, where so much of the industry is relying on large and centrally governed SOEs.

The findings in this paper are not only relevant to the energy industry, but also to other industries, such as the food industry, in which communication and ties between suppliers are crucial for safety and quality (Roth et al., 2008). Therefore, the amount of accidents and food scandals that recur in China might reduce if Chinese policy makers and managers pay more attention to the relationships between suppliers and purchasers. As the institutions of quality assessment in China are still developing, this paper only begins to trace the various instances that facilitate or complicate quality considerations and technological learning. More research is needed in order to determine exactly what an 'optimal' relationship is, and how such relationships are characterised in China.

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Appendix 1: Overview of stakeholders in the offshore supplier segment

Segment	Company	Background and ownership	Central-SOE?
Foundations and installation	Jiangsu Longyuan Zhenhua Marine Co. (also installation)	Joint venture between Longyuan and ZPMC, a ship construction company	Yes
	China Offshore Oil Engineering Corporation (COOEC)	Offshore oil and gas structures, the largest offshore engineering construction company in China and part of China National Offshore Oil Company	Yes
	Nantong Ocean Water Conservancy Engineering (also installation)	Subsidiary of the Jiangsu Hantong Group, involved with maritime and offshore structures	No
	Jiangsu Daoda Heavy Industry (also installation)	Privately-owned shipyard	No
	CCCC 3rd Harbor Engineering (also installation)	Subsidiary of China Communications Construction Company (CCCC), a large group involved with the design and construction of transportation infrastructure, dredging and heavy machinery manufacturing	Yes
Vessels	Jiangsu Hantong Group	The company has, amongst other things, produced specialised installation vessels for offshore wind	No
	Shanghai Zhenhua Heavy Industries (ZPMC)	CCCC has a majority stake in ZPMC	Yes
	COSCO Nantong Shipyard	Subsidiary of the COSCO group, a shipping and logistics services supplier	Yes
Cables	Zhongtian Technologies Submarine Optic Fiber Cable	An optical fiber cable company supplying mainly to telecommunications and the electricity grid in China	No
	Qingdao Hanhe Cables	A company developing and manufacturing wires and cables	No
	Ningbo Orient Wires and Cables	A subsidiary company of the Orient Group, a privately-owned conglomerate	No
	Fujikura Shanghai Cable	A JV formed in 2005 between the Japanese Fujikura group and Shanghai Cable Works	
Coating	Only foreign suppliers		
Offshore sub-stations	Only foreign suppliers		
Developers	Longyuan	Subsidiary of Guodian, one of the five largest power and power equipment producers in China	Yes
	China Three Gorges	One of China's largest energy companies, engaged with hydropower projects	Yes
	Huadian	One of the five largest power and power equipment producers in China	Yes

	Datang	One of the largest power and power equipment producers in China	Yes
	China National Offshore Oil Company	The largest offshore oil and gas producer in China, with operations in more than 40 countries	Yes

Sources: Company webpages, BTM (2012).