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Title page:

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The role of Danish suppliers in upgrading the wind energy industry in China

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Technology transmission across national innovation systems: The role of Danish suppliers in upgrading the wind energy industry in China

Abstract:

This paper advances our understanding of how technology upgrading in the Chinese wind turbine industry is linked to internationalisation of Danish component suppliers. In order to grasp the interlinkages and implications hereof, the paper combines perspectives of global value chains (GVC), national innovation systems (NIS) and firm level capabilities. The paper employs a qualitative methodology, drawing on explorative case studies of component suppliers and their links to lead firms in the wind turbine industry. The findings of the paper highlight the new pattern of upgrading by upstream linkages, i.e. linking up with global suppliers in the wind turbine global value chain, and the new role of component suppliers as technology transmitters across national innovation systems into emerging markets. Conceptually, the paper contributes to understanding how technological catching up in value chains links to the intersection between national innovation systems, a process driven by global value chain dynamics.

Keywords: suppliers, lead firms, wind energy, China, technology transmitters, innovation systems, global value chain

1. Introduction

In the past decades, China has earned the reputation of the 'manufacturing power house' of the world. However, more recently, the growing and fast-maturing Chinese market has started attracting the attention of many European companies, who are now seeking to integrate China in downstream segments of their value chains. This is also the case for the strategic industries appointed by the Chinese government, such as the industries for renewable energy. The global wind turbine industry has been reorganising towards China both their upstream activities (production) and, now increasingly, their downstream activities (business development, sales and marketing). Moreover, industrial policies have made the Chinese location highly attractive for all actors in the industry and have consequently facilitated a restructuring of the global industry towards the Chinese market (Lewis and Wiser, 2007; Lewis, 2013; Zhou et al., 2013).

Wind turbines consist of thousands of components, some of which are highly specialised. The operation and integration of these components into turbine solutions have evolved from a very long period of development, mainly within Northern European national innovation systems, e.g. in Denmark. This development has resulted in the emergence of specialised Danish component suppliers, many of which are still in the segment of small and medium-sized enterprises (SMEs) and highly embedded in their home-based networks within the Danish national innovation system (Karnøe and Garud, 2012). However, with the emergence of a China-bound strand of the global value chain for wind turbines, combined with a policy framework focusing on local content requirements, Danish component suppliers have – more or less voluntarily – followed their lead customer firms and expanded their operations into China.

The real take-off in the Chinese wind turbine industry is attributed to the Chinese Renewable Energy Law (REL) introduced in 2005 (Chang and Bruyninck, 2011). Today, China has become a

core location for wind industry and the largest market for wind turbines in the world. Initially, the evolution of this industry relied on European lead firms and their technology. However, during the past decade and following the introduction of the REL, the Chinese domestic industry has been advancing fast. Chinese lead firms have been gradually developing production capabilities and advancing the wind turbine technology previously imported from Europe while building national technological capabilities and establishing a large supplier base. The developments in the Chinese wind industry have attracted attention among international business scholars. However, most research has been on the development of the market and the Western lead firm strategies for market access (Lema et al., 2013; Tse et al., 1997; Chen et al., 2006); or on innovation, capability building and technology transfer in the industry (Lema and Lema, 2012). Very little attention has been paid to the role of foreign component suppliers in the Chinese industry dynamics. The objective of this paper is to bridge this gap by focusing on how and to what extent the recent changes and technology upgrading in the Chinese wind turbine industry relate to linking up with Danish component suppliers.

In pursuing its objective, the paper combines the perspectives of global value chains (GVC), national innovation systems (NIS) and firm level capabilities. This combination allows for a better understanding of upgrading by linking up with global suppliers and the role of suppliers as global technology transmitters. Conceptually, the contribution of this paper lies in understanding how technological upgrading and catching up of emerging markets' national innovation systems potentially link to global value chain dynamics.

The paper has four remaining parts. Section 2 introduces the conceptual backdrop of the paper and presents the qualitative methodological approach. The empirical part of the paper presenting the cases of specialised Danish component suppliers and the Chinese lead customer firms is in Section 3. Finally, the discussion and analysis in Section 4 lead to conclusions in Section 5 on how new

opportunities emerged for component suppliers. Their role as technology transmitters between national innovation systems involved transferring capabilities through the global value chain and facilitated a catch-up in the Chinese lead firm segment. Hence, global value chain dynamics may facilitate technology transfers by linking national innovation systems. Furthermore, the section brings suggestions for how to unravel the tentative results of the study further in the final section.

2. Conceptual backdrop: Value chains, innovation systems and capabilities upgrading

In order to embrace the dynamics of upgrading and technology transfer in the wind turbine industry, we combine three analytical frameworks establishing a multilevel analysis: 1) the industry level and the perspectives of restructuring global value chains increasingly towards emerging markets, understanding types of linkages through governance modes and possibilities for catch up; 2) the national innovation systems perspective, which allows for bringing in embeddedness of technology and innovation within a system or network of actors within geographical proximity; and 3) the firm level perspective looking into firm level capabilities and agility to adapt to new environments, to understand the role and possibilities of firms that are not the lead firms of the value chain. Combining these three perspectives allows for an understanding of the changing role of component suppliers, as well as the consequences related to technology dispersion across national innovation systems.

2.1 Global value chains

Over the past decades, the process of restructuring production into global networks and value chains connecting producers and buyers across the globe has called for analytical tools grasping the dynamics of industrial restructuring (Feenstra, 1998; Dicken, 2011). Important questions in this

regard are: who are the winners and losers of global restructuring, who is setting the standards, and who is driving or governing the chains? From the global value chain (GVC) literature, there is substantial evidence that the reconfiguration of industries is orchestrated and driven by global lead firms, predominantly Northern based MNCs, through the construction of buyer-driven chains (Gereffi, 1994). Northern lead firms have in general dominated GVCs through different types of governance and through slicing up production processes, offshoring and outsourcing (Dicken et al., 2001; Mudambi, 2007). Today, components take up a large share of global trade, indicating that production processes are indeed globally dispersed, organised and governed (UNCTAD, 2013).

Still, in certain manufacturing chains, there is a preference by lead firms to use the same suppliers although in different locations. In the automobile industry, this phenomenon got labelled as 'follow sourcing', i.e. component suppliers following lead firms to new locations where the lead firms see potential for market expansion, production or other operations (Humphrey, 2003). In this process, lead firms (assemblers) and suppliers develop parallel networks in which lead firms' preference stays with their first-tier supplier and their subsidiaries in emerging markets. As core components are sourced from these suppliers, the study by Humphrey shows that de-nationalisation of component suppliers does not lead to upgrading possibilities for local suppliers in the host location (ibid.). Furthermore, with increased liberalisation, production of sophisticated components by established component suppliers has been switched from domestic production in the Triad countries to low-cost destinations.

The restructuring of value chains and the role of component suppliers from Triad countries in the 1990s had the following features: 1) design activities moved from assemblers to suppliers leading to specialised component suppliers and customised solutions; 2) a rise in modularisation and full-package specialised suppliers; and 3) lead firms engaged with fewer suppliers in long-term relationships (Dedrik et al., 2009). Component suppliers involved in this process got previously

unseen global reach, R&D and design capabilities, and also new market opportunities. Sometimes unintentionally, as Humphrey and Memedovic put it: 'major component suppliers were both pressured to follow their major customers and were [sic] attracted by the growth potential of these markets' (Humphrey and Memedovic, 2003: 26).

However, in highlighting these developments and the lack of upgrading in the host country supplier base, the literature does not go far enough in looking into the consequences of a localised foreign component supplier base introducing specialised technology into the domestic market for the host country lead firms. Moreover, it becomes increasingly relevant to look into the extent to which foreign component suppliers play a role in upgrading and building technology capabilities of emerging market multinationals in the buying segment. On the other hand, developing countries' upstream industry actors and Northern lead firms have attracted the attention of most GVC research. Incumbent lead firms are seen to largely govern the dynamic global processes through *coordination* or *governance* regimes spanning from hands-off market relations to vertical integration. In between these two, relational, modular and captive network types of governance have emerged (Humphrey and Schmitz, 2004; Gereffi et al., 2005).

In the captive mode, lead firms dictate conventions, standards and directions upstream to suppliers in the value chains. With the growth of vertical specialisation as has been seen in the electronics industry (Ponte and Sturgeon, 2014), other types of network relationship have emerged, involving governance forms in which suppliers have increased control. As suppliers get specialised into high-tech segments of the chain, modular and relational chains emerge (Sturgeon, 2002; Dedrick et al., 2009; Gereffi et al., 2005). Transactions in these types of chains are characterised by suppliers with high capabilities, codifiable and less complex transactions (e.g. through common standards). If the transaction of components is easily codifiable, modular types of governance tend to dominate, whereas if the transaction of components is difficult to codify, relational types of governance

appear, owing to the need for co-creation and knowledge exchange (Pietrobelli and Rabellotti, 2011). Modular and relational types of governance dominate when suppliers are highly capable and strong in production of complex components or highly specialised in technology, and provide high value added to the final product.

But what happens when the specialised suppliers are put in a situation where they can access a different strand of a GVC and expand their customer base to also catering for emerging market multinationals? In fact, component suppliers may be able to gain a more powerful position in a GVC strand driven by emerging market multinationals. Although the GVC approach has addressed the restructuring of industries, the main focus remained on Northern lead firms reorienting production to low-cost destinations, while keeping their market orientation in the developed markets. However, there is an ongoing reverse process resulting in new value chain set-ups. These new set-ups also call for new strategies and behaviours of all chain actors and new opportunities for specialised component suppliers as well as new upgrading opportunities for emerging market newcomers, as there may be possibilities for evolving into lead firms.

As a result, the chain and network governance dynamics change as the industry experiences a divide of the value chains into different strands for different markets: one highly specialised and customised high-end strand for the traditional lead firms and one more generic strand for lead firms from emerging markets (Haakonsson, 2009a). Suppliers of core technology components are relevant actors in both these strands. However, their roles are different. In the new strand targeting emerging market buyers, suppliers are likely to have the potential for gaining a better position to drive (or orchestrate) the chain as they provide access to technology from established national innovation systems. Hence, GVC dynamics and linkages in such set-ups provide linkages between the geographically bound innovation systems.

2.2 National innovation systems

A national innovation system (NIS) consists of structures and institutions embedded in a national context. According to Lundvall (1998), these structures and institutions play an important role in determining the rate and direction of innovation activities and a particular country's innovation capacity. As a result, technological systems and characteristics of technological innovation may vary greatly by country (Lundvall et al., 2011). Meanwhile, the sectorial and technological innovation systems perspectives acknowledge that the process of innovation may cut across distinct national geographies hence technology is to some extent transferable between national innovation systems (e.g. Edquist and Johnson, 1997; Malerba, 2009). The process of follow sourcing and de-nationalisation of component suppliers in global value chains mentioned in the previous sub-section points to further implications for de-nationalisation of technology and emergence of cross-border technology transfers across national innovation systems. In these cross-border systems, learning and innovation capacity of actors results not only from the national innovation policy initiatives, but also through the interactive processes occurring in the industry as well as at the firm level (Pietrobelli and Rabellotti, 2009; Ding, 1997; Haakonsson, 2009b).

This interplay is visible in industries where lead firms have been seen as the primary source of technology and for which the global value chains have changed to also targeting emerging markets. From the perspective of catching-up processes and developing national innovation systems in emerging markets, innovation and learning are key elements (Gu and Lundvall, 2006; Gu et al., 2016). In a NIS perspective, upgrading becomes more than just 'climbing up' the value chain; it is essentially about 'deepening the capabilities within the same function or in additional functions along the value chain' (Morrison et al., 2008: 41). Morrison et al. (2008) take an evolutionary approach to include learning and firm-specific strategies. This is especially important for understanding recent industrial developments, including a potential for the changing roles of

specialised component suppliers in the development and upgrading of emerging market lead firms. Through linking up with specialised foreign suppliers, emerging market lead firms can potentially access technology without necessarily upgrading internally, i.e. through technology transfer, but by obtaining a receiving position in a long lasting process of technology transmission.

In order to understand catch up processes at the firm level, there is a need to understand the capabilities development and the institutional settings.

2.3 Capabilities upgrading

As mentioned above, one outcome of specialisation in the supplier base is the changing dynamics of GVCs as engagement of the specialised component suppliers in the two value chain strands transformed these suppliers from 'follow sourcing' actors to important actors in the industrial dynamics for capability building of lead firms and technology transmission between NISs.

In order to capture the possibilities emerging from changing dynamics at the industry level, certain issues have to be implemented at the supplier firm level. Specialised component suppliers face new challenges in this restructuring towards emerging markets. Several factors may influence the role of the suppliers as technology transmitters across NISs. First, the component suppliers' organisational arrangements, behaviour and strategies are important. Although institutional factors play an important role in emerging markets such as China (Gu and Lundvall, 2006), more attention should be given to the processes at the firm level. The former has been in the spotlight for years, but the firm level capabilities to optimise the orchestrating potential have often been ignored. Second is the degree to which component suppliers, often small and medium-sized companies (SMEs), manage to standardise or package components into modular solutions through increasing the codifiability, and how they contain the complexity of the components, e.g. through black-boxing core technology.

Third is the perceived value of entering the emerging market strand of the value chain, which is likely to be a lower-value market than their traditional markets, but a significantly larger one, as it requires some degree of 'downgrading' and 'de-featuring' of their products. Finally, we must consider the flexibility and mobility in the chain.

Some of the existing literature expects that suppliers will 'act in a vassal role for the big companies' (Noori and Lee, 2006: 1023) and will 'be locked into a high customer dominance' (Quayle, 2003: 84). According to Noke and Hughes (2010), SMEs that are less endowed in human, financial and technological resources than large firms end up as casualties of these large firms and become downgraded to the position of subcontractors characterised by lowering profit margins and increasing low-cost competition. Furthermore, SMEs are generally less 'fit' for internationalisation than large firms. They have traditionally relied on their home networks related to their NIS, proprietary processes and unique products; therefore, they are highly dependent on long-standing relationships with buyers (e.g. Freytag and Mikkelsen, 2007; Knudsen and Servais, 2007). This reliance may indicate significant implications for the internationalisation practices of these firms and manifest itself in 'follow sourcing' strategies that many specialised suppliers adopted when their Western lead customers were expanding to China. This approach to internationalisation may also be seen as an outcome of asset parsimony when despite resource constraints the suppliers manage to leverage a repository of intangible resources and network-based capabilities that allows them to successfully enter international markets and find their niche there (Cavusgil & Knight, 2015).

Figure 1 integrates the three perspectives discussed above (i.e. GVC, NIS and firm level). As the development of technology originally relates not just to the lead firms and suppliers implementing the technology but to the NIS hosting the firms, transmission of technology relates to the firms as GVC actors involved in one or both of two strands of a GVC, i.e. the strand governed by traditional

lead firms and the strand with emerging market buyers taking the lead firm position, however without necessarily governing the chain. The firm level capabilities of the specialised component suppliers are determinants for the extent to which the suppliers manage to keep (and improve) their position in the two strands. However, their role in the chain differs. As will be shown in the analysis component supplier capabilities relate directly to the restructuring of the GVC for wind turbines towards China.

*** Please insert Figure 1 about here ***

Figure 1 illustrates two main phases, namely (Value Chain A) the early emerging market development depending on foreign lead firms expanding the GVC into emerging markets, and (Value Chain B) the later development with emerging market lead firms entering the GVC by linking up with component suppliers. As shown in the Value Chain B the transmission of specialised technology is facilitated by component suppliers linking the two NISs. However, the transmission of technology takes place from the home NIS of the component supplier to the emerging market NIS – and so far not the other way. This indicates that the emerging market industry is still in the phase of catching up. Future developments in the GVC are likely to change this.

Applying the framework, this paper draws on explorative interviews with Danish specialised component suppliers, emerging lead firms in the Chinese wind turbine industry and incumbent lead firms from the Danish NIS. The Danish wind industry is an interesting case, as it has been a global technological 'hub' for wind power technology since the 1970s. Two of the largest wind turbine lead firms are based in Denmark, Vestas and Siemens (formerly: Bonus), along with leading research institutions and universities specialised in wind energy. Furthermore, the Danish NIS has fostered a wide variety of highly specialised component suppliers, whether university spin-offs,

small and medium-sized enterprises generating tacit knowledge over time, or through externalisation from the lead firms.

This paper zooms into the journey of the Danish component suppliers after their decision to go global, in particular bringing their component technology to China. The industry was intensely followed by the authors in the period from 2011 to 2016. The multiple case study approach allows for a wider perspective on the global value chain for wind turbines, the individual companies and the context. In total, seven Danish technology intensive component suppliers were interviewed along with seven Chinese lead firms and two Danish lead firms. The current research relied on triangulation. Multiple sources of evidence (semi-structured interviews, industry conferences and exhibitions, documents and on-site observations) as well as triangulation of multiple data-points within each source of evidence (e.g. multiple respondents at various management levels both in China and in Europe) were used.

3. Industry description and case studies

The development of the Chinese wind turbine industry is to a large extent a result of China's energy policy transformation and the policies focusing on building endogenous innovation which were integrated into the political plans aiming at catching up (Gu and Lundvall, 2006). With this shift, there was also a change towards investing in the development and implementation of green solutions (Gu et al., 2016). Until the 10th Five Year Plan, wind turbine technology was tested at a limited scale in research institutions such as the Chinese Academy of Sciences. In the 10th Five Year Plan, sustainable development was introduced as a guiding principle. In this plan, Feed-in-Tariffs on renewable energy were implemented in the Chinese system. Almost simultaneously with the 11th Five-Year-Plan in 2006, the Renewable Energy Law was implemented and with this also

new policy initiatives on Renewable Portfolio Standards (Jiang, 2016; Wang, 2010). Renewable energy industries got categorised as a preferential area for high-tech development (SCT, 2006).

In their analysis of the Chinese wind industry evolution, Chang and Bruyninck (2011) also highlight the importance of the Renewable Energy Law (REL) and its direct impact on the renewable energy sector in general and on the wind industry in particular. For the wind industry, the new REL initiated institutional framework signified a shift from fragmented ad hoc programmes and renewable energy development projects run by donor agencies from e.g. Denmark and Germany, to more holistic and strategic policies concerning both large state-owned enterprises and a broader group of stakeholders, including foreign multinationals (Lewis, 2013; Lewis and Wiser, 2007).

Moreover, the REL aimed at establishing a NIS fostering the establishment of research institutions and companies within wind energy and paved the ground for a split of the global value chain for wind turbines into two strands although both directed towards the growing Chinese market. The Chinese wind turbine industry has been through a process of upgrading in which upstream and downstream Chinese actors have been catching up and have experienced immense growth (Haakonsson and Kirkegaard, 2016; Lema and Lema, 2012). As of today, four of the ten largest wind turbine manufacturers worldwide are Chinese: Goldwind, DongFang, MingYang and Envision. In 2015, Chinese Goldwind took over Danish Vestas as the world's largest wind turbine manufacturer. Although production and installation of wind turbines in China increased immensely, the turbines produced by Chinese lead firms are predominantly for the domestic market. One explanation to this is that the growth of the industry primarily has been facilitated by Chinese policies for import substitution.

The global value chain for wind turbines is relatively short and wide, involving core and non-core component suppliers and wind turbine manufacturers assembling and designing wind turbines. Each turbine includes thousands of components of different technology intensity and trajectory (from

relatively simple plates and screws to more advanced glass fibre blades, design, and control systems). With increased competition and internationalisation, lead firms have reorganised their activities, resulting in component suppliers emerging in advanced specialised components. The European lead firms engage with specialised component suppliers in long-term and exclusive relationships, e.g. for blades, brakes or gearboxes. Having a long history of 'we grew up together' (interview, manager, 2014), these relationships are predominantly of the relational governance type. Meanwhile, the young entrants, the Chinese lead firms, predominantly engage in assembly and hence sourcing of all components. This can partly be explained by their need to access core technology not available in-house or within the Chinese national innovation system (Haakonsson and Hollitsch, 2016). Consequently, the Chinese lead firms and the efficiency of installed wind turbines are to some extent constrained by: 1) the catching up level, e.g. technological limitations in the catching up, as these firms rely on slightly older technologies than the incumbent lead firms, and 2) the physical infrastructure, e.g. for connecting the turbines to the electricity grid. As Lam et al. (2017) pointed out, impressive levels of installed capacity expansion are not always matched by the innovativeness and learning rates of Chinese wind turbine manufacturers as they are still lagging behind their Western counterparts (see also Lema et al., 2016).

Moreover, the Danish component suppliers have a history of co-evolution along their lead firms in the Danish NIS. The component suppliers tend to be based in the same home country as their main customer. In other words, many specialised component suppliers have grown with the lead firm that they supply the most. They have co-evolved in their NIS. With the lead firm internationalisation, the SMEs faced new challenges. Overcoming the challenges from their key customers moving into the Chinese market along with the fact that Chinese policies in 2003-2009 required up to a 70 per cent local content in wind turbines raised in China, Danish component suppliers had no other choice than to develop new strategies. The new strategies involved internationalisation and exposed them

to numerous challenges of operating in the volatile environment of the Chinese wind industry. Besides receiving the threat from the lead firms that they would engage with, and technologically upgrade, domestic Chinese component suppliers, the market was promising and Danish component suppliers took the consequence and established in China.

The changing structure and the emergence of a GVC strand for wind turbines led by emerging Chinese lead firms changed the strategies of Danish component suppliers to also target these. As the cases below show, the Danish suppliers redirected their strategies towards providing technology with proven track-records to the new lead firms. Looking more in-depth into, first, the evolution of seven Danish component suppliers in China and, second, how these played a role in Chinese lead firms will illustrate the extent to which technology transmissions have taken place between the two national innovation systems as they relate to wind turbines.

GlasFibre (GF) produces glass fibre components for wind turbines, such as blades, profiles and gratings. GF is a niche player that established itself in China in 2009 as the market for wind turbines continued to grow. As the Danish lead firms faced the political requirements for local content, pressure was passed upstream in the value chain to establish local production of components in China. While the initial strategy for entering China was to supply the traditional lead firms, and the facilities were also placed in close proximity to these, the consolidation of the Chinese lead firms increasingly reshaped the focus of GF's market strategy. GF reoriented the strategy and developed a more modularised product base for the Chinese strand of the value chain: 'It was easy to sell our products based on quality and the bank of knowledge and technological expertise defining our company.' So as GF kept producing customised components for its traditional buyers in exclusive relationships, similar but more modular type products were developed to meet the demand from the Chinese lead firms. While this process created a new market and an insertion into a new strand of

the wind turbine value chain, GF also took on the role of filling a competence gap in the Chinese industry.

Brakes&Hydro (B&H) specialises in brake systems for wind turbines. Today, B&H provides different qualities and has several packages of service, from a one-stop shop for off-the-shelf systems to co-created specialised solutions. B&H entered the Chinese market in 2003 and started production in China in 2006. Although several Chinese component suppliers produce brakes, B&H has a strong position in the market, as expressed by the Chinese manager: 'We have the proven technology […] much better than the competitors […]. We provide the certificates and tests as they [Chinese lead firms] require' (interview). In other words, Chinese lead firms buy the components with the tacitness of the technology B&H developed in collaboration with B&H's customers back home. This modular relationship helps the Chinese lead firms to overcome their capability barriers. The technology is black-boxed: 'One of my customers asked me: "So, what kind of material do you use for the block?" I answered: "Are you kidding me?"' Today, B&H's main problem is its size: 'This is not such a big company, so we cannot say if there comes a project that we will put all our R&D capacity into this […]. We have decided that we have only seven big customers […]. The others, we will try to give them a standard solution – or an existing solution – a one-in-a-box solution.' In other words, the Chinese market can be overwhelming for highly specialised SMEs such as B&H due to limited operational capacity.

Gearbox (GB) established a subsidiary in China in 2007 first with an office and in 2009 with local production. GB is a supplier of hydraulic systems for gearboxes in wind turbines and has strong long-term collaboration with one of the large Danish lead firms, which also purchases 70 per cent of its products: 'In our history, we have been growing with [Danish lead firm]. In Denmark we are very close.' GB also acts as supplier of gearboxes bought by the new lead firms. To do this, GB combines its knowledge into an integrated system: 'We supply the whole unit […]. Because we

have a lot of experience in Denmark for solving different components, we can easily produce very good solutions and components.' Over the past years, GB has also expanded in China and plays an important role when Chinese lead firms develop new products: 'we help them with the new types of turbines and we get into their businesses step by step.'

Two of the Danish component suppliers (CS1, CS2) compete individually as they are specialised in developing the 'brain' of the wind turbines, **the control system**. This is the core and most advanced technology in a wind turbine, relying on complex algorithms and calculations. CS1 and CS2 both entered the Chinese market in the mid-1990s. At that time, there were no control system competencies present in China. So, with the boom of the wind energy industry in the mid-2000s, both companies expanded their presence in China: 'It is not a choice whether you want to establish facilities here or not. It is really a question of whether you want to be in the Chinese market. If so, you need to be here' (interview, manager CS1). Originally CS1 and CS2 firms supplied and produced for European lead firms and they still do in China. Meanwhile, their market has expanded in China: 'They [Chinese firms] can copy the hardware but not yet the software.' Along with control systems, CS1 also provides related services into the design and implementation of wind parks. This gives CS1 a strong position in the market as it helps the Chinese lead firms to overcome their capability gap and enhance the efficiency of their wind turbines. 'Plug'n'play – they just plug in the cable and the control system is functioning' (interview, manager CS1). CS1 and CS2 have both developed modular products that are integrated into the design of new wind turbines which they also engage in.

LightingEquipment (LE) delivers light systems for wind turbines. LE has been operating in China since 2009 first with a sales office in Beijing and since 2010 also with production. Of the Chinese production, 80 per cent is sold to incumbent lead firms for their market in China, but recently products are increasingly sold to Chinese lead firms. Today, 20 per cent of products are for local

Chinese customers. The requirements are different according to the type of customer: 'Normally, the local customers will get the standard product that we have made in many years.' (interview, Chinese manager). Chinese lead firms require a package solution while Western lead firms are more demanding in terms of technical collaboration, which is done in Denmark.

Manpower (MP) supplies specialised services to the wind industry through a network of highly specialised human resources – technicians. This has been the case for decades in Europe and since 2001 in China. First, it was necessary to get European experts to the Danish lead firms' China facilities: 'We were actually told by […] our biggest customer [Danish lead firm] that we had to localise out here.' Initiated by the local content requirements, European technicians were imported on short-term contracts for MP's customers. Since 2008, the local capabilities have improved and MP's share of Chinese technicians has increased. The customer base has also expanded to Chinese firms: 'We have been going almost the full circle from having all the foreign OEMs to also having the Chinese OEMs. They are a little more difficult to deal with. We have quite a lot of Chinese customers.'

Table 1 shows the time of entry of different activities and the type of engagement the component suppliers have with the Western and Chinese lead firms, respectively.

*** Please insert Table 1 about here ***

Looking broadly at the seven Danish component suppliers' entry into China, it becomes clear that, as the Chinese lead firms engaged in sourcing of core components, the Danish suppliers adapted their linking strategies for these new buyers, and took an active role in the formation of the new strand of the wind turbine GVC. Coming from a chain with strong relational governance forms with lead firms within the Danish NIS to take on a supplier role a chain with modular relations has been

steering their interactions with Chinese lead firms owing to their capabilities within: proven track-record, tacit knowledge and specialised technological competencies. This has implications for the upgrading and catching up of Chinese lead firms who are now mainly doing assembly. For the Chinese firms the networks with component suppliers have resulted in great success stories.

The Chinese lead firms were established on the basis of transfer of European design and technology, but they became more independent over time. Sinovel, for example, purchases blades from a Danish blade producer located in China. The same is the case for gearboxes and generators. This is owing to a lack of technological capabilities in the Chinese NIS needed to meet the requirements of customers, i.e. wind park developers, as was also expressed by a manager: 'In recent years the wind turbines have gone really serious. The developers may require that we should buy the generator from this specific company and the gearbox from that specific company.' The software used by Sinovel was developed by a Danish supplier. Also, its customers are not supportive: 'Our weakness compared with [Danish lead firm] in the view of buyers is the proven quality. They think we are new – we are young.' Engagement with component suppliers with proven technology helps Chinese lead firms overcoming their technology gap to the market. However, it is also costly, in particular for the high-tech components, where the suppliers also want to profit on their patents. So, it is about track-record as well as access to technological capabilities. As a manager from MingYang put it: 'When MingYang started in 2006, there was hardly any technology on wind turbines in China. We had to get it from outside. So, MingYang has established an office in Denmark.' Envision also buys many components from Danish suppliers, including blades, gearboxes, brakes and control systems.

According to the Chinese Wind Energy Association, the government requirement for localisation, encouraged technology transfer and re-localisation of production of components and technology from Europe into China. For less technology intensive components, e.g. bearings and towers,

Chinese suppliers have emerged. In particular, components for smaller turbines have been localised into China, both by domestic firms and, for core-technology, by European component suppliers: 'There are two categories of components at the Chinese market: for turbines of below 1.5 MW, most components can be produced in China. For turbines above 2MW, most of the components need to be imported from outside. Some investors in winds farms actually require that some key components are foreign: e.g. control systems, converters, bearings are mostly imported' (interview, CWEEA). For the smaller turbines, some Chinese lead firms have a strong industrial base from previous industrial engagement (Sinovel and DongFang). MingYang produces its own blades and converters, but relies on suppliers for the rest.

Goldwind is today the world's largest wind turbine company. It was also one of the early movers into the wind industry in China: 'Twenty years ago we had a very small business area and a very small company. Then we made collaboration with the Danish Bonus [now acquired by Siemens] and RISØ [the Danish wind energy research centre]. In 1980 and 1986 projects were funded by the Danish government, Danida. We imported 13 units of 150 kW Bonus machines. These machines were set up in Xinjiang and are still running. This was the beginning of a lot of collaboration with foreign companies. Later also with several German companies.' Goldwind has upgraded from importing whole turbines to importing design and specialised components, and has acquired the capabilities to assemble turbines in China. Goldwind also relies on suppliers: 'Our suppliers make a very strong network for us. Blades, for example, with [Danish supplier]. For innovation projects, we do new development projects in collaboration with suppliers. For us, R&D means we are looking for the market and following demand. Then we arrange with suppliers. We go for "who is the expert?"' For blades, Goldwind collaborates with a Danish glass fibre specialist known for efficiency: 'We built up a facility for them near our facility and rent it to them. They can very quickly enter our production, and they are very satisfied with our deal. Win–win situation.' Looking

at the value chain, Goldwind mostly focuses on assembly: ‘This is our core competence. We do design collaboration with component suppliers. We send requests telling what we want, but other times we take what they have (standard components). For some there are certain standards.’

4. Linking national innovation systems, the role of Northern SMEs to catch up of the emerging market value chain strand for wind turbines

The Chinese market for wind turbines has doubled every year since 2005 and today is the largest in the world. However, contrary to expectations, it has turned out to be a difficult market for European lead firms. This is because Chinese industrial policy strongly supports domestic industry and domestic capability building. Today, Chinese lead firms dominate the Chinese market while European lead firms struggle to maintain a foothold in the market. The global value chain for wind turbines has been split into two strands. The main differences between these two strands and the lead firms driving them are ownership of core technology and end-product price. As the European lead firms deliver advanced, large, lasting and efficient turbines based on their track-records and certifications, the Chinese lead firms are in a fast-moving process of learning by doing and catching up. One clear trend in this regard is a process of ‘learning by suppliers’ where the role of Danish component suppliers has become more than just supplying core components. The Danish component suppliers have played an important role (and still do) in transmitting technology from the Danish national innovation system into the emerging wind turbine industry in China, through transferring core components to Chinese lead firms through modular governance relations.

For the Chinese lead firms, accessing technology from European lead firms is not an option. The incumbent lead firms keep technology and knowledge close, in particular in China, and their technology is too expensive for the Chinese market. However, a significant number of component

suppliers – in many cases insignificant in size, but specialised in supplying essential core technology – were encouraged to follow the lead firms and establish a branch in China. As was shown in the cases above, the component suppliers established a position as core suppliers, and prevented a situation where the Danish lead firms would share core technology by upgrading Chinese suppliers – and hence create competitors. There was a considerate follow sourcing and de-nationalisation of Danish component suppliers to China between 2000 (for market) and 2008/09 (production) that took place in parallel with the incumbent lead firms entering into the Chinese market. From the component suppliers' perspective, this strategy was mainly based on piggy-backing: Danish SMEs being pulled into China by their lead firms from home.

As the presumed adventure of the incumbent lead firms in the Chinese market did not turn out as expected, the component suppliers looked for new strategies in this new location. One obvious strategy was to establish supplier relationships with the Chinese lead firms and to move into new and stronger positions in the global value chain with a higher degree of control, i.e. to become specialised suppliers in modular relationships. This involved a shift to produce for the new strand of the global value chain for wind turbines in providing full-package solutions, standard products and combined components from different suppliers, taking in knowledge-intensive business services as design and development. On the one hand, this shift created new opportunities for the suppliers. On the other hand, as Brandt and Thun (2010) argue, from the technological perspective, this shift may partly lead to downgrading, as the component firms switch from made-to-order components produced in an environment of intensive cooperation with Danish lead firms to diversifying their product portfolio to also supplying standardised components to their new Chinese customers.

Having established themselves in China, the component suppliers have linked further into the Chinese lead firms and now play an important role in their catching up process compensating for lacking capabilities in the Chinese industry. Moreover, they have become technology transmitters,

linking the Danish national innovation system with the Chinese. Figure 2(a) illustrates the value chain flows within the wind turbine industry, while Figure 2(b) illustrates how technology is dispersed and transmitted between the two national innovation systems.

*** Please insert Figure 2 about here ***

With the global restructuring, Danish component suppliers internationalised their market and production into China. The suppliers engaged with Chinese lead firms in the new strand of the value chain. The lead firms in this new strand are domestic Chinese firms primarily oriented towards the Chinese market. These relatively young lead firms are increasingly also orienting their markets through upgrading of products and standards and through learning by linking up to specialised component suppliers. So far, these firms have not entered the international markets, but the Chinese lead firms all mentioned it as their long-term strategy. The component suppliers have to a large extent protected their technology by introducing standardised solutions such as modules within their technology. This shift from customised to modular units obviously has some quality implications. However, as most of the wind turbine technologies are mature, this becomes a trade-off between uniqueness and standardised solutions.

The reorganisation of the wind turbine industry into a two stranded global value chain played an important role in interlinking the Danish national innovation system with the catch-up processes and building of technological capabilities for wind turbines in the Chinese national innovation system. This is a new role for specialised suppliers, namely facilitating technology transmission between national innovation systems, which is a process driven by the construction and consolidation, and not least the splitting up of the value chain into two strands. One of the distinguishing features of the two strands is the larger role that the component suppliers gain over time in the governance in the new (China-bound) strand. In moving from a follow-sourcing entry strategy to also supplying domestic firms, the specialised component suppliers have gained more

control and coordination in modular governance relations with their Chinese buyers. Hence, it has indeed improved the suppliers' position in the value chain while also facilitating transfers of technology through continuous technology transmitting to the Chinese lead firms. Still, this restructuring was an unintended consequence for the component suppliers, however it was a fortunate way for Chinese lead firms accessing technology by linking up with actors from the Danish innovation system for wind turbines.

Conceptually our findings contribute to the concept of upgrading in the GVC literature as follow sourcing in this case did not result in technological upgrading of the emerging market lead firms. There has been very little *transfer* of knowhow between component suppliers and emerging market lead firms. In fact, the component suppliers strategically design component in ways that are hard to imitate. The follow sourcing has however resulted in a continuous process of technology *transmission*. This consequently has an impact on the emerging market lead firms' catch up potential. Although having access to component technology that facilitated the fast following, the lead firms do not have internalised technological capacity in core technologies. This transmission of technology is currently a one-way process, hence preventing emerging market lead firms from moving from a fast follower position to market leaders in terms of technology.

5. Conclusion

The restructuring process of the global value chain for wind turbines into China was not exclusive to lead firms. This paper shows how specialised component suppliers engaged in this process with a strategy of follow sourcing as they were pulled by lead firms, mainly owing to market growth and Chinese industrial regulation. This internationalisation of suppliers was not voluntary. Moreover,

the position of the suppliers was under pressure as the lead firms had to meet local content requirements.

Quickly, the specialised component suppliers got increasingly embedded into the domestic industry through the emerging market lead firms. This was a result of their technological capabilities and high specialisation. In this process, the specialised component suppliers gained the role of technology transmitters from their home national innovation system. This transmission helped the new emerging market lead firms to overcome their limitations in technological capabilities. Consequently, the component suppliers transformed into also being technology transmitters in a new emerging market strand of the wind turbine value chain. They went from piggy-backing to being important technology actors by following a strategy of feeding into two very different strands of the value chain, although targeting the same market.

Our findings suggest that although suppliers got the initial impetus for internationalisation by follow sourcing from the lead firms, following the new situation of linking up with emerging market lead firms, the suppliers got more independent and are today driven by new business opportunities in China. With this change in strategy, and the two-stranded value chain for wind turbines, the component suppliers have also expanded their position from exclusive suppliers of co-created components through captive or relational relationships with specific lead firms, into suppliers of package solutions in modular relationships. The Danish SMEs have undergone an internationalisation they did not anticipate or intend in the first place, as they did not consider themselves 'fit' for this process.

This study shows how new opportunities emerge for component suppliers when linking up as technology transmitters for emerging market lead firms. These new opportunities may not be directly related to technological upgrading of component suppliers, but they still provide them with valuable knowledge about new markets. In fact, some of these component suppliers have gained

very central positions in the value chain. Meanwhile, transferring the capabilities of these suppliers to emerging market lead firms in the value chain helped the Chinese lead firms to address quality problems and upgrade their products. This further indicates that the gravity of global value chains is shifting towards emerging markets. This study is one example of how suppliers are dragged into this process and the opportunities of this. However, there are also challenges as the suppliers have to manoeuvre their relationships with lead firms in both strands of the value chain. As the paper attempts to capture the changing role of the component suppliers in the dynamics of the industry, the study only briefly looks into capability upgrading as catch up in the Chinese lead firms and industry. This oversight is one of the limitations of the current work and provides an avenue for future research.

At the theoretical level, this study illustrated new dynamics in the global value chains. It is important that value chains are understood not only from the perspective of European lead firms. The findings call for more research into understanding and conceptualising the concept of lead firms as suppliers take on more powerful positions in the chains. Likewise, the paper shows how the governance structures of value chain strands have different drivers depending on the type of location of the market. One such driver is technology transmission between national innovation systems. Component suppliers play a key role in technology transfer and the upgrading dynamics of emerging market lead firms and global value chains facilitate such transfers by linking national innovation systems.

Even though this study deals with the case of renewable energy industry in China, it may have lessons for industrial policy and industrial development in other emerging markets as well. The study suggests new avenues for upgrading national industry and linking national innovation systems of emerging markets with more mature ones abroad. In the case of wind turbines in China, upgrading came about from having access to technology transmission processes from advanced

economies' national innovation systems. Moreover, in the construction of a south-bound global value chain for wind turbines, suppliers of core technology components played an important role in the establishment of new emerging market lead firms. This was built on transfer of design and technology rather than establishing a fully-fledged national innovation system around wind turbine technology. This study shows that implementing policies that facilitate this new way of tapping into foreign national innovation systems pays off. When flows of transmission are activated, not all technology has to be consolidated in the domestic system. Hence, the capabilities of integrating technology from different foreign sources (including foreign suppliers) are equally important for upgrading. In other words, technology transmission dynamics within the global value chain potentially leads to upgrading opportunities obtained from engaging with foreign upstream actors. These linkages may potentially lead to further upgrading the capabilities of emerging markets' national innovation systems.

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Figure 1: GVC, NIS and firm level perspectives on the evolution of the wind turbine industry and the changing role of the component suppliers

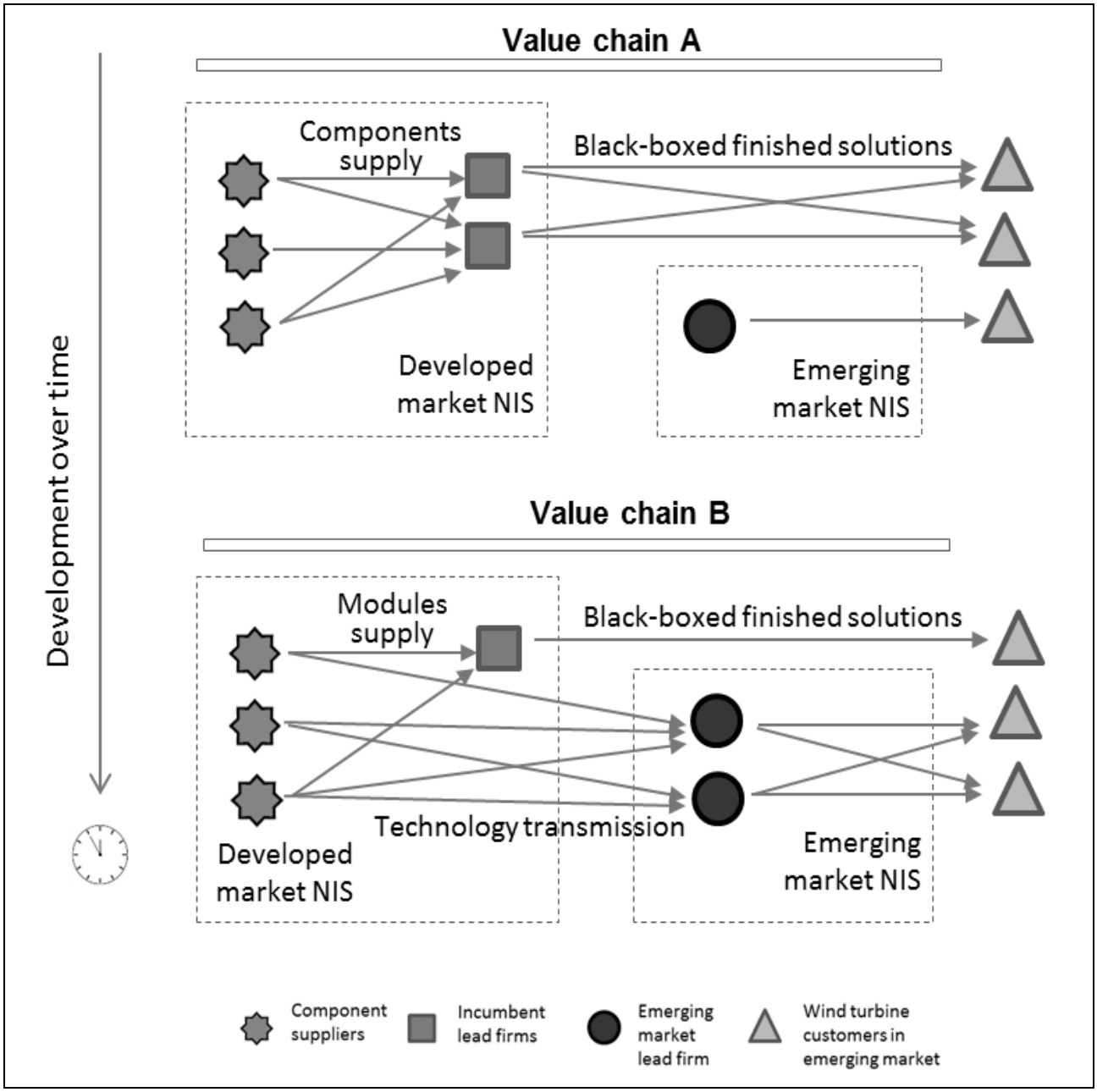
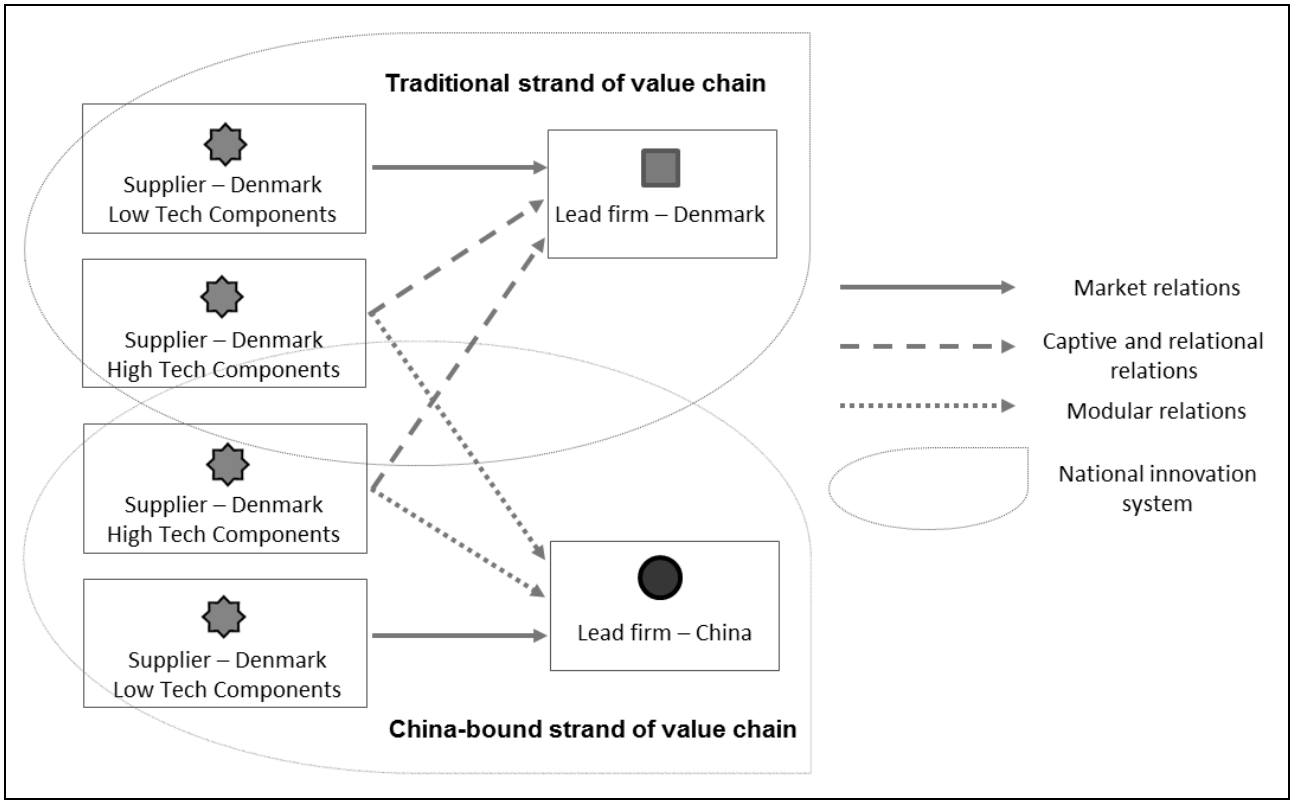


Table 1: Time and type of engagement of Danish component suppliers in China.

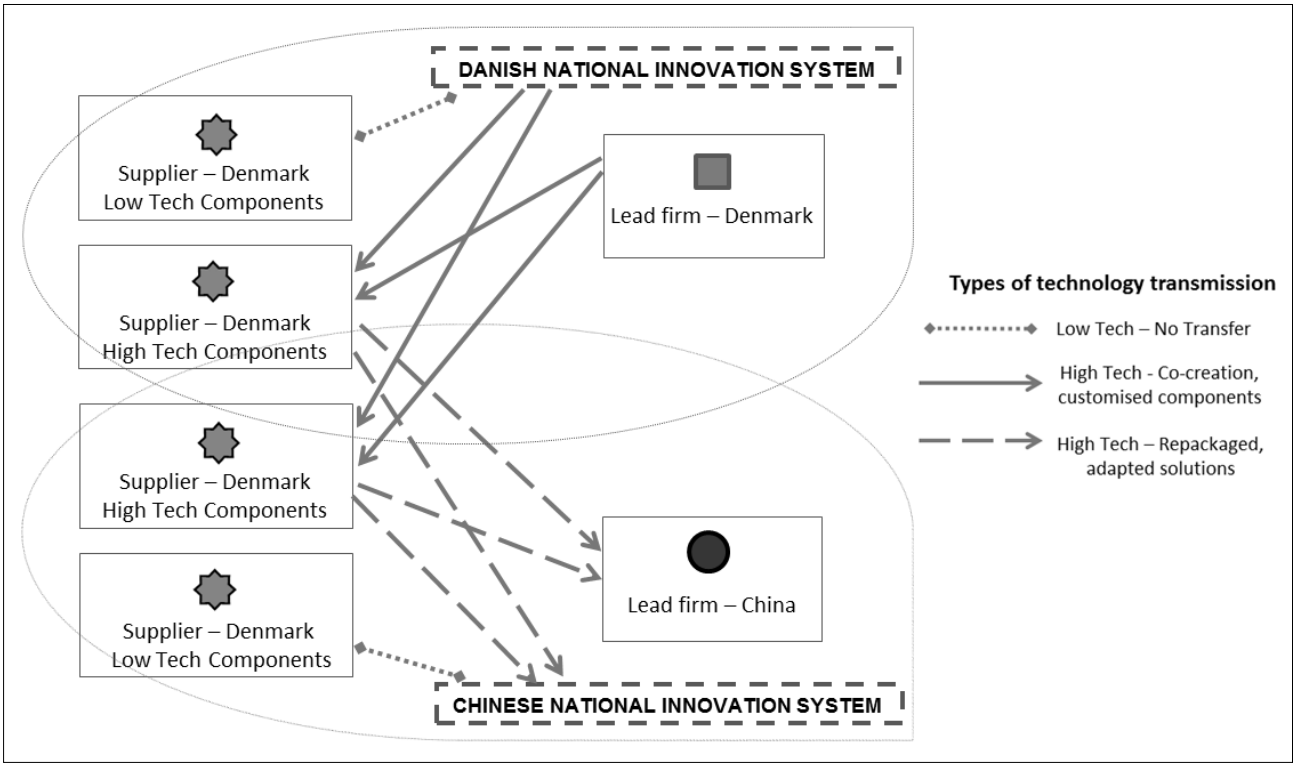
Component supplier	Entry (market)	Entry (prod.)	Followed lead firm	Relations to Danish lead firms	Relations to Chinese lead firms
CS1	1990s	2000s	No, market driven	Relational Co-creation	Modular Package Black box
CS2	1990s	2000s	No, market driven	Relational Co-creation	Modular Package Black box
MP	2001	2008	Yes, required	Maintenance Captive	Market Human resources Rebuilding
B&H	2003	2006	No, market driven	Relational Co-creation	Modular Standard solutions One-stop shop
GB	2007	2009	Yes, required	Relational Long-term co-creation	Modular Standard solutions
LE	2009	2010	Yes, required	Co-creation Design, relational	Modular Standard solutions
GF	2009	2009	Yes, required	Exclusive relations Co-design	Product base for China Modular

Source: Own data

Figure 2: Value chain composition (a) and technology flows (b) in the global value chain for wind turbines



(a) The Traditional - and China-bound strands of the global value chain for wind turbines



(b) Technology transmissions between the Danish and the Chinese NIS in wind energy