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China's Impact on the Global Wind Power Industry

Rasmus LEMA, Axel BERGER, and Hubert SCHMITZ

Abstract: China's economic rise has transformed the global economy in a number of manufacturing industries. This paper investigates whether China's transformative influence extends to the new green economy. Drawing on the debate about how China is driving major economic changes in the world – the "Asian drivers" debate – it identifies five corridors of influence and investigates their relevance for the wind energy industries. Starting with the demand side, it suggests that the size and rapid growth of the Chinese market have a major influence on competitive parameters in the global wind power industry. While Western firms have found ways of participating in the growth of the Chinese market, the government's procurement regimes benefit Chinese firms. The latter have invested heavily and learned fast, accumulating production capabilities that have led to changes in the global pecking order of lead firms. While the combined impact of Chinese market and production power is already visible, other influences are beginning to be felt – arising from China's coordination, innovation and financing power.

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Keywords: China, wind energy, global value chain, economic power, Asian drivers, coordination power, innovation, finance

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Introduction

It is now commonly accepted that the rise of China has transformed the global economy (Jacques 2009; Eichengreen and Tong 2006; Hung 2009; Schmitz and Messner 2008). The fast and deep build-up of industrial capacity in China has affected competitiveness in many sectors and countries, particularly in industries in the advanced stages of their product cycle. Existing research has already shown clearly how China has caused major disruption in a diverse range of industries, including consumer electronics (Ernst 2009), textiles (Song 2006) and shipbuilding (Poulsen and Sornn-Friese 2011).

This paper[1] examines an industry which is relatively young and in which the impact of China is less clear: the wind power industry. Some Western governments and companies are confident of their own ability to maintain and deepen their positions as global leaders in this area. Germany and Denmark in particular have made massive investments in this sector in order to reduce carbon emissions, strengthen their own energy security, promote their industrial competitiveness, and create jobs. They have high wind shares in their energy mix and they are the world's leading producers and innovators of wind turbines. A small number of US and Spanish firms are also amongst the leaders, but Germany and Denmark have set the pace. Their ambition is to strengthen their position in this industry of the future.

China, however, has not remained stationary. On the contrary, it has also made big public and private investments in this new industry. The

1 The paper is an output of the project "The impact of emerging powers: China-EU cooperation and global governance". The latter is a collaboration between IDS, DIE, and the Chinese Academy of Social Sciences (CASS) and is funded by three organisations: the British Academy, the German Ministry for Research and Education (BMBF), and CASS (through the ERA-NET CO-REACH programme). Research time for the lead author was funded by the Federal Ministry for Economic Cooperation and Development (BMZ), Germany (through the DIE project Low Carbon Innovation Policy in Brazil, China, India and South Africa). We owe a debt of gratitude to Song Hong of CASS, who worked closely with us in the CO-REACH project. We are also grateful for comments from three anonymous reviewers along with those provided by Ingo Bordon, Wolfgang Jussen, Miriam Meissner, Andreas Stamm, and Peter Wolff. We are grateful to Feng Zhao of BTM Consult (Navigant) for his time and to Søren Møller Andersen and Roberto Gonzalez for research assistance. Finally, we are indebted to all of the people in the firms and supporting institutions in the wind power industry who generously shared their time and insights with us.

question driving our paper is whether and how China is reshaping the global wind energy industry. In order to tackle this question, the paper draws on the Asian driver debate, which identified the corridors through which the economic rise of China (and India) began to change the world (Kaplinsky and Messner 2008; Schmitz 2006). Inspired by this debate, we unpack the "China effect" and structure the paper around five categories of economic power in the wind energy value chain.

To explore Chinese market power, we start the empirical analysis with the demand side of the value chain. We show how the large size and rapid growth of the Chinese market is changing the dynamics of this industry. We then move from market to producer power, showing how the rapid growth of Chinese turbine producers has changed the international pecking order of lead firms. The combination of Chinese market and producer power is beginning to change the face of this industry, not just in Asia but globally.

We also analyse other dimensions of China's power, the effects of which are less visible in the short run but are likely to be fundamental for the medium and long run. Chinese wind turbine makers can draw on a modular supply chain, which provides considerable advantages in terms of cost and speed. Realising this potential requires a coordination power that Chinese firms have begun to demonstrate both in the domestic and external market. The big question mark regarding Chinese firms is whether they can challenge competitors through technological innovation. While some say that Chinese firms continue to rely on licensing from Western firms, we suggest that China is on its way to becoming an innovation power. Finally, we draw attention to the need to bring financing power into the picture. Chinese government support for the industry is not hampered by financial austerity, and Chinese firms can provide supplier credit to their customers to an extent that Western firms cannot match. We conclude that China is transforming the global wind power industry and challenging Western leadership in this green industry, but also providing new opportunities for cooperation.

What Can We Learn from the Asian Driver Debate?

China's impact on the world has received a lot of attention and generated a lot of controversy. Complicating the debate is the lack of a common denominator: the effects are different in kind and often vary from one sector to another. Although this paper concerns a specific sector –

namely, the wind power industry – the challenge of distinguishing between kinds of effects still remains to be tackled. We turn for this purpose to the Asian driver debate, because scholars working within this framework have gone to considerable lengths to introduce distinctions useful for empirical analysis.

The Asian driver literature was from its inception concerned with the threats and opportunities created by the rise of China and the East Asian production system (Kaplinsky 2006). The need to distinguish between different kinds of effects was addressed in particular by Schmitz (2006) and Kaplinsky and Messner (2008). We draw on these and several other contributions to the Asian driver debate to develop an analytical categorisation for our paper. We distinguish between the following five categories of Chinese economic power: production power, coordination power, innovation power, market power, and financing power. The remainder of this section shows briefly how this categorisation was inspired by the Asian driver debate.

Production Power

This is the bedrock of the Asian driver debate. More generally, it is enshrined in the popular notion of China becoming the "workshop of the world". The fast build-up of production capabilities across many industrial sectors in China has had significant external effects. Much attention has been given to how Chinese exports challenge the competitiveness of producers in other countries' home markets and export markets (e.g. Jenkins and Barbosa 2012).

Coordination Power

It is well known that the power of some Western lead firms is not necessarily based on production power but on their ability to set the terms under which suppliers of inputs operate. Such coordination power is no longer limited to the West (Enright, Scott, and Chang 2005). For example, the Hong Kong-based company Li & Fung, Ltd., has become one of the world's leading supply-chain coordinators, particularly in textiles and garments. We will examine the relevance of such coordination power in China's wind power industry and the competitive implications.

Innovation Power

While the build-up of China's production capabilities is uncontested, it is less clear whether China is also succeeding in building up significant innovation capabilities. Altenburg, Schmitz, and Stamm (2008) show that China and India have embarked on the transition from production to innovation and that the breakthrough is uneven: Cutting-edge innovation remains rare, but adaptive innovation is significant for an increasing number of sectors. Many other studies carried out since then have confirmed that the picture is highly varied between and within sectors. In the case of the wind energy sector, we will examine whether China has acquired innovation power.

Market Power

The preceding three categories were identified in the early stages of the Asian driver debate (Schmitz 2006). It was only later that the importance of another category was recognised: the size and rapid growth of China's home market and the demand it creates for producers located both inside and outside its borders (Kaplinsky and Farooki 2011). This has become increasingly acute as many Western markets have stagnated. Questions arise as to how such market shifts affect investment decisions of private firms, how the host government seeks to influence decisions of different types of private investors, and how value chains are reorganised. As we shall see, China's market power is particularly relevant in the wind power industry.

Financing Power

From the beginning, the Asian driver debate has focused attention on the role of finance (Gottschalk 2006; Griffith-Jones 2004). Much of this debate was concentrated on how China's official financial flows helped to sustain the US current account deficit. The Chinese public sector invested heavily in US treasury bonds, which helped to sustain US growth and global dynamism – until the financial crisis of 2008. This crisis exposed the fragility of the Western financial system and underlined the financial strength of the Chinese economy. Jacques (2009: 585–589) provides a succinct analysis of the macro-economic implications. The present paper, on the other hand, is more concerned with China's relevance for a particular sector, the wind power industry. What does

having deep financial pockets mean for China's role in the global wind power industry? This is particularly relevant in wind energy generation since it requires huge upfront investments, and the Chinese and Western capacities for financing such investments have gone in opposite directions.

In conclusion, this paper asks how China is presently reshaping the global wind power industry. Since this is the kind of question which the Asian driver debate specialised in tackling, this section has asked what corridors of influence were identified during that debate. We have captured these influences in a fivefold categorisation of power which will in turn structure the analysis of this paper.

Applying these five categories is a tall order, since the Asian driver literature does not operationalise them. We will, however, use them to structure the paper; they can be grasped intuitively, and they help us to unpack the "China effect". Our task here is to examine their relevance for a particular sector.

This paper will examine the effect of China's rise on the global wind power industry. Our empirical analysis is based on the usual secondary sources – academic and business literature – and on field work conducted in the second half of 2010 in China and Europe (Germany and Denmark). In these countries, we conducted a total of 30 key informant interviews. Most of these were with firms in the value chain: utility firms, turbine manufacturers and component suppliers. We also interviewed representatives and informants from government institutions, research institutions, consultancy firms and business associations in both China and Europe. In this paper we distil some of the findings set out in more detail in Lema et al. (2011).

Wind Energy Value Chains

A number of studies have examined the wind industry in China in relation to the rest of the world (e.g. Conrad and Meissner 2011; Recknagel 2010; *Nature* 2009; Han et al. 2009). They provide insights on many dimensions but relatively little information on the issues we concentrate on here. For our purposes it is therefore useful to examine the wind industry in a value-chain framework because it invites questions about issues raised in the previous section. It has the added benefit of entailing a demand-oriented rather than supply-oriented approach. This matters for our paper because the strong growth of Chinese demand (compared with

weak growth in Europe) is the single most important factor changing the dynamics in the global wind industry. We therefore first discuss how the value-chain approach helps us to understand these dynamics and explain the nature of the wind value chain.

Value Chains and the Dynamics of Change

The value-chain approach starts with the end market. It asks what is required to compete in this market, how the chain supplying this market is organised, and which players define the parameters that influence how other firms operate (Gereffi 1999). This approach helps clarify how the market influences organisation and location of production and innovation (Kaplinsky and Farooki 2010). A clear understanding of the size, growth and nature of final markets is the starting point.

This is not to suggest that demand is the only factor to be considered. Dynamics in an industry change for two main reasons. First, the lead markets change over time. Recent years, for example, have been stamped by market saturation and economic crises in rich countries and market growth in emerging economies (Kaplinsky and Farooki 2010; Altenburg 2008). Second, new lead firms gain capabilities that increase their options and reduce their dependence on established markets and sources of technology. Suppliers may start to cooperate with new lead firms, and this may alter the power balance in "established" value chains (Humphrey and Schmitz 2002). It is the relative change in capabilities and economic power – both horizontally between lead firms from different countries and vertically within value chains – that determines the geographical distribution of competiveness, jobs and rents (Altenburg 2006).

These insights matter for an understanding of the wind industry, because markets of the rich countries are large but stagnant and markets of poorer countries are small but growing rapidly. Global industries are restructuring as a result. Which lead firms and countries gain – or lose – depends to a considerable extent on the mobility of the various parts of the value chain. That is why we need to explain the composition of the wind power value chain.

Manufacturing and Deployment Chains

The wind energy industry consists of firms which are part of two distinct, though interconnected, value chains: (a) the manufacturing chain

concerned with designing, producing and assembling the key equipment and (b) the deployment-services chain concerned with all aspects related to deployment and utilisation, including pre-project financing and post-project operation and maintenance. Lema et al. (2011) set out the manufacturing and deployment chains and their various elements in greater detail.

It is the turbine manufacturers and suppliers in the manufacturing chain who have so far driven increases in flows of trade and foreign direct investment (FDI). Dominant firms – from China and Europe in particular, but also from the US and India – compete head to head for market shares. By comparison, firms in the deployment chain – such as utilities, wind park construction firms, operation and maintenance (O&M) providers and technical consultancy firms – are less globalised (Lema et al. 2011; Kirkegaard, Hanemann, and Weischer 2009).

Due to the low level of globalisation in the deployment chain we focus on the manufacturing chain in particular. Turbine producers are usually responsible for overall wind turbine design and undertake assembly of the turbines. The latter accounts for approximately 20 per cent of the overall added value. The producers are called turbine "manufacturers" although, as we will show later, they are vertically integrated to different degrees with many components produced by external suppliers. Key parts (in terms of cost) are towers, blades, gearboxes and power converters, but a turbine is made up of more than 8,000 different components. Many component suppliers have adopted follow-sourcing strategies: They situate themselves in close proximity to the overseas operations of turbine firms. We will also show how some of them have become global suppliers with operations across different continents. We go on to demonstrate how firms in the manufacturing chain are now beginning to bring along with them elements of the deployment chain. This regards not only post-project O&M services but also financing services that make new projects possible.

The Role of Government

A salient feature of the wind power industry is that governments around the world play an important role in determining locational patterns. This is due to the fact that wind energy is not yet able to compete with conventional energy sources on a pure market basis (although the gap is closing rapidly). The industry is dependent on investments in green transformation – and corporate activities follow the government-led

creation of wind energy demand (Kirkegaard, Hanemann, and Weischer 2009).

Government policies play an important role not only in creating markets but also in influencing the nature of global value chains. The wind industry is dominated by lead firms which undertake local production in proximity to the main markets. International trade is only a supplement to flows of foreign direct investment. In combination with high transportation costs, this is due to government policies that favour local production and the associated creation of green jobs (Lema et al. 2011).

All five types of economic power discussed in this paper are influenced by government policy, although in different ways and in different policy arenas. The important role of the state in the Chinese "wind miracle" has been shown in the existing literature (Li, Hubacek, and Siu 2012; Liao et al. 2010; Klagge, Liu, and Campos Silva 2012), including studies of the role of the Chinese government in shaping international competition (Zhao et al. 2012; Conrad and Meissner 2011). Subsequent sections of this paper refer to the influence of the different policies, but our main aim is not to specify the role of government in strengthening this industry but to show the different types and implications of Chinese economic power in the wind industry.

The Rise of Chinese Market and Producer Power

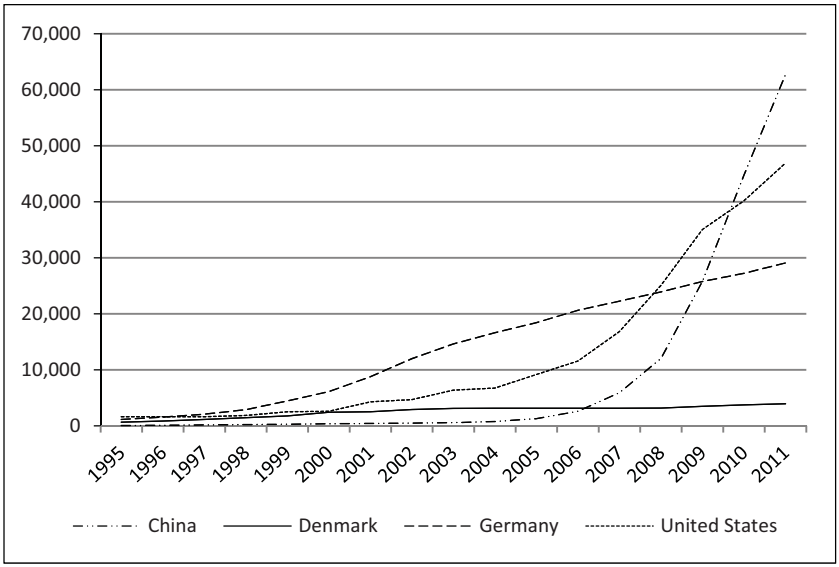
In the previous section we argued that quantitative and qualitative changes in demand have had a significant impact on the structure of global value chains. Such a reconfiguration of global value chains is currently visible in the global wind industry. It is the result of the rise of China as a wind power market and the closely related rise of China as a wind power producer.

The Rise of China as a Wind Power Market

The global demand for wind power is shifting to the East. European countries and the US have long been the dominant markets in the previous phase of development in the global wind power sector. However, as a result of the financial crisis that started in 2008 and the saturation of market demand for onshore wind power in Europe and the US, demand for new wind capacity has slowed, even for offshore deployment.

In 2010, for the first time, more than half of newly installed wind power capacity was added outside these traditional markets. China has been the main driver of this development. Within only half a decade, China has managed to build the largest market for wind power in the world (see Figure 1).

Figure 1: Cumulative Installed Wind Power Capacity, 1995–2010 (in MW)



Sources: Earth Policy Institute 2010; WWEA 2011.

In 2005, China's wind power capacity was 1.26 gigawatt (GW), accounting for 2 per cent of the world market. Between 2005 and 2009, total installed capacity in China more than doubled each year. In 2010 the Chinese wind power market still grew at a rate of more than 60 per cent compared to 2009, and China ranked number one in terms of installed capacity with 42.28 GW, or 22 per cent of global capacity.

The rapid expansion of wind power capacity in China is mainly a result of favourable government policies. These policies have created an internal market for wind power which would not have developed otherwise: The cost of generating wind power is still higher in most Chinese locations than that of fossil-fuel-based energy.

The main push toward expanding the Chinese wind market thus came from a reorientation of the Chinese government toward wind energy. The main law supporting the shift toward a low-carbon energy system was the Renewable Energy Law adopted in 2005 and amended in 2009. Its aim was to increase the share of renewable energies, wind in particular, in China's energy mix as well as to support the domestic renewable energy industry (Li, Shi, and Hu 2010). The amendment of 2009 requires grid companies to purchase a certain proportion – specified by further regulations – of renewable energy and empowers government agencies to enforce this target through a penalty system.

One of the most important pieces of legislation divides the market into a two-tier system of "small" and "big" projects. If the installed capacity of the projects is below 50 megawatts (MW), it is subject to provincial government approval and monitoring. Projects above 50 MW are regulated by the National Development and Reform Commission (NDRC). The NDRC-led concession programme has a range of specific criteria such as minimum turbine size. The central government introduced the concession model in 2003. It included a bidding process for wind farms selected by the NDRC. In the first four years of the concession model, the developer who offered the lowest price for the installed capacity would win the bid.

The effect of this model was that the emphasis was put on the deployment of wind power capacity rather than the actual production of energy. The concession model resulted in an intense competition with winning bidding prices often being below the prices necessary to ensure the economic profitability of the wind farm (Li and Hu 2007). In effect, the large state-owned power companies often succeeded in these bidding wars since they were able to cross-subsidise their investments in wind parks in order to meet mandatory market share requirements and promote their "green" image towards the government (Recknagel 2010; Han et al. 2009). The concession model was revised in 2007. Instead of selecting the cheapest offer, the new criteria involved the average bidding price: the bidder who offered the median of all offers would win the contract (Recknagel 2010). Displacing the tendering procedures, the NDRC introduced a national feed-in tariff system in 2009. This system offers a long-term investment framework with a tariff of roughly 0.5 to 0.7 CNY per kilowatt-hour that is set for 20 years. The tariff varies depending on the location of the project in four geographical regions which have different wind resources (Li, Shi, and Hu 2010: 46).

The Chinese government has experimented with different ways of promoting wind energy, and has had varying degrees of success, as discussed above. In the end, these favourable policies have driven the growth of the Chinese market and triggered a major reconfiguration of the global demand for wind power generation capacity. This increase in aggregate global demand notwithstanding, the main impact of the rise of the Chinese market relates to the type of demand. While the policy emphasis is now changing, the framework has (so far) concentrated on increasing installed capacity and low turbine and deployment costs, rather than on energy output. This has created a specific demand pattern which has had important ramifications for business development and power structures on the supply side.

The Rise of China as a Wind Power Producer

Until the end of the first decade of the 2000s, the global wind turbine industry was dominated by companies from Europe. Since then, Chinese turbine manufacturers have been able to benefit from national policies and acquire substantial global market shares. The rise of Chinese wind turbine producers results, first and foremost, from their deployment in the Chinese market. However, due to the significance of the Chinese markets, the names of Chinese producers also figure prominently in global statistics. One of the reasons why the Chinese wind turbine industry has been able to develop so fast is that firms have grown out of other segments of the diverse industrial base. The leading firms emerged out of large heavy-machinery manufacturers and utility firms that had capabilities in key fields related to manufacturing as well as in large-scale project management for deployment. Almost all segments of the wind power value chain have been localised in China. The strength of the Chinese wind power value chain comes from the manufacturing segment. There is now an effective supply base catering to all elements of the manufacturing value chain.

In addition to the demand-side support policies of the Chinese government discussed earlier, one of the key initiatives supporting the development of a Chinese wind power industry was a "local content" requirement. This policy, enacted in 2003, facilitated the localisation of large parts of the value chain. Although some authors argue that R&D support and funding for demonstration projects are currently insufficient (Li, Shi, and Hu 2010: 78), the Chinese government also provides support for technological development – as will be shown later.

Table 1: Global Top-Ten Turbine Manufacturers, 2005 and 2010

2005			2010		
Company	Share (%)	Origin	Company	Share (%)	Origin
1. Vestas	27.90	EU	1. Vestas	14.8	EU
2. GE Wind	17.70	US	2. Sinovel	11.1	CN
3. Enercon	13.20	EU	3. GE Wind Power	9.6	US
4. Gamesa	12.90	EU	4. Goldwind	9.5	CN
5. Suzlon	6.10	IN	5. Enercon	7.2	EU
6. Siemens	5.50	EU	6. Suzlon	6.9	IN
7. Repower	3.10	EU	7. Dongfang Electric	6.7	CN
8. Nordex	2.60	EU	8. Gamesa	6.6	EU
9. Ecotécnia	2.10	EU	9. Siemens WP	5.9	EU
10. Mitsubishi	2.00	JP	10. United power	4.2	CN
Others	5.00		Others	17.5	

Note: World market shares.
Source: BTM 2006, 2011.

The rise of China as a wind power producer is reflected in the changing pecking order of global lead firms. The period of most rapid change was from 2005 to 2010. Table 1 shows clearly the size and speed of change. While there was no Chinese firm in the top 10 in 2005, there were four by 2010. The leading Chinese firms Goldwind (2006), Sinovel (2007), Dongfang (2009) and United Power (2010) made their way onto the top-ten list during this period. This meant that the Chinese wind power industry collectively had higher sales than those of any other nation by 2010. As shown in Table 1, Sinovel ranked second in the world (11.1 per cent global market share), Goldwind fourth (9.5 per cent), Dongfang seventh (6.7 per cent) and United Power tenth (4.2 per cent).

There are also a number of other significant Chinese players operating just below the top-ten radar. These include Mingyang, Sewind (Shanghai Electric), XEMC, A-Power and Envision. The total number of Chinese turbine manufacturers is to the order of 80 to more than 100, although not all of these produce commercially available turbines (Lewis

2011; Meyer 2010). The rapid expansion of the Chinese wind turbine industry over recent years has resulted in a substantial overcapacity, which has also been a concern of the Chinese government.

Global Implications of Chinese Market and Producer Power

This section asks how the rise of Chinese market and producer power influenced the dynamics of the global wind energy industry. The rise is widely acknowledged (GWEC 2011; Li, Shi, and Hu 2010), but the ramifications for global change in the industry are not well established.

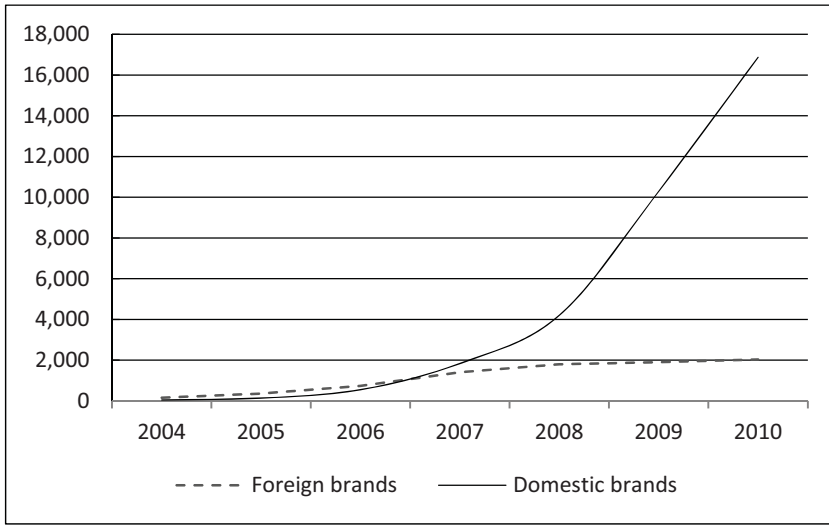
Global Lead Firms in the Chinese Market

China is pushing other countries to respond to its rapid expansion and increasing competiveness in the wind energy industry. In order to understand this effect, we first examine investment in the Chinese market by global firms and then those of Chinese firms in global markets.

Until 2005, the Chinese wind power market was largely dependent on foreign technology produced by subsidiaries of foreign, mainly European, turbine manufacturers. These firms accounted for 70 per cent of the Chinese market in 2005. Procurement practices and the government's local content requirement meant that within half a decade China managed to build up a national turbine manufacturing industry that now delivers 85 per cent of the turbines installed in China in 2009 (Li, Shi, and Hu 2010: 37). The shift in market sales between local and foreign producers is displayed in Figure 2.

The loss of market shares of foreign turbine manufacturers over the last few years is at least partly explained by the dual market structure described in the previous section. Chinese and foreign companies have only been competing in the "provincial" markets for turbine parks below 50 MW due to the national procurement specifications and the national innovation accreditation policy, which gives preference to domestically owned technology. Nevertheless, in absolute terms the global (read: foreign) players have continued to grow (slowly) due to sales to these smaller (below 50 MW) projects. They have succeeded in doing so despite the fact that their upfront prices are typically higher than those of domestic Chinese manufacturers (BTM 2008).

Figure 2: Cumulative Installed Capacity of Domestic and Foreign Brands in China, 2004–2010 (in MW)



Sources: BTM 2008, 2011; Meyer 2010.

While large Chinese wind turbine manufacturers benefitted greatly from preferential policies adopted at various levels of governance, the crowding out of global manufacturers is also explained by substantial differences in turbine prices. In 2006, when the domestic segment took off, the turbines were typically priced 15 to 20 per cent lower than their foreign counterparts. By 2010, the price gap had increased to more than 27 per cent (BNEF 2010: 9).

However, many observers agree that Chinese companies can rarely compete with foreign, particularly European, competitors with regard to adaptability (design skills for turbine customisation) and reliability. In many new growth markets, however, global firms may find it difficult to compete, because attention is paid mainly to price.

Maintaining a strong presence in China has been a priority for leading foreign firms, since they expect continued demand in future, even though the market is crowded at present. There is also agreement in general and among Chinese policy-makers that China will need to give more emphasis to quality as the sector matures, and that foreign manufacturers and suppliers will play an increasingly important role.

For foreign-owned component suppliers, the new growth potential lies in working for Chinese turbine manufacturers. For example, European suppliers have established subsidiaries which provide small, specialised components and services in fields such as electric control systems, hydraulics, and oil filter systems and gears. These suppliers are growing more important as the Chinese manufacturers seek to upgrade the quality of their products. In a few cases, there are also alliances for producing large components; for example, the European blade supplier LM is working with Goldwind, Sinovel, Dongfang and Envision. Thus in contrast to foreign turbine producers, many foreign component suppliers are gaining market shares in China.

In summary, the combination of a rapidly growing market in China and a slowly growing market in Europe has forced the traditional leading European makers of turbines and components to concentrate their efforts on the Chinese market. While Chinese regulations continue to favour Chinese firms, European firms in China have thus been able to grow more in the area of components than in the complete turbine market.

Chinese Lead Firms in Global Markets

We saw in the previous section the rapid change in the global pecking order of turbine manufacturers (Table 1). By 2010, four of the world's ten largest manufacturers were Chinese, compared with none in 2005; moreover, these four provided 32 per cent of global installed capacity that year. While this was primarily due to rapid expansion on the Chinese domestic market, it is expected that the large Chinese wind turbine manufacturers, just like their European and North American competitors (and the Indian company Suzlon), will increasingly try to sell their turbines abroad.

Before 2008, no Chinese turbines had been installed in any country outside China. In recent years, however, some leading Chinese firms have begun to gain and exploit export experience and will soon most likely challenge US and European manufacturers. Turbine prices have recently fallen below 1 million EUR per megawatt for the first time since 2005 (BNEF 2010). Competition from Chinese firms with low production costs is likely to put pressure on European and North American firms in the near future (Prideaux 2011). It is therefore likely that Chinese firms will set up manufacturing plants in new markets outside China. Like established global lead firms, Chinese firms are likely to com-

bine local production and trade, with an emphasis on the former over the latter. They will use market-proximate facilities to produce the many components that incur high transportation costs (and/ or are subject to political barriers to trade) while shipping other elements from their Chinese factories.

Table 2: Wind Turbine Exports and Contracts of Selected Chinese Firms

Company	Year	Destination	Units	Unit Type	Volume (in MW)
A-Power	2010	US	1	2.05 MW	2.0
A-Power*	2011	US	240	2.05 MW	600
Dongfang*	2012	India	166	7.5 MW	N/A
Goldwind	2008	Cuba	6	750 kW	4.5
Goldwind	2009	US	3	1.5 MW	4.5
Goldwind	2010	Cuba	6	750 kW	4.5
Goldwind	2011	US	69	1.5 MW	109.5
Goldwind	2011	Ethiopia	34	1.5 MW	51.0
Goldwind	2012	Chile	N/A	1.5 MW	105
Goldwind	2011	Ecuador	11	1.5 MW	16.5
Goldwind*	2012	Australia	73	1.5 MW	165
HEAG	2010	Chile, Belarus	3	N/A	4.5
Ming Yang	2010	US	1	1.5 MW	1.5
Ming Yang*	2012	India	N/A	N/A	250
New Unite	2009	US, Thailand	2	1.5 MW	3.0
Sewind	2009	UK	3	1.25 MW	3.75
Sewind	2009	Thailand	2	1.25 MW	2.5
Sinovel	2009	India	10	1.5 MW	15
Sinovel*	2012	Greece	N/A	N/A	300
Sinovel*	2012	Turkey	N/A	N/A	600

Note: * announced contracts.

Sources: CCB International 2011 and authors' compilation.

The deployment of Chinese turbines in foreign markets has been modest so far. Chinese exports from 2010 to 2012 are shown in Table 2. Goldwind started exporting to Cuba in 2008, and in 2009 sold three turbines in the US. The firm has recently established a wholly owned subsidiary in Chicago, seeking to address a US market dominated by General Electric (GE). It was the first Chinese manufacturer to sell turbines outside of China (Zeller and Bradsher 2010). This was preceded by the firm's buying up a production base in Germany (Vensys) and setting up a subsidiary in Australia.

Sinovel has declared its goal of becoming the largest turbine maker in the world by 2015, with half of sales going to foreign markets. Based on sales, Sinovel was already the second-largest turbine firm in the world in 2010, just behind Vestas. Even though its export figures are still small, this initial export experience has marked a change in the company's ambitions and outlook. The US market will be particularly important for it, but the European market is also likely to be targeted. In 2011, Sinovel signed a strategic alliance agreement with the Greek utility firm Public Power Corporation (PPC) to develop both onshore and offshore projects over the coming years, and assembly and generator manufacturing plants in Greece are currently under construction. Importantly, Sinovel will invest around 450 million EUR not only to build power parks but also in the form of project financing for jointly developed projects. This is the company's second major European initiative, following an agreement signed with Mainstream Renewable Power of Ireland for new projects amounting to 1 GW of installed capacity. According to *China Daily* (Li 2012), wind turbine exports from China amounted to 222 million USD in 2011.

Market-differentiated Dynamics

We have seen that changes in the global wind power industry, which formerly were mainly instigated in Europe, are now increasingly coming from China. The Chinese market is geared to continued growth, but a big influx of new players from Europe and from within China has also resulted in substantial overcapacity. The Chinese market is likely to see some consolidation through mergers and acquisitions in the coming years. This is also likely to happen in the global industry. We expect that Chinese firms will seek to acquire substantial shares in European firms. There is already evidence that this is starting to happen. For example, the Chinese firm Titan Wind Energy recently acquired Vestas' towers factory

in Denmark and thereby established a production capacity in Europe. Goldwind has acquired a majority stake in the German turbine design house Vensys, while XEMC has acquired Dutch Darwin, also a design house. Such acquisitions are likely to strengthen the competitive position of Chinese firms. Even as the maturing Chinese wind-energy sector gives more emphasis to quality, however, there is likely to be decreasing tension, since there will be a more important role to play for foreign firms in Chinese markets. It is now becoming apparent that foreign firms in China are increasingly localised, with little content shipped in from overseas, and that European turbine firms are sourcing from Chinese as well as international suppliers.

In third markets, there has been less of a trade-off so far. The European market is currently dominated almost exclusively by European firms. However, this has begun to change. Chinese firms are likely to bid for overseas projects in the future. In Europe, there is already significant competition among firms from different countries, and this competition will intensify as Chinese firms manage to throw in different price equations, consortia models, and financing options. Whether global lead firms will seek to lower costs via innovation or will prefer to compete in terms of quality rather than price remains an open question.

Chinese and global companies will also compete head-to-head in other markets. It remains to be seen whether and how Chinese firms and established players will develop a geographical and/ or technological division of labour. One hypothesis is that by increasing the global wind market and driving down prices, China will help wind power to become more affordable and credible overall. This will help create new markets in rapidly growing economies such as Brazil, South Africa, India and Indonesia.

The key point is that the competitive dynamics vary between markets with different demand characteristics. The contrast in this sector is primarily between (a) the fast-growing markets of China and some other emerging economies, which are segmented according to high and low quality, and (b) the relatively static, homogeneous, high-quality markets of the EU and other OECD countries. To this we may add (c) the small markets of developing countries such as Ethiopia (where Sinovel recently completed a substantial project), which are likely to have low-cost demand preferences and create opportunities for Chinese players.

Coordination, Innovation and Financing Power

As shown in the previous section, the combination of Chinese market and producer power is now apparent. We argue in this section that less-apparent changes will be equally important in the longer run. New corridors of influence (coordination, innovation and financing) are likely to have a significant impact on the global wind power industry in the years to come. In this section we therefore set out these new corridors of influence and discuss their nature and the extent to which they will reinforce the global changes.

The Emergence of Chinese Coordination Power?

Chinese turbine firms share distinctive features. Compared to the technologically leading European manufacturers, for example, Chinese turbine manufacturers are less vertically integrated, with relatively few components manufactured in-house. With regard to the supply base, a broad network of Chinese suppliers has emerged to produce components like blades, transmission, towers and gearboxes on a large scale within China. Until 2007, Chinese wind turbine manufacturers were almost entirely dependent on the import of bearings and electronic control systems (Li and Hu 2007: 17), but this has changed due to increased investment in this segment (Schwartz and Hodum 2008). More than 250 suppliers in China now produce all key components such as control units, power electronics, gearboxes and so forth (Meyer 2010). The relationship between domestic turbine firms and key component suppliers shows a very high degree of supply-base sharing (Figure 3).

Depending on turbine type and size, 70 to 95 per cent of turbine assembly in China can be met by domestic components (Meyer 2010). Only a few high-tech components are sourced from global suppliers based in China or suppliers in Europe or the US. Firms such as Goldwind and Sinovel tend to sign long-term cooperation agreements with international component suppliers such as LM, Windtec and Mita Teknik. As will be shown later in more detail, the similarity in Chinese turbine designs (partly arising from design licensing) makes supply-base sharing easier and this, in turn, increases the economies of scale of the industry. The strong component supply chain that has emerged in China is also increasingly used by international firms that try to increase their cost competitiveness by sourcing from Chinese component suppliers.

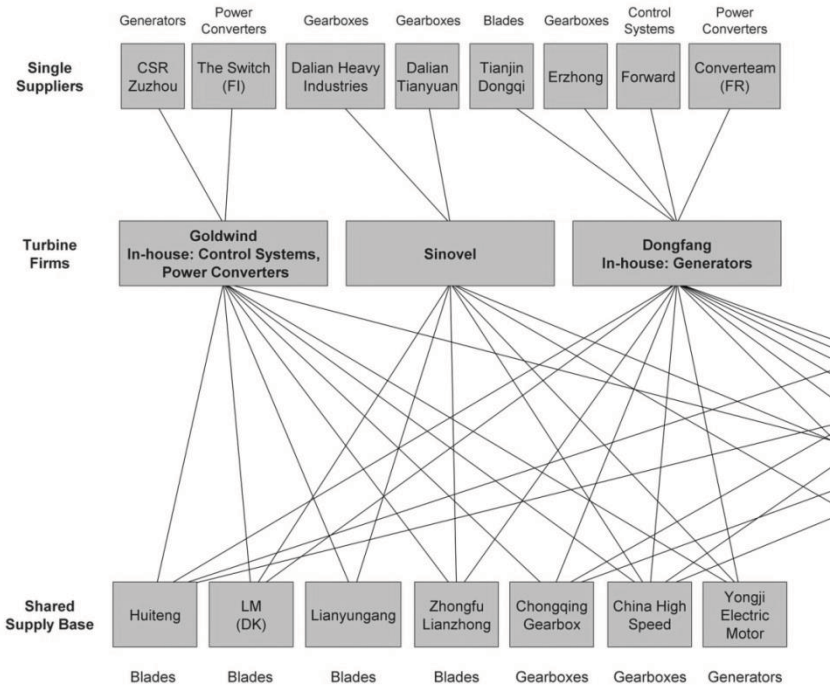
The competitiveness of the Chinese wind power industry thus depends greatly on the mode of governance of the entire manufacturing value chain. The supply-chain relations described here constitute a "Chinese model" of organisation. In terms of value-chain governance, the Chinese wind turbine industry resembles a flexible "modular" value-chain structure where relationships are typically short-term and competition amongst substitutable suppliers drives down costs (Gereffi, Humphrey, and Sturgeon 2005). This contrasts with the European model (e.g. Vestas), in which (as of now) the majority of components are produced in-house, and long-term relations exist with the suppliers of remaining components.

Modularity in the Chinese turbine industry has two main sources. First, turbine production has largely been based on a limited number of licences from European design houses or smaller turbine firms; these included licences for "mature" turbine designs that were a few years behind the technological curve (Lewis 2007). Moreover, many European and North American design houses have licensed out models to more than one firm. The fact that Chinese turbine firms often use similar or shared designs implies an increased potential for achieving economies of scale in the component supply base.

Second, there has been relatively little need for customisation and fine-tuning of turbines for particular conditions due to the narrow policy focus on installed capacity rather than actual electricity generation effectiveness. In general, Chinese firms have a smaller range of turbine models than their European rivals, along with a large base of shared suppliers who produce the needed components. This explains the enormous speed at which turbines have been installed without running into major problems of component shortages.

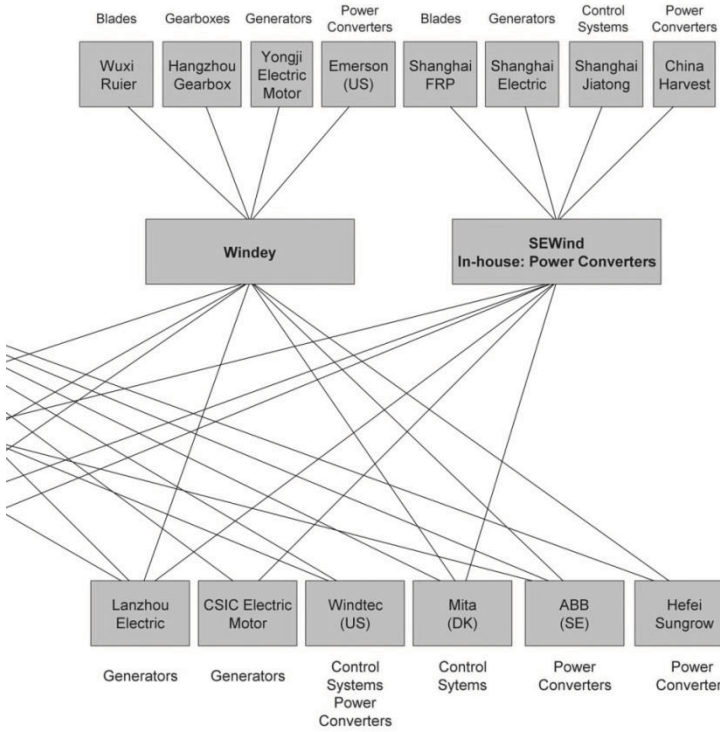
In order to make effective use of this modular supply chain, the lead firms in China need to develop new coordination capabilities. Developing these capabilities and making use of their coordination power is essential for achieving the high speed and low cost that make China competitive. While initially developed on the national market, the coordination capabilities increasingly count also on the international market. For example, a value breakdown of a Sinovel 3 MW turbine installed in the US, showed that more than half of it (blades: 23 per cent, gearboxes: 13 per cent, other components: 10 per cent) was sourced from firms originating in China (BNEF 2010). On the other hand, the higher quality requirements overseas imply that Chinese turbine makers will have to

Figure 3: The Top-Five Chinese Turbine Manufacturers and Key Component



Source: Data from BTM 2008.

Suppliers


Blades
Gearboxes
Generators
Power Converters
Blades
Generators
Control Systems
Power Converters
Wuxi Ruier
Hangzhou Gearbox
Yongji Electric Motor
Emerson (US)
Shanghai FRP
Shanghai Electric
Shanghai Jiatong
China Harvest
Windey
SEWind
In-house: Power Converters
Lanzhou Electric
CSIC Electric Motor
Windtec (US)
Mita (DK)
ABB (SE)
Hefei Sungrow
Generators
Generators
Control Systems
Power Converters
Control Sytems
Power Converters
Power Converters

forge relationships with global suppliers. Goldwind recently signed a long-term supply deal with a number of large European and international component suppliers – including LM (blades), The Switch (power converters) and Timken (bearings) – in order to cultivate a global supply chain. This is an element in the drive to explore the overseas market. Utilising a combined Chinese and international supply base – and creating a strong cost-quality combination – means that China is developing competitive advantages that are attractive outside China. This will therefore have an important impact on global competition in the wind market.

Is China Becoming an Innovation Power in the Wind Industry?

One of the main conclusions from the previous sections is that China is catching up with the old leaders in wind power. Whereas China needed 30 years to reach a world-class level of production in other sectors such as electronics (Ernst 2009), it was able to close the gap in wind power production capability in only ten years. Only very recently, however, has it begun to catch up in innovation capability as well.

International technology transfer has been an important source of technological capacity in wind turbine development in China. The option of tapping into the established design and engineering capabilities of overseas firms has been key to the Chinese success story (Lewis 2007, 2011). Licensing agreements have been an effective means of gaining a foothold in the industry and have established a basis for innovative improvements of the transferred technology.

In the last few years, the "technology transfer mechanisms" have shifted from traditional mechanisms (such as FDI, trade and licensing) to non-traditional mechanisms such as joint design, R&D collaboration and overseas R&D units (Lema and Lema 2012). At the same time, lead firms have begun to shift their own innovation activities to China. For example, Vestas opened its first Chinese R&D centre in Beijing (a 50 million USD investment) in 2010 to undertake work in areas such as high-voltage engineering, aerodynamics, and material and software development.

Our research shows that Chinese turbine manufacturers have adopted innovation strategies that combine internal development with heavy reliance on external knowledge sourcing (Lema and Lema 2012; Lewis 2011). The main driver of this strategy seems to have been the organisational decomposition (Schmitz and Strambach 2009) of the in-

novation process. Most importantly, smaller turbine design houses have made their technologies and services readily available on the market. This has opened up opportunities for engaging in turbine design licensing and overseas R&D collaboration with other firms. However, the change was also driven from within the Chinese companies, particularly by creating R&D subsidiaries through acquisitions of overseas firms but also through the establishment of R&D subsidiaries in established knowledge clusters. This strategy seems to have been effective, helping Chinese companies to build up their innovation capabilities quickly. The fact that the process has been driven from within the Chinese companies is noteworthy. It contrasts with our finding that Western lead firms in the automobile and software industries were driving the process through FDI offshoring and outsourcing of R&D and D&E (design and engineering) to emerging markets (Lema et al. 2012). Such a relocation of innovation by Western lead firms is now picking up in the wind power sector, but it was not a main cause of innovation capability in domestic Chinese firms. Rather, it was the Chinese lead firms' own decomposition strategies that contributed most to the changing global distribution of technological innovation capacities in the manufacturing segment of the wind power industry.

Table 3 shows licensing links between Chinese firms and European design houses. Many of these licensing arrangements have gradually turned into co-design relationships. It shows companies involved in new turbine development and examples of such co-design relationships. In addition to co-design, Chinese manufacturers have in some cases bought up complete engineering bureaus in order to enhance their internal technological design capacities.

Despite the decomposition trend, the bulk of Chinese innovation in the wind sector still takes place within the R&D departments of large, established Chinese companies. Sinovel, for example, reportedly has more than 600 people working on R&D, where efforts typically address increases in turbine size, cost reduction, and wind power products tailored to future offshore markets.

Such internal innovation efforts are buttressed firmly by state support. For example, the Chinese government has stipulated that turbine manufacturers should aim to acquire orders for turbines bigger than those of overseas competitors – not least for the offshore market. To support this, R&D expenditures on big turbines are earmarked for VAT refunds (Lema and Lema 2012).

Table 3: Links between Foreign Design Firms and Chinese Turbine Firms

Design House	Chinese Firms
Aerodyn (DE)	Haizhuang, Huayi, Ming Yang, Sewind, United Power
DeWind (DE)	Beizhong, Sewind
Fuhrlander (DE)	Sinovel, A-Power
Norwin (DK)	A-Power
REpower (DE/IN)	Dongfang Electric, Goldwind, Windey
Vensys (DE)	Goldwind
Windtec (Austria, US)	Sinovel, Jingcheng, Sinovel, Zhuzhou, Dongfang, Shenyang, ZELRI

Sources: CCB International 2011 and authors' compilation.

Table 4: New Turbine Development

Turbine	Company	Design	Prototype	Serial production
3.0 MW	Sinovel	Sinovel and AMSC	2009	2010
3.0 MW	Goldwind	Goldwind	2009	2010
3.0 MW	Ming Yang	Ming Yang and Aerodyn	2010	–
3.6 MW	Shanghai Electric	Shanghai Electric	2010	–
5.0 MW	Sinovel	Sinovel and AMSC	2010	–
5.0 MW	Dongfang	Dongfang and AMSC	2012	2013
5.0 MW	XEMC	XEMC Darwind B.V.	2010	2011
6.0 MW	Sinovel	Sinovel	2011	–
6.0 MW	Goldwind	Goldwind-Vensys	2012	–

Sources: Azure International 2010 and authors' compilation.

The question of whether China is becoming a technology leader in this industry is controversial. Some argue that China's rapid technology catch-up has been based on its licensing of foreign technology, question-

ing whether China can innovate on its own. Our research indicates that indigenous technological capability is growing rapidly in China, but that the real innovative power lies in business-model innovation.

Inter-company relationships are central to the Chinese model: Lead firm–supplier relations buttress a flexible low-cost industry structure, and links to technology suppliers complement in-house expertise. Chinese firms do not seek to "go it alone" in technology development. Instead, Chinese lead firms seek to develop turbine technology in cooperation with foreign partners. This may prove just as effective as a technology strategy that prioritises independent in-house development. Chinese firms are now working with overseas partners on turbine prototypes that are just as advanced as those being developed by firms in the West.

Financing Power: Strategic Advantage?

We deal with financing power last because it is the area that has been least explored; data concerning it is limited, and it raises more questions than it answers. But it could well represent China's main strategic advantage.

As mentioned earlier, the Asian driver debate gives substantial attention to major shifts in global financial power, but does so primarily at the national level of "China becoming the banker of the US". The present paper, on the other hand, is concerned with the sectorial level, for which the issues have rarely been elucidated. Doing so, however, is important – particularly with regard to a renewable energy sector like that of wind power. The investment requirements are high, and the time frames are long. Being able to finance such investments is critical.

Project finance may become an important element of China's "mode of entry" into foreign markets. While the Western world is "strapped for cash", the Chinese government and Chinese companies are flush with funds. Sinovel, for example, has a 6.5 billion USD line of credit from government-owned Chinese banks (Zeller and Bradsher 2010). Other firms also have strong relations with Chinese financial institutions and have secured significant lines of credit for the purpose of expanding sales outside China. China Exim Bank has injected capital into Ming Yang and Goldwind to support its expansion into the US and the EU.

This opens up the possibility of an export model that has not been directly utilised by European firms – the twinning of wind farm project finance and turbine exports. Chinese manufacturing firms are thus indi-

rectly providing credit to projects that would perhaps otherwise not be financed by financial institutions in export markets due to the modest record of Chinese turbines to date. This financing element may thus help Chinese firms get a foot in the door in the US and European markets. Future research will be needed to tell us how relevant such project financing is. The relevance of supplier credit for China's competitiveness in the wind power sector is a particularly acute issue at the current time, when much of the Western world is suffering a credit crunch.

The differences in financing power might also help explain differences in governmental action. In order to promote the uptake of renewable energy, governments have provided financial incentives through feed-in tariffs and other instruments. In Western countries, governments have come under severe pressure to reduce such incentives in the course of prioritising financial austerity. This has slowed the growth of Western markets while Chinese markets have continued to grow rapidly. Since the Chinese market is not a level playing field, this has benefitted Chinese industry above all. Future research will be needed in order to determine the relevance of this differential in the government's financial room to manoeuvre. The question is how important it is for the growth of Western companies versus Chinese companies.

Conclusion

In recent years, China has been the driver of major changes on the global map of the wind power manufacturing industry. This paper has investigated whether China's transformative influence extends to the new green industries and has focused in particular on the wind power industry. Industrialists and politicians in the West often assert that green industry offers opportunities to re-establish pre-eminence in production and innovation.

In order to examine China's global influence in this industry, we have drawn on the Asian driver literature. The main lesson from this debate is that there is a need to distinguish among different corridors of influence. This led us to single out five categories of power which might also be useful for future research in other industries.

So far, the biggest influence in the wind energy sector comes from China's market power. While Western markets have been growing only slowly, China's (large) market has expanded rapidly. Western firms seek to operate in this market, but have been compelled to yield to govern-

ment-imposed conditions which favour Chinese producers. Benefitting from this protection, Chinese enterprises have been able to invest and learn very fast, attaining a level of producer power that has brought about major changes in the international pecking order of turbine makers.

While the combined impact of Chinese market and producer power is already visible in the global power industry, there are further ways in which Chinese lead firms are beginning to exert influence. While the extent of this influence is not yet clear, its sources are discernible: coordination power, innovation power and financing power. What is beginning to emerge is a Chinese competitive advantage based on the ability to combine high speed and low cost complemented with financial options that Western suppliers may find difficult to match. The greatest uncertainty is over innovation. Can China come up with new technologies that create new avenues for green transformation and reduce costs substantially?

While providing a differentiated assessment, this paper suggests a clear overall conclusion: China has already had a major influence on the global wind power industry, and this influence is likely to increase in the years to come. We cannot, however, conclude that these advances will all be in opposition to or at the cost of Western companies. The headlines which emphasise competition or conflict between Western and Chinese companies often fail to capture the complexity of the current situation. While competition among lead firms is increasing, there are also prospects for a growth of inter-firm collaboration all along the value chain (Lema et al. 2011). China, Europe and the world can benefit from such collaboration in order to reduce technological complexity, drive down costs, improve quality, and make wind power a more effective energy option for the world.

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