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Tackling Chinese Upgrading Through Experimentalism and Pragmatism: The Case of China's Wind Turbine Industry

Julia Kirch KIRKEGAARD

Abstract: This paper examines the development of China's wind turbine industry, shedding light on the Chinese mode of disruptive industrial upgrading through policy pragmatism and fragmented, experimental governance. Based on a historical analysis of China's wind turbine industry, the paper highlights three distinct phases, which are all marked by their own inbuilt and potentially self-disruptive impasses and associated crises. In turn, these impasses have forced the Chinese government into radical and flexible interventions, which have spurred on Chinese companies to creatively find new ways to develop and upgrade. The paper illustrates the transformation of Sino–foreign relations by China's non-linear upgrading approach, particularly during the Chinese wind power industry's quality crisis, and its development model. It also discusses the implications this examination of China's approach has for the literatures on China, upgrading, and catch-up. Finally, the paper calls on future studies to enquire further into China's distinct mode of industrial upgrading and its embeddedness in China's institutional context.

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Keywords: China, industrial upgrading, self-disruption, wind power, policy experimentation, pragmatic governance, fragmented authoritarianism

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Introduction

Within the last decade, China has emerged as the world leader in wind power, shaking up old competitive relations in the global value chain of the wind turbine industry (GWEC 2016; Kirkegaard 2015; Lewis 2013; Korsnes 2014; Lema, Berger, and Schmitz 2013; Chen et al. 2014; Mathews and Tan 2015). In 2015 China boasted an astonishing 33.6 per cent of global cumulative installations (GWEC 2016: 32). What is even more remarkable is the pace with which China has ascended within the global wind power scene. Following the influential 2005 Renewable Energy Law, China's installed wind power capacity grew from 0.8 gigawatts (GW) in 2004 to 145 GW in 2015 (GWEC 2016: 4). Furthermore, Chinese wind turbine manufacturers are increasingly becoming global lead firms. With China's emergence as a major force in clean energy development and as a potential green "saviour" of the world (Mathews 2016; Mathews and Tan 2015; Liu and Liang 2013), we need to better understand China's particular mode of clean energy upgrading and catch-up.

This paper[1] examines, on the one hand, how China – an authoritarian regime – has been able to upgrade and catch up in the field of wind power with such unprecedented pace and scale and, on the other hand, how and whether such rapid upscaling and upgrading has transformed Sino–foreign relations in the wind turbine industry. Previous research already sheds light on parts of this puzzle – for example, pointing to the central role of transforming industrial trends of China's integration into global value chains and global innovation networks (e.g. Silva and Klagge 2013; Chen et al. 2014; Lewis 2013; Lema, Berger, and Schmitz 2013), of innovative manufacturing (Nahm and Steinfeld 2014), and of the organisational decomposition of innovation processes (Lema, Haakonsson, and Kirkegaard forthcoming) in China's upgrading in Chinese wind power. Others have highlighted the institutional specificities and political embeddedness of Chinese wind power development by, for instance, pointing to favourable Chinese government policies (Kirkegaard 2015; Christensen 2013; Lema and Ruby 2007) and China's specific institutional conditions of decentralised fragmentation and centralised control together with policy experimentation and policy learning (Kirkegaard

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2015; Korsnes 2014), which have "been fundamental for policy flexibility and institutional adaptability" in China's wind turbine industry (Korsnes 2014: 175).

Despite these valuable insights, I argue that a more fine-grained understanding of some of the defining institutional conditions of Chinese industrial upgrading is still needed to truly comprehend whether and how China's mode of upgrading has changed the dynamics of Sino–foreign customer–supplier relations in China's wind turbine industry. Rather than providing a linear account of upgrading that looks at chains and networks as relatively stable and undisputed structures, this paper offers a dynamic account of the co-evolving institutional context of simultaneous forces of control and experimentation and the reconfiguration of Sino–foreign micro-level relations in the wind turbine industry. Such a dynamic, non-linear, and "multilevel" perspective has been lacking in the literature. Aiming to extend and refine Ang's (2016) argument on China's non-linear economic development as a result of co-existing and complementary forces of "direction and improvisation" in Chinese governance (Ang 2016: 69), this paper looks to answer the research question of whether and how China tackles upgrading through experimentalism and pragmatic governance, and whether and how this has had an impact on Sino–foreign customer–supplier relations in China's wind turbine industry. This paper hypothesises that it is through "failures" and pragmatic experimentation that China has produced self-disruptive phases of impasse, which – somewhat paradoxically – have forced China to learn, upgrade, and "jump the ladder."

Founded on rich empirical data from China for the period 2011–2016, the paper explores this issue through a case study on the historical development of Chinese wind power. The paper proceeds by first providing a brief overview of how upgrading and catch-up processes have been conceptualised in different streams of literature, focusing on the literature on upgrading within China's wind power sector. Next, it discusses the data and the three-staged analysis method it employs to evaluate Chinese upgrading. It then examines China's potentially unique non-linear upgrading (un)logic or what rather may be termed an upgrading trajectory with Chinese characteristics. Before concluding, it further discusses the advantages, disadvantages, possibilities, and tensions such an approach offers as well as how its

findings relate to the extant literature and other newly industrialised countries.

Upgrading and the Role of China's Institutional Context for Wind Power

In the following I provide a brief review of the existing literature in order to set the context for this paper's analysis of the development of China's wind turbine industry. Specifically, I highlight industrial upgrading and technological catch-up and the institutional particularities of Chinese governance.

Accounts of Industrial Upgrading in Chinese Manufacturing and Wind Power

The economic geography literature – especially that which discusses global commodity chains (GCCs) (e.g. Bair 2005; Gereffi 1999), global value chains (GVCs) (e.g. Gereffi, Humphrey, and Sturgeon 2005; Lema, Berger, and Schmitz 2013), global production networks (GPNs) (e.g. Cooke 2013), and global innovation networks (GINs) (e.g. Ernst 2006; Parrilli, Nadvi, and Yeung 2013) – provides rich insights into how industries can upgrade through integration into global chains and networks of production and innovation. Upgrading has often been conceptualised as a somewhat linear movement in the GCC between assemblers, original equipment manufacturers (OEMs), brand manufacturers, and design manufacturers (Gereffi 1999: 51) or as a matter of process, product, functional, and chain- or inter-sectoral upgrading (Humphrey and Schmitz 2002). The GIN framework looks at regional upgrading processes as a matter of "linking up" with external resources and innovation systems – that is, as a matter of "strategic coupling" (Parrilli, Nadvi, and Yeung 2013: 970). Apart from shedding light on the enabling factor of integration into global chains and networks of production and innovation, the literature also examines barriers to upgrading – for example, constraining factors of hierarchical governance modes or the lack of technological capabilities of suppliers (e.g. Humphrey and Schmitz 2002; Fu, Pietrobelli, and Soete 2011; Morrison, Pietrobelli, and Rabellotti 2008). In particular, the GVC literature shows how the specific governance mode (i.e. the coordination of customer–supplier relations based on a

transaction–cost rationale) of a chain determines not only the process of adding and distributing value along the chain but also upgrading possibilities, barriers to upgrading, and thus the potential for transformation and catch-up (Humphrey and Schmitz 2002; Gereffi, Humphrey, and Sturgeon 2005: 83–84).

Several related studies focus on Chinese upgrading within manufacturing in general (Steinfeld 2004; Ge and Fujimoto 2004; Brandt and Thun 2010; Herrigel, Wittke, and Voskamp 2013; Breznitz and Murphree 2011; Nahm and Steinfeld 2014; Butollo 2013). Part of this literature expresses the concern that (1) China's value chain integration into today's globalised, highly deverticalised supply chains through cost-cutting manufacturing is shallow (Steinfeld 2004: 1971; Ge and Fujimoto 2004: 23; Butollo 2013) and (2) there are limits to long-term Chinese catch-up success when manufacturing is simply based on modularity and related outsourcing (Lee, Cho, and Jin 2009). Another body of literature on so-called innovative manufacturing (Nahm and Steinfeld 2014; Herrigel, Wittke, and Voskamp 2013; Herrigel 2010) consists of micro-processual studies on learning and upgrading which assert that China has "developed unique capabilities surrounding technology commercialization and manufacturing-related innovation" (Nahm and Steinfeld 2014). This allows for manufacturing upgrading and learning to actively take place in China (Herrigel, Wittke, and Voskamp 2013) as well as the reconfiguration of Sino–foreign customer–supplier relations in manufacturing (e.g. producing fragile sustained contingent relations as Chinese actors redefine their capabilities, roles, and positions) (Herrigel 2010).

Regarding upgrading in China's wind power sector, the literature primarily sees it as an issue of China's rapid integration into GVCs and GPNs and also gradually into GINs and innovation systems (e.g. Silva and Klagge 2013; Klagge, Liu, and Silva 2012; Gosens and Lu 2013; Chen et al. 2014; Lewis 2013; Lema, Berger, and Schmitz 2013; Nahm and Steinfeld 2014). GIN scholars, in particular, argue that China's integration into GINs and innovation systems (Ernst 2006; Gu and Lundvall 2006) – or into the more or less interchangeable notion of international networks for learning and innovation (Lewis 2013) and collaborative innovation networks (Chen et al. 2014) – has played a rarely examined but crucial role in the development of its wind industry (Lewis 2013; Silva and Klagge 2013). This literature illustrates how traditional technology transfer mechanisms (e.g. FDI,

trade, and licensing) have shifted over time to non-traditional mechanisms of mutual learning such as joint design, research and development (R&D) collaboration, and overseas R&D units (Lema, Berger, and Schmitz 2013; Lewis 2013; Kirkegaard 2015).

China's Institutional Specificities: Accounts of Chinese Catch-Up and Experimentalism

Despite the many valuable insights it provides into upgrading processes, the upgrading literature only takes institutional contexts into account to a limited extent. This paper, however, is informed by the view that it is vital to consider China's specific institutional context and status as a newly industrialised "developmental" state in order to understand the upgrading of China's wind turbine industry and the deconfiguration and reconfiguration of Sino–foreign relations.

The developmental state literature does this, offering rich insights into how newly industrialised countries have succeeded in catching up with developed countries. For example, it illustrates how the miraculous growth of the Southeast Asian tigers during the 1970s and 1980s was enabled through extensive state intervention and those developmental states' strategic, longer-term policy focus (e.g. Evans 1995; Wade 2004; Amsden 2004; Johnson 1995; Kim 1997; Chen and Lees 2016; Carlsson and Stankiewicz 1991; Hobday 1995; Mathews and Cho 2007; Ang 2016; Angel and Rock 2009). Moreover, developmental state literature discusses a state's ability not only to catch up with developed countries but also to leapfrog them and move faster towards a sustainable transition through its ability to harness:

> global economic forces for technological and sustainability transitions through an openness to trade and investment and effective public–private institutions able to link cleaner technologies and environmental standards to production activities in firms. (Rock et al. 2009: 241)

China, however, constitutes a "socialist developmental state" (Gore 2014: 302), and some scholars argue that the country's establishment of a renewable energy industry is driven by its desire to upgrade and catch up with developed economies rather than by environmental concerns (Chen and Lees 2016; Mathews and Tan 2015).

In relevant strands of the political economy literature that compare China's institutional political economy with those of other na-

tions, many authors classify China's "variety of capitalism" as a "hybrid" between "liberal market economies" or "coordinated market economies" (e.g. Hall and Soskice 2001; McNally 2013). This is largely due to the way in which China's state-permeated capitalism (McNally 2013; Ten Brink 2013) – which is marked by a socialist, authoritarian, and state-centric yet fragmented mode of governance – has become a puzzle for "ideal type" theorization based on the varieties of capitalism dichotomy, whereby China is confined to a "variety of capitalism with Chinese characteristics" (Peck and Zhang 2013). Whereas the varieties of capitalism literature argues that institutional comparative advantage stems from complementarity between institutions, Chinese institutions often do not add up or reflect complementarity but rather different forms of capitalism – a phenomenon referred to as "variegated capitalism" (e.g. Peck and Zhang 2013; Peck and Theodore 2007). The concept of variegated capitalism illustrates how China's lack of complementarity can be a productive force for transformation and development (Peck and Zhang 2013; Peck and Theodore 2007).

The variegated capitalism literature has links to China studies, which examines China from a Chinese perspective. The influential notion of fragmented authoritarianism (Lieberthal and Oksenberg 1988; Lieberthal 2004: 187) explains how Chinese development is marked by "*both* divergence and connection" and "*directed improvisation*" (Ang 2016: 66) and is thus a productive force of variety within China, which is fragmented and subdivided into "criss-crossing jurisdictions" of vertical "lines" of bureaucracy (条, *tiao*) and horizontally coordinated "pieces" (块, *kuai*) (i.e. bodies) at various levels. This means that despite being a strong authoritarian state, paradoxically, "much of China's developmental initiatives take place at the local level by local states" (Gore 2014: 303). The fragmented nature of Chinese governance contributes to an unpredictability and ambiguity in the implementation of top-down policies at the local level (Breznitz and Murphree 2011: 38; Korsnes 2016; Ang 2016); others refer to it as "structured uncertainty" (Breznitz and Murphree 2011) or "experimentation under hierarchy" (Heilmann 2008: 29). According to Ang (2016), China has experienced rapid yet disruptive and non-linear economic development by exploiting its weak non-consistent institutions, enabling development to take place through a co-evolutionary process of mutual adjustment between markets and local and

central government. Last, these institutional traits have been linked to a particular governance mode of Chinese experimentalism, pragmatism, flexibility, adaptability, and creativity (Ang 2016; Korsnes 2014; Heilmann 2008, 2009, 2010, 2011; Breznitz and Murphree 2011) in which the central "*direction* underscores the role of top-down planning," whilst local improvisation "champions the merits of bottom-up initiative" (Ang 2016: 69).

Pragmatic Governance in the Electrical Power and Wind Power Sectors

Observers have drawn on the developmental state literature to explain the growth of China's renewables sector – the design and implementation of which is marked by top-down command and control strategies and a long-term focus on building industrial and technological capacity (Chen and Lees 2016; Angel and Rock 2009; Mathews and Tan 2015). In turn, the very notion of "fragmented authoritarianism" was coined in a study of China's state-owned and state-controllled power sector (Lieberthal and Oksenberg 1988). Various studies have enquired further into the fragmented and pragmatic governance mode used to reform China's power sector (e.g. García 2013; Meidan, Andrews-Speed, and Xin 2009; Martinot 2010; Korsnes 2014; Chen and Lees 2016; Kirkegaard 2015, 2016, forthcoming). Further, in regard to the wind power market, Liu and Kokko illustrate how the Chinese state, through the extensive role of state-owned enterprises (SOEs):

> participates directly in the wind power sector in several ways by commissioning wind power projects, operating wind farms, and producing equipment for the wind power industry. (Liu and Kokko 2010: 5523)

Whereas coordination has been important for the growth of China's wind industry (Lema and Ruby 2007), China's wind turbine industry has been driven by the government's oscillation between centralisation and decentralisation, on the one hand, and between centralised ambitious visions and ambiguity in regard to local implementation, on the other (Korsnes 2014, 2016).

The literature on industrial upgrading and institutional accounts of catch-up provide valuable insights into institutional context, which aids our understanding of China's wind power market. In addition, like Ang (2016), I argue that the recent move in the literature towards

"localized, adaptive approaches in the development field is extremely promising" and needs further exploration "to learn more about the ways of combining direction and improvisation" and non-linearity in development (Ang 2016: 69).

This paper enquires into the potentially distinct Chinese mode of non-linear and disruptive upgrading by offering a dynamic processual account which does not assume that relations, roles, and positions are stable. By doing so, this paper seeks to go even further – namely, by providing a multilevel account. This account relates the meso-level historical account of the Chinese wind turbine industry to the reshuffling of Sino–foreign relations at the micro level and puts these in China's institutional context as a developmental state with the paradoxical characteristics of central planning and local experimentation. Even though experimental policy learning has generally been linked to China's innovation performance (Gu and Lundvall 2006; Breznitz and Murphree 2011; Heilmann 2010), no studies have linked the distinct phases of Chinese industrial upgrading (meso level) to either the deconfiguration and reconfiguration of Sino–foreign relations (micro level) or their institutional embeddedness in the Chinese political economy of experimentalist pragmatism (macro level). Doing so can help us to detect whether there is a unique Chinese model of disruptive, non-linear upgrading.

Method

Building on extant literature, the study provides a historical and somewhat schematic and simplified account of three different distinct phases in the Chinese wind power market: (i) the late 1980s–2002, (ii) 2003–2011, and (iii) 2012–present. Although these rather simplified phases somewhat overlap, they are all identifiable through having been disrupted by radical government intervention; in the last two phases intervention occurred following the realisation of self-disruptive limitations of the previous phase. On this basis, the present paper seeks to provide the foundation for a broader discussion of China's potentially unique (un)logic of non-linear upgrading and shed light on the changing quality of governance relations between Chinese and foreign customers (wind turbine manufacturers) and component suppliers over time.

To ensure an empirically rich account, this paper uses an extensive amount of primary and secondary data. The primary data consists of findings from 98 semi-structured interviews conducted during doctoral fieldwork primarily in China and, to a lesser extent, in Denmark and Germany. The interviews were carried out in Chinese, English, or Danish between 2011 and 2013. Follow-up interviews were conducted in each country in both 2015 and 2016. The secondary data stems from a substantial review of news, policies and five-year plans, industry reports, and participation at wind energy events in China since 2011. To ensure a multilevel approach, I conducted interviews with wind turbine manufacturers, component suppliers, universities and research institutes, industry associations, relevant ministries, the China State Grid Corporation, design and consulting companies, renewable energy think tanks, certification bodies, test laboratories, and finance institutions. Whenever possible, I carried out company interviews with innovation managers, R&D directors, R&D engineers and/or chief engineers, directors, general managers, vice presidents, chief executive officers, managing directors, policy advisors, technical experts and scientists, international business managers, sales managers, or chief strategists. The interviews took between 30 minutes and three hours.

Due to the need to develop personal relations (关系, *guanxi*) to establish contact with potential respondents, I adopted snowball sampling for data collection. Being able to both write emails and conduct interviews in Chinese (Mandarin) helped me considerably to gain access to informants and establish trust with respondents. Most of the primary data were transcribed, translated if necessary, and coded in order to detect themes and to provide a basis for a historical outline. Throughout the paper, a few key quotes from central actors are used to qualify the core narrative. However, I have maintained these actors anonymity, which is a highly sensitive and prevalent issue in the area of fieldwork in China (Heimer and Thøgersen 2006).

Rapid Upgrading in China's Wind Turbine Industry through Self-Disruptive Moves

In the following section the paper identifies three distinct phases which have all led to stages of impasse in China's wind turbine industry. In turn, these stages of self-inflicted disruption have necessitated

radical interventions by the Chinese government, which have radically redefined roles, reconfigured governance relations, and, ultimately, resulted in disruptive moves of rapid upgrading.

Phase One (Late 1980s–2002): The Ascendance of China's Original Equipment Manufacturers

China has experimented with grid-connected wind turbines since the 1980s. Initially, wind power investment primarily consisted of scientific research or state demonstration projects without commercialisation (Zhao, Wang, and Wang 2012; Lema and Ruby 2007). From the early 1990s, efforts at building a wind turbine manufacturing industry became slightly more coordinated. The Ride the Wind Programme (1996), for example, constituted part of China's so-called technology-for-market-access or trade-market-access-for-technology policy. It was meant to attract foreign companies to the Chinese market and encourage domestic manufacturers to cooperate with foreign manufacturers that had localised in China by means of technology transfer and had formed Sino–foreign joint ventures (Klagge, Liu, and Silva 2012). Overall, the attraction of foreign technologies, know-how, and technology acquisition (e.g. through reverse engineering and backward design of foreign design licences) was critical to the construction of China's nascent wind turbine industry (Cherni and Kentish 2007; Lewis and Wiser 2007; Lewis 2007, 2013; Klagge, Liu, and Silva 2012; Lema and Ruby 2007; Li 2010; Korsnes 2014; Lema, Berger, and Schmitz 2013; Chen et al. 2014; Silva and Klagge 2013). Yet, even though China's manufacturing base started to emerge, phase one of China's wind power market (late 1980s–2002) was marked by piecemeal, incremental experimentation and indeterminacy as to whether or not to build up a domestic industrial chain or rely on turbine imports instead (Lema and Ruby 2007). Consequently, the development of China's wind power sector was a relatively slow, step-by-step process marked by extensive fragmentation of authority between different bureaucracies and across national and local levels (Lema and Ruby 2007; Liu and Kokko 2010).

Phase One Impasse: Limitations of Technology Transfer

During phase one, China succeeded in attracting foreign technologies. Nevertheless, China's wind turbine industry had some inbuilt

self-limitations, which led to inertia. First and foremost, the market was still dominated by foreign wind turbine manufacturers, and emerging Chinese wind turbine manufacturers largely functioned as assembly manufacturers without indigenous design capabilities. These assembly OEMs can be said to have followed a "Lego approach" – that is, they relied on foreign design licences and bought and assembled the different parts on design licences' component lists without having to worry about the systemic interplay of the many different turbine parts. Apart from lacking a systemic overview, the lack of a domestic supply chain also meant that Chinese assembly companies were dependent on relatively expensive foreign components (Haakonsson and Kirkegaard 2016). Once the Chinese government recognised the need to build up a domestic supply chain to reduce dependence on expensive foreign components and decided to develop a more coherent and coordinated policy for the wind power sector, and once the Chinese industrial base had acquired experience and had developed higher ambitions, phase one came to an end (Liu and Kokko 2010; Lema and Ruby 2007; Korsnes 2014). This shift took place around 2002 when a major reform of China's power sector was introduced, leading to the unbundling of power generation from transmission. Furthermore, the delegation to the National Development and Reform Commission (NDRC) of responsibility for coordinating supply and demand for wind power signalled the beginning of a new era in China's wind power market (Yu et al. 2009; García 2013; Liu and Kokko 2010; Lema and Ruby 2007).

Phase Two (2003–2011): China's "Turbine Wave Attack"

Having realised the continued self-limiting dependency on foreign technologies and having become determined to build a homegrown industry, the Chinese government encouraged the Chinese wind turbine manufacturing industry to build up a domestic supply chain and expand wind power capacity. Along with the power sector reform, the government interventions outlined below should be seen in the context of the introduction of the Chinese Communist Party's doctrine of "Scientific Development" (2003) and its key means of "indigenous innovation" (Christensen 2013), which marked a general shift in focus from importing technologies to spurring local innovation and upgrading.

First and foremost, wind farm concessions and wind tender programmes, which were introduced in 2003 and ran until 2009, helped stimulate the development of large-scale wind farm development in China, which had a guaranteed grid-connection tariff determined by a national-level tendering process and focus on lowest-priced bids (Li 2010: 1159). In the government-led tender system, wind farm developers were invited by the NDRC to bid for sites that had been chosen by the government and assessed for good wind resources. Before 2009, tenders for wind power construction projects had to meet a localisation rate of 70 per cent, which forced foreign manufacturers to establish themselves in the Chinese market. Overall, the concession programme marked a shift towards the centralised, large-scale commercialisation of wind farms and transformed Sino–foreign business relations, as foreign wind turbine manufacturers (and their component suppliers) had been attracted to China through preferential treatment during phase one. Meanwhile, the concession programme introduced evaluation criteria which favoured domestic state-owned wind farm developers, and lowest-bid prioritisation often meant that foreign manufacturers were unable to win bids (Lewis 2013: 82; Chen and Lees 2016: 578). Second, the influential 2005 Renewable Energy Law and several five-year plans resulted in the rapid growth in installed wind power capacity, in manufacturing upscaling, and in the large-scale commercialisation of wind farms (Li 2010; Korsnes 2014; Klagge, Liu, and Silva 2012; Lema and Ruby 2007). Third, wind farm planning was fragmented and often decentralised during phase two, leading to head-on provincial competition for the largest installed capacity, which soon led to overheated investments.

As wind turbine manufacturers and component suppliers followed the signals from the Chinese government to establish a Chinese wind power market, and as provincial governments strived to meet the ambitious targets of installed capacity, investments from power-generating companies increased quickly and dramatically, leading to the rapid growth of the wind turbine industry. For instance, in 1998 Goldwind was the only Chinese wind turbine manufacturer; in 2005 there were still only a couple. By the end of 2008, however, the number of Chinese wind turbine manufacturers exceeded 70, and the number of component suppliers – this included manufacturers of blades, converters, control systems, bearings, and gearboxes (Li 2010: 1159) – was in the hundreds (García 2013: 137–138; Yu, Zhang, and

Chen 2009: 5222). By utilising mature technology through licensing and thus avoiding high R&D expenditures, Chinese turbine manufacturers were soon able "to produce turbines at much lower costs than their foreign counterparts" (Klagge, Liu, and Silva 2012: 376).

Phase Two Impasse: The Creation of a "Quality Crisis"

The emphasis during phase two was on building a domestic supply chain. The chosen strategy was successful as China's wind turbine manufacturing industry soon became more mature and covered the entire supply chain. This was enabled through a relentless focus on quantitative upscaling and a licensing strategy that enabled China's domestic enterprises to move "quickly up the technological ladder," winning "local market share and, as the sector matured, [strengthen] global competitiveness" (Chen and Lees 2016: 578). The growth in both the country's industrial base and installed capacity was facilitated by, for example, (i) tendering processes for wind power development which favoured lowest bids and largely disregarded quality measures, (ii) decentralised wind farm planning, (iii) a focus on installed capacity over generated electricity, (iv) and a lack of certification criteria. Additionally, the quantitative targets of various development plans only concentrated on installed capacity measured in gigawatts (GW) rather than on actual generated-electricity targets (such as gigawatt hours, GWh). According to one foreign scientist,

> back then, the only thing that mattered, and the only thing really demanded in the Renewable Energy Law, was just megawatts […] how many megawatts could be installed. Whether the turbine would run, they didn't care. It was all about capacity [measured in gigawatts] and nothing about productivity [measured in gigawatt hours]. (Anonymous 1 2013)

This basically meant that Chinese wind turbine manufacturers and wind farm developers did not need to bother themselves with ensuring that their turbines could actually provide stable and optimal output or be connected to the power grid. Moreover, along with largely pursuing the "Lego approach" of phase one and not meeting any certification requirements, Chinese component suppliers and turbine manufacturers without any prior experience were allowed to enter the market and outcompete Western manufacturers. In addition, through extensive fragmentation and decentralisation of wind power planning, local provinces competed for the largest installed capacity rather than

ensuring grid integration. Last, the financial support scheme during this period was unable to cover the costs of developing wind power. This basically only left space for China's state-owned companies, which – given their soft budget constraints – could more easily bear the burden of debt and low profits (Zhao, Wang, and Wang 2012; García 2013; Korsnes 2014; Li 2010; Liu and Kokko 2010; Yu, Zhang, and Chen 2009).

Although the growth strategy had proved successful, phase two soon faced an impasse: the industry was marked by overcapacity, high curtailment rates, quality issues (e.g. blade and shaft fractures, generator fires, and gearbox or brake failures), and low-capacity factors (García 2013; Li 2010; Cherni and Kentish 2007; Klagge, Liu, and Silva 2012; Kirkegaard 2015):

> By late 2010 there were visible flaws in China's wind power industry. The first was the production quality of the turbines. Since the government planners demanded quantity, and not performance, wind farm developers tended to cut corners. Thousands of China's turbines lack the more expensive technology that keeps them operating when there is a disturbance on the power grid. (Riley and Ashley 2012)

Having allowed the installation of "gigawatt by gigawatt of very poor quality," "massive quality problems" and "massive grid break downs" started to emerge (Anonymous 2 2012). Overall, China had upscaled with tremendous pace, both in the wind turbine manufacturing and component manufacturing industries. This was largely as the result of extensive price competition and a strategy of reverse engineering of foreign technology. Yet, such rapid industrial growth came with a price (Korsnes 2015: 75), bringing about what has been coined as a largely self-induced "quality crisis." This quality crisis, in turn, soon threatened to undermine the survival of the entire market, as the wind power industry's legitimacy as a "sustainable" energy source was called into question (Kirkegaard 2015, forthcoming).

In this way, phase two also entailed disruptive self-limitations, which produced a second stage of impasse. In turn, the quality crisis in China's wind power sector began to transform Sino–foreign relations: foreign wind turbine manufacturers and component suppliers struggled or even failed to survive in the market during the period of cutthroat competition. Today, the top 10 wind turbine manufacturers in the Chinese market are all Chinese (GWEC 2016: 32). Foreign

component suppliers soon had trouble keeping their Chinese customers, as the Chinese wind turbine manufacturers – who through the "Lego approach" appeared to function purely as "assembly original equipment manufacturers," – started to source from the Chinese supply chain, which offered much lower prices; this, therefore, left Sino–foreign customer–supplier relations highly volatile (Kirkegaard 2015).

Phase Three (2012–Present): A Flexible "Turn to Quality"?

To contain the quality issues in the Chinese wind turbine industry and embark on a consolidation phase, the Chinese government employed a variety of new radical interventions after 2012 – namely, policies, plans, standards, targets, and regulations. This marks the central government's attempt to ensure a "turn to quality" (Kirkegaard 2015). According to one interviewee,

> Beijing needs to take control [by] putting in standards and requirements for a higher quality. Standards and requirements for [things] other than just installing gigawatts into the ground. (Anonymous 2 2012)

> Now the second wave [of a quality focus] is coming [after the first wave of rapid industrial growth in installed capacity], now that they [the Chinese government] have realised that it [wind turbines] may not be the best quality. (Anonymous 3 2012)

This indicates there has been a political reorientation towards centralised control from extensive decentralisation and fragmented coordination. Below, I discuss six key interventions used by the Chinese government to create the conditions for a "turn to quality" in the wind turbine manufacturing sector.

First, the central government sought to raise quality and overcome the relative backwardness in technologies by introducing industrial and technical standards. As early as 2010, the Ministry of Industry and Information Technology (MIIT) had – amongst other things – released a draft circular on access standards for the wind power equipment manufacturing industry, which aimed to:

> promote the optimization and upgrading of the industrial structure of the wind power equipment manufacturing industry, enhance enterprises' technical innovation, improve product quality,

> [and] restrict the introduction of redundant technology [to] guide the industry's healthy development. (MIIT cited in Lewis 2013: 57)

In addition, the wind power industry was listed under "encouraged development" in the NDRC's 2011 "Guideline Catalogue for Industrial Restructuring," which made wind power eligible for preferential treatment due to its status as a "strategic" modern pillar industry (Chen and Lees 2016: 581). However, these preferential policies were not extended to companies that produced wind turbines with a 2.5 megawatt (MW) capacity or lower. In practice, this excluded inexperienced wind turbine manufacturers from the market. Furthermore, the National Energy Administration issued 18 new technical standards in 2011 to improve the regulation of technology development in the wind sector and grid connection (Lewis 2013: 58, 74). Overall, these new certification requirements initiated a consolidation phase as no more than 10 of China's estimated 80 wind turbine manufacturers were able to meet the certification requirements and new standards (*People's Daily Online* 2011).

Second, the Chinese government gradually shifted its plans and policy instruments, moving from purely focusing on capacity installations (GW) towards ensuring generated electricity (GWh). This was achieved through introducing both supply- and demand-related schemes, such as mandatory market shares (Bloomberg New Energy Finance 2012: 2), experimentation with national renewable energy portfolio standards, power purchase agreements, and cost-sharing schemes – all of which should ensure that grid companies, generating companies, and provinces fulfil their obligations to generate, distribute, transmit, and buy wind power (Lema and Ruby 2007; Lewis 2007; García 2013; Liu and Kokko 2010; Bloomberg New Energy Finance 2012; Cherni and Kentish 2007). As investors, wind power developers, and producers were now to be rewarded only for actual generated electricity rather than installed capacity, stricter requirements were introduced to ensure that wind turbines were capable of delivering controllable optimal outputs (Bloomberg New Energy Finance 2012; Kirkegaard 2015). This constituted a new critical incentive measure for raising turbine quality (Yu, Zhang, and Chen 2009; Gosens and Lu 2013; Bloomberg New Energy Finance 2012; Kirkegaard 2015).

Third, the government also changed its price-setting model and began to increasingly concentrate on quality by, inter alia, (i) gradually changing the focus of China's concession projects from competitive bidding towards other quality-related criteria (Korsnes 2014; García 2013: 130) and (ii) pragmatically experimenting with proper levels for the support scheme (Zhao, Wang, and Wang 2012; García 2013; Korsnes 2014).

Fourth, the Chinese government decided to increase its centralised control over wind power development by requiring national-level approval for large wind farm projects. This move was intended to counter overheated investment activities at the local provincial level (Yu, Zhang, and Chen 2009; García 2013; Korsnes 2014; Kirkegaard 2015) and proved central to the turn to quality.

Fifth, the government and the CPC began to allow the largely state-controlled media to highlight quality issues regarding wind turbines. Because the media in China can serve to either legitimise or delegitimise the wind turbine industry (Korsnes 2014: 188–189), this can be seen as a measure designed to steer growth in the Chinese wind power sector as stories about the quality and poor functioning of wind turbines only started to surface in 2011 despite such issues having emerged prior to the downturn in 2011 (Korsnes 2014: 188–189).

Finally, the State Council issued its twelfth "Five-Year Plan for the Scientific and Technological Development of Wind Power" in 2012, which constituted the first plan devoted to the scientific (and sustainable) development of wind power. Proclaiming its guiding ideology to be the doctrine of "scientific development," the plan emphasises the need to upgrade Chinese indigenous innovation capabilities within core technologies, particularly in the areas of control system and simulation tool software and basic research into mathematics, aerodynamics, and certification and standardisation.

On the whole, these interventions – along with a break on favourable government loans to investors – helped to steer the industry towards a more quality- and innovation-focused track and facilitated the emergence of Chinese OEMs in the wind power industry. Today, Chinese OEMs compete against foreign competitors on more equal terms, and some are now brand manufacturers, such as Goldwind and Envision – both of which have successfully engaged in Sino–foreign mutual learning. In this respect, Chinese OEMs are increasingly adopting the role as active system co-players. This can be seen

in how they integrate into emerging global innovation networks (Silva and Klagge 2013); file for patents; participate in standard formulation with research institutes and Chinese certification bodies; and even engage in the mergers and acquisitions of Western design firms, in outward FDI (e.g. by establishing innovation centres abroad), and in collaborative design and co-development (Lema, Berger, and Schmitz 2013; Lewis 2013; Klagge, Liu, and Silva 2012; Li 2010; Silva and Klagge 2013; Chen et al. 2014; Kirkegaard 2015).

Imminent Phase Three Impasse? Competition over Core Technologies and Fragile Relations

The radical government interventions outlined above enabled China's wind power industry to reach a consolidation phase around 2011–2012, which is reflected by the slowing installed capacity growth rate and the decreasing number of wind turbine manufacturers. As a consequence, it is projected that a maximum of only five Chinese wind turbine manufacturers will survive in the market. Indeed, when the Chinese central government makes a decision, it can trigger "seismic changes across the country" (Ang 2016: 73). According to various industry actors, this has long been the underlying strategy of the government to enforce a shake-out in the wind power market and has allowed dozens of actors to compete and push prices down. As expressed by a foreign wind power scientist:

> They [the Chinese] have had a lot of different agendas along the way. Well, they also had an industrial policy agenda, and that was very obvious, and they didn't conceal that either. Wind power development – that was industrial policy. In the beginning, it was about building an industry. And then within a number of years, China was meant to become competitive. Chinese industry experts were predicting that, within a certain number of years, based on the industrial base, China would be able to produce quality wind turbines. But quality was not the first step. That was not the important thing in the beginning. The most important was to make the industry […] let them try out producing turbines. (Anonymous 1 2013)

Overall, the development and progression of different phases illustrate an oscillating movement between planning and experimentation, on the one hand, and between centralised, coordinated control and decentralised fragmentation (characteristic of Chinese fragmented

authoritarianism), on the other (Korsnes 2014; Kirkegaard 2015). China's OEMs upgraded in a non-linear and disruptive fashion during the iterative phases of impasse following the radical interventions of the Chinese government. To ensure quality and to build innovation capacity, Chinese wind turbine manufacturers are currently experimenting with internalising the design, development, and manufacturing of turbine core components, rather than relying on outsourced components (Haakonsson and Kirkegaard 2016). This is transforming relations between Chinese and foreign actors. As Chinese actors struggle to build indigenous innovation capabilities in critical core technologies, Sino–foreign relations have become increasingly contested during the turn to quality. For instance, Chinese manufacturers have already upgraded in the production of hardware parts for the main control systems of turbines, and the majority are increasingly experimenting with and capable of developing their own software tools. However, they often still remain dependent on foreign software tools for core algorithmic parts and when developing indigenous turbine designs. These core parts of the software are often black-boxed, however, through encryption devices and other means. At the same time, Chinese capabilities and ambitions to improve the quality of indigenous innovation have risen. These dynamics have produced power struggles around core technologies between Chinese and foreign actors. As such, technologies are critical for realising the Chinese wind power industry's "turn to quality" and ability to catch-up and align with China's official scientific development vision through indigenous innovation. Fearing the loss of their Chinese customers, some foreign control system suppliers have consequently started to experiment with opening up selected source codes and/or modularising specific algorithms in order to satisfy their customers' new requirements (Kirkegaard 2015).

With the turn to quality taking place, Chinese actors are upgrading in a non-linear fashion, thus reconfiguring Sino–foreign relations. This implies that Sino–foreign supply chain relations have become fragile and volatile, characterised by simultaneous competition and collaboration (Kirkegaard 2015; Kirkegaard forthcoming). Indeed, that being witnessed may be termed the emergence of sustained contingent relations (Herrigel 2010), where roles and positions as well as goals and aims are constantly being renegotiated. Last, phase three may run into a third stage of stagnation and impasse as a result both

of these contested relations and of the future need for Chinese actors to invest more in basic research and applied core mathematics. Despite this, China's wind turbine industry has succeeded in non-linear upgrading through pragmatic and experimental governance – that is, through iterative moves of recentralisation and reintervention as well as through a developmental state logic to transfer and adapt the best available foreign technology whilst actively protecting China's domestic industry (Chen and Lees 2016: 578, 582).

Discussion: China's Rapid Upgrading through Self-Inflicted Stages of Impasse

The above analysis has identified three distinct phases in the trajectory of Chinese wind power development. Each phase was marked by rapid moves of upscaling and upgrading. At the same time, each phase reached a certain stage of impasse. Phase one led to the extensive dependence of Chinese manufacturers on foreign suppliers and their expensive products. Phase two resulted in a Chinese quality crisis and limitations of the assembly approach. Phase three culminated in the potentially disruptive nature of imminent power struggles between Chinese and foreign players during the turn to quality.

The self-inflicted stages of potentially self-disrupting impasse were the result of the Chinese government's fluctuation between radical intervention and a lack of intervention. Consequently, the repeated phases of impasse and radical government intervention have resulted in the constant deconfiguration and reconfiguration of Sino–foreign relations in the wind turbine industry. In phase one Chinese assembly manufacturers relied heavily on foreign technology and components, leaving foreign wind turbine manufacturers in a relatively favourable position. During phase two, cutthroat price competition made it virtually impossible for foreign manufacturers and suppliers to sell their products, while rapid development led to unstable relations between Chinese and foreign actors. This saw foreign suppliers lose many Chinese customers, and foreign turbine manufacturers lost many bids. In phase three, Sino–foreign relations are being reconfigured as Chinese manufacturers now focus increasingly on quality, which leaves more space in the Chinese market for foreign actors/manufacturers – who still generally provide higher quality. Meanwhile, the new enhanced focus on quality and the critical role of core

technologies has made some Sino-foreign relations more volatile and more fragile. Nevertheless, as Chinese companies catch up, the traditional technology transfer mode of licensing is gradually being overtaken by more equal partnerships, mutual learning, and cooperative innovation. This has enabled Chinese actors to redefine themselves and their mutual relations through constantly engaging in transformative reconfigurative games (Kirkegaard 2015) and "breaking down" otherwise path-dependent and often deterministic accounts of value chain upgrading and constraining governance structures.

In contrast to the findings of most of the extant literature, industrial upgrading in the Chinese wind power sector does not seem to follow a linear trajectory. Rather, China has pursued a non-linear and disruptive trajectory in which a series of impasses have been constructed, led to radical government interventions, and forced Chinese companies to find flexible solutions for creative upgrading. After each disruption, China's wind turbine industry seems to have found new routes by flexibly and pragmatically responding to the earlier "mistakes," thereby creating ever higher development goals. This Chinese-style trajectory further illustrates how China's leadership has sometimes allowed stages of impasse to take place with the deliberate aim of learning from them. According to one Chinese industry expert and government advisor, the reasons for and the pragmatic handling of the quality crisis in the Chinese wind power sector is linked to the way in which problems "force us to have the solutions. This is good" (Anonymous 4 2013). Thus, China has been using a "first do, then solve" approach (先做，才解决!, *Xian zuo, cai jiejue!*):

> If the problem had not appeared, nobody would have considered it. […] That is not a strategy […] that is a […] reality. To learn from the practice is much better than to learn from the theory or learn from imagination […] It's the Chinese way. (Anonymous 4 2013)

In this "Chinese way" – which may be termed a pragmatic crisis-and-response development model – what would normally be regarded as "mistakes" are not necessarily negative, because they force actors to experiment and creatively find solutions. Therefore, the fragmented Chinese governance of the wind power sector has resulted in disruptive upgrading, which sometimes brings about "inherent tensions" that require "state responses to these tensions" (Ang 2016: 68). The iterative stages of impasse have been pragmatically allowed as they are

seen as potential conduits of learning from experimentation. In such a context, the constant readjustment of failures, upgrading, experimentation, expectations, and imaginaries are fine-tuned and constitute Chinese "arts of the state" or Chinafication, whereby innovation and quality are made to fit the (Chinese) agenda (Korsnes 2014). To some extent, this aligns with Ang's (2016) notion that China has enabled economic development by exploiting and learning from its weak and fragmented institutions, which has resulted in non-linear development. Indeed, the story of Chinese wind power is one of non-linear trial and error and the "volatile yet productive combination of decentralized experimentation with ad hoc central interference" (Heilmann 2008: 29).

In this way, the paper has illustrated the importance of understanding China's upgrading in the wind power sector within a Chinese institutional context. More specifically, I have argued that China's non-linear disruptive upgrading in wind power would not have been possible without the ingenuity and pragmatism of Chinese governance or its nature of structured uncertainty. Even though "directed improvisation" (Ang 2016) may seem a "contradiction in terms" at first sight (Ang 2016: 69), it makes sense to dismantle the dichotomy and look at how direction and improvisation coexist in the case of China's development. Doing so enables us to see that China seems to have achieved rapid and disruptive upgrading through adaptive pragmatism and experimentalism. This paper hereby aligns with both Korsnes (2014), who points to the importance of China's policy flexibility and navigational skills in nurturing its wind turbine industry, and Heilmann (2008: 18), who argues that China's governance mode is "guided by intentional anticipation instead of blind trial and error." Yet, at the same time, this paper contributes to the literature a dynamic and multilevel accounts of the constant reshuffling of Sino–foreign relations within China's changing institutional context and of the process of disruptive upgrading. Indeed, the long-term sustainability of China's fragmented governance mode is still up for discussion (e.g. Breznitz and Murphree 2011; Nahm and Steinfeld 2014; Rock and Toman 2015; Liu and Liang 2013: 486) – for instance, overcapacity seems to be a common Chinese problem in several industries (Rock and Toman 2015). Whilst it can be claimed that the quality crisis ran the risk of delegitimising the wind power market and even China's experimental and fragmented governance mode in gen-

eral, it is necessary to enquire further into other strategic industries in China and to detect whether similar disruptive movements of non-linear upgrading can be detected. This is an exciting area for future research. In fact, it may be claimed that other renewable energies are prone to such non-linear upgrading due to the strategic roles of those sectors and the way in which renewables, by their nature, disrupt China's fossil fuel–based power sector. To make China an emerging "global green leader," the Chinese government must employ disruptive moves to unlock the country from its trajectory as a coal kingdom.

Last, there is a need to enquire into the extent to which China is adopting a "specifically Chinese" non-linear upgrading model or merely emulating the experience of other developmental states (Liu and Liang 2013; Gore 2014; Chen and Lees 2016; Shen 2016). To some degree, it may be argued that Japanese companies experienced similar development during the 1960s and 1970s, when quality crises prompted policy adjustments and government responses. Further, it has been argued that the central role of the Chinese state "as ultimate pilot, coordinator and agent of change" is pragmatically modelled on the prior "successful development experiences of Japan, Korea, Taiwan and Singapore" (Mathews and Tan 2015: 146). Yet, despite the similarities, the scale and pace with which China has upgraded makes Chinese experimental pragmatism unique. In addition to this, the competitive situation facing China is very different from those that faced Japan and other East Asian countries. The Southeast Asian tiger economies faced an era characterised by the vertical integration of companies. China, in contrast, is facing an era of vertical disintegration due to the increased modularity of technologies (Nahm and Steinfeld 2014). Moreover, with the opening of China's markets following its accession to the World Trade Organization in 2001 (Angel and Rock 2009), China is upgrading in a "transformed era" (Steinfeld 2004: 1983) in which Chinese companies have to deal with new, more complex competitive pressures and networked forms of production (Nolan 2001; Steinfeld 2004; Nahm and Steinfeld 2014). Given this new context, blindly copying the strategies of the Southeast Asian tigers is unviable as Chinese companies are more constrained in terms of room for manoeuvre when it comes to traditional developmental, interventionist industrial policy (Nahm and Steinfeld 2014). Meanwhile, China has sought to distance itself from neoliberal economic

policies (Mathews and Tan 2015: 146) and now looks increasingly likely to set "a new standard for industrial development" with regard to green governance, which is already being emulated elsewhere (Mathews and Tan 2015: 11). In this sense, China is increasingly seeing itself as a "model for other developing countries" when it comes to ensuring energy security and industrial development in alignment with societal concerns over economic and environmental acceptability (Mathews and Tan 2015: 146, 148).

Conclusion: Redefining the Competitive Field and Increasing Mutual Learning

This paper has enquired into some of the defining institutional conditions of Chinese industrial upgrading, which can help explain China's success in "jumping the ladder" – that is, breaking free from preexisting relations and structures and finding new radical solutions for self-transformation.

By identifying three distinct phases of non-linear upgrading and subsequent stages of impasse and radical government intervention, this paper illustrates (i) how China has used experimentalism and pragmatic governance to tackle upgrading in the Chinese wind power industry, (ii) how this has impacted relations between Chinese and foreign actors in China's wind turbine industry, and (iii) how China has used its fragmented and experimental governance to kick-start economic development. China did not necessarily intend for the problems and stages of impasse to occur, but they did not prevent them either. Instead, they used them as learning resources. The wind power sector's embeddedness in a Chinese experimental and pragmatic governance mode, which has roots in China's institutional fragmented authoritarianism, can have both advantages and disadvantages. The gamble faced by the Chinese government is that fragmentation may eventually spin out of control and pose a risk to the legitimacy of the wind turbine industry and other green industries. The government's "turn to quality" in response to the potentially self-disruptive quality crisis in the Chinese wind power sector (which has been enabled through its pragmatic experimental and fragmented governance) has made non-linear upgrading possible. China's crisis-and-response development model has worked in practice so far but has had implications for Sino-foreign customer–supplier relations.

For instance, China's new capabilities and rising ambitions have led to constant a renegotiation of relations. This has rendered relations and their governance highly volatile and has produced simultaneous forces of competition and collaboration.

In conclusion, a unique Chinese mode of upgrading (or upgrading with Chinese characteristics) has taken place within the Chinese wind power sector. These Chinese characteristics are found in China's institutional settings and are marked by experimental and pragmatic governance, the constant oscillation between centralisation and decentralisation, fragmented authoritarianism, and structured uncertainty. By providing insights into how pragmatic governance and experimentalism has enabled Chinese upgrading, this paper has shed light on a hitherto overlooked piece of the puzzle that is China's rapid catch-up in the wind power industry.

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