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# The International Transfer of Wind Power Technology to Brazil and China

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## Abstract

Enhancing developing countries' access to climate technologies is an important contribution to effectively addressing climate change at the global level. In this study, we analyses the drivers and barriers for the transfer of wind power technology from the perspective of multinational technology suppliers. The findings and comparison of two case studies on the transfer of wind power technology to China and Brazil are presented, focusing on which transfer channels were chosen and why, as well as what kind of impact this choice had on the local diffusion of the transferred technology.

While the case study on China arrives at the conclusion that a variety of transfer channels are used and hybrid governance modes, such as licensing and joint ventures, are favored in particular, the Brazilian case revealed that transfers within multinational companies to their subsidiaries are by far the dominant transfer channel. Both case studies revealed that government restrictions have a considerable impact on the choice of transfer channel, which is due both to the strong involvement of the receiving countries' governments in market creation activities for renewable energies and to their control over energy markets and infrastructures.

The fact that the technological gap pertaining to onshore wind power equipment was closed within a relatively short period of time can be regarded as a success of international technology transfer. For China as well as Brazil, the regulatory framework for the development of the wind power sector can be seen as the most important driving force for this development. Both countries were successful in creating market demand for wind energy, although the political approach of the Chinese government towards the wind power sector is considered to be more ambitious and comprehensive. Most importantly the Chinese government combines market formation policies with industrial and research policy initiatives that are targeted at the build-up of a domestic wind power industry. In contrast, the Brazilian government's approach is much more narrowly directed at developing wind energy as a cost-efficient alternative to other energy sources, although domestic production of wind power equipment is likewise strongly encouraged by local content requirements. Patent and in particular publication data suggest that China is catching-up rapidly. Nevertheless, our findings highlight that absorptive capacity is based on more than just the ability to innovate; otherwise the success of Chinese companies in the wind technology sector would not be possible. This could be an indicator of the importance of a "learning through imitation" model in the technology absorption process.

With regard to both, China and Brazil, the weak governance quality of the energy sector was seen as a significant barrier to technology transfer. In China, for example, deficits with regard to the implementation and enforcement of regulations as well as the fragmentation of the energy bureaucracy were bemoaned. A barrier pertaining to the situation in Brazil is the lack of a complementary infrastructure that refers in particular to bottlenecks in the wind power supply chain.

**Keywords:** International Technology Transfer; Transfer Channel; Wind Power; Knowledge Spillover; Transaction Costs Economics

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# 1 Introduction

The UN Framework Convention on Climate Change (UNFCCC), established in 1992 as one of the most important pieces of transnational environmental governance, has included articles on technology transfer from the beginning; however, the issue was largely neglected for the first fifteen years after its inception (Verbeken, 2012). Given that the share of $CO_2$ emissions by non-OECD countries has increased from 44% in 1992 to 61.7% in 2012, with a projected rise to well over 70% by 2035 (IEA, 2014), while the non-OECD countries' share of global patents in climate technologies is small (6.8% for the period 2008-2010) and has only increased marginally over this same time frame (Gandenberger, Peuckert, Christmann-Budian, & Bodenheimer, 2014), enhancing developing countries' access to climate technologies can provide a significant contribution to addressing climate change on a global scale. This fact was also acknowledged by the 2007 Conference of the Parties in Bali, where an Action Plan was adopted that led to the creation of the UNFCCC's Technology Mechanism in 2010. Along similar lines, the group of Like-Minded Developing Countries in Climate Change (LMDC) continues to call for enhanced action on technology transfer (Like-Minded Developing Countries on Climate Change, 2014).

There are, however, experts who believe that the successful diffusion of cleaner energy technology does not depend significantly on actions taken in the arena of transnational governance. Rather, Gallagher states clearly that "there is no need to wait for an international agreement, [since] national policies are both necessary and sufficient" for the transfer of cleaner energy technologies (2014, p. 176). According to her research, national market creation policies are crucial for the development and transfer of climate technologies, since their diffusion largely takes place through the market and is primarily carried out by corporations. However, others have pointed to the fact that "most of the climate-related investments in 'developing' countries turn out to have been geared to a few emerging economies, generally involving established technologies with limited transfer" (Kolk, 2013, p. 1).

Irrespective of the question whether transnational governance is needed to foster the global diffusion of climate technologies or national policies are sufficient, a better understanding of the drivers and barriers for the international transfer of climate technologies will help policy makers in their design of appropriate mechanism to foster international transfer of climate technologies. In this study, we analyses these drivers and barriers from the perspective of multinational technology suppliers and presents the findings and comparison of two case studies on the transfer of wind energy technology to China and Brazil, focusing on which transfer channels were chosen and why, as well as what kind of impact this choice had on the diffusion of the transferred technology.

The wind energy sector is of particular interest since its development is highly dynamic and has also reached the newly industrializing countries. Each of the case studies examines the market situation and regulatory environment of the recipient country, assesses both the technological gap and absorptive capacity between the recipient country and market leaders and looks at the transfer channels chosen by foreign firms entering the Brazilian and Chinese markets. Finally, an analysis of the most important drivers and barriers to technology transfer and diffusion is conducted for each country and the two case studies are compared analytically.

The paper is structured as follows: Section 2 will provide an overview of innovation activities in the global wind energy sector; Section 3 focuses on the theoretical background underpinning the analysis; Section 4 first presents the two case studies separately before then comparing their results and Section 5 concludes.

## 2 Innovation in the Global Wind Energy Sector

Wind energy technology can be divided into two categories, onshore and offshore. Onshore technologies are currently more technologically advanced and generally associated with lower costs relative to offshore technologies (Wiser et al., 2011). The basic system configuration of the onshore market-dominating three-blade rotor horizontal axis system is shown in Figure 1. Such a modern wind power station consists of the rotor blades, the rotor hub, gearbox (optional), the generator, the tower, the foundation and the power connector. Depending on the wind turbine type, additional components may be added or omitted.

The general trend in wind turbine design – both on- and offshore – focuses on increasing the size of turbines in order to minimize investment, generation, and operation and maintenance costs per unit of capacity. While turbines started with a rotor diameter of 17 m and a rating of 75 kW in the 1980s, they have grown significantly since then: In 2009, most onshore wind turbines had a capacity of between 1.5 and 2.5 MW with rotor diameters of 70-80 m, while offshore turbines typically range from 2 to 5 MW capacity (Wiser et al., 2011).

Innovation is ongoing in the wind power sector, but, as such, cannot be measured directly. Instead, there are a number of measures that are well-suited as proxy indicators to get a sense of the amount of innovation taking place in a particular sector, country or time period. Most popular among these indicators are public R&D expenditures, since they have been collected for many decades and are usually readily available (Kleinknecht, van Montfort, & Brouwer, 2002). At least for OECD countries, it is possible to get a very clear picture of the public R&D expenditures that have been made to advance wind energy technology since the mid-1970s.

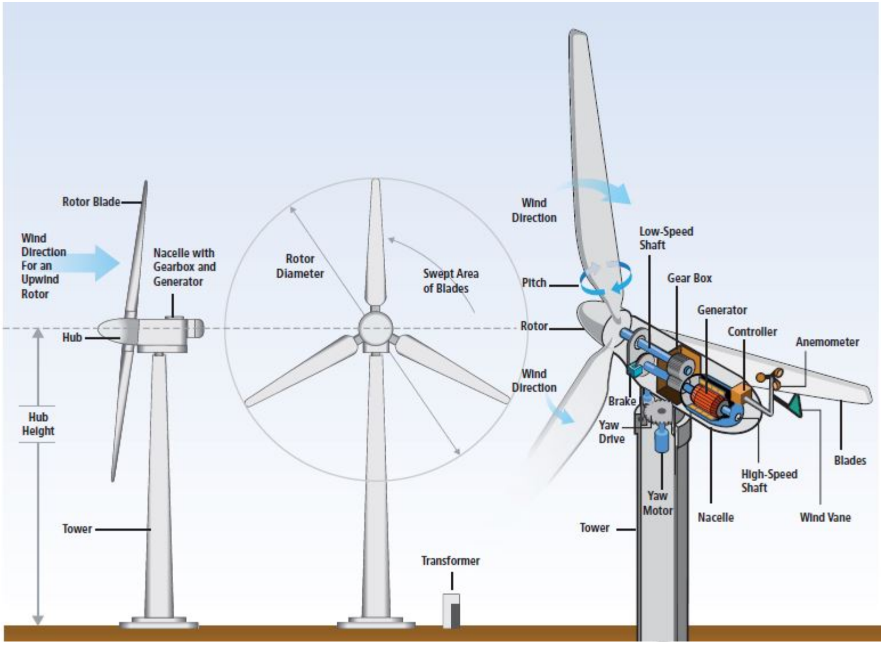


Figure 1: Basic components of a horizontal-axis wind turbine (Wiser et al., 2011, p. 552)

Looking at Figure 2, it is clear from the R&D investments of the last few years that investments in wind energy technology have increased significantly since 2009. While there was an early peak between 1979 and 1981, R&D investments quickly dropped again in 1982 and flattened out to fairly steady levels throughout the 1990s and early 2000s until 2007. After a further drop in 2008, the rates suddenly skyrocketed with a three-fold increase from 2008 to 2009, with a further significant increase in 2010. In terms of geographic distribution, Germany and the United States have both the largest and most continuous shares of R&D investments in the wind energy sector. The Netherlands, Denmark and United Kingdom likewise have a long tradition in researching wind energy technology, but with smaller overall investment levels, although the

United Kingdom has been quite active – in some years out-spending both Germany and the US – as of 2005. After a brief involvement in the early 1980s, Spain began investing noticeably in wind energy R&D as of the late 1990s.

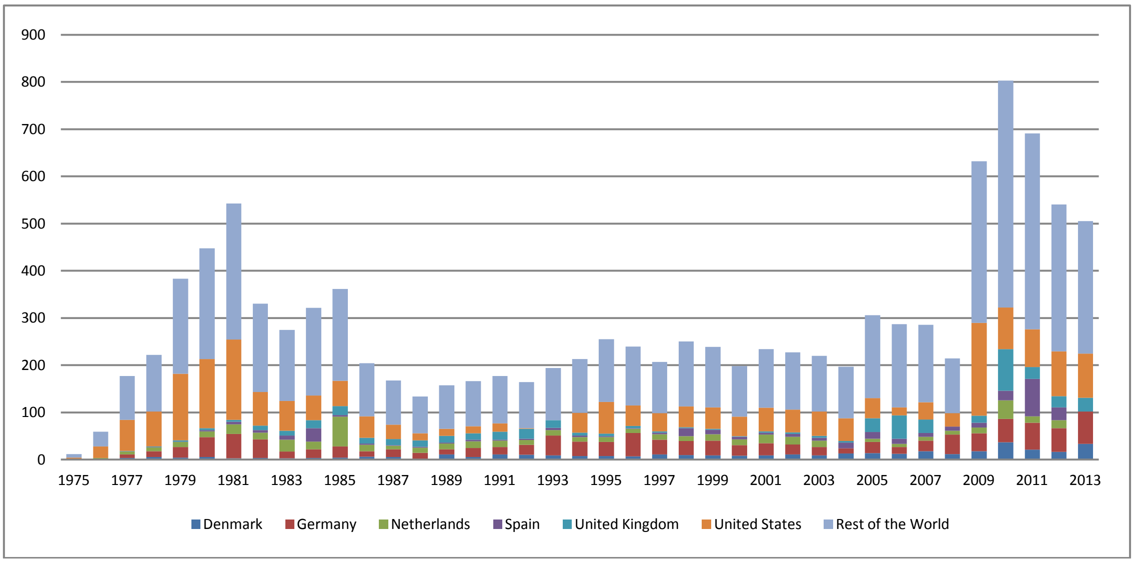


Figure 2: Wind Energy R&D Budgets in Mio. $ (based on IEA Database)

While R&D expenditures represent the inputs for innovation, both scientific papers and patent applications can be used as (intermediate) output indicators generated in the form of science and technology results (Kürtössy, 2004, pp. Fig. 1). Figure 3 shows the number of scientific papers published on wind energy technology by different countries during various time periods.[1]

Looking at this data, several trends become evident: first, the United States became dominant in this area of research early on, producing approximately twice the number of publications as the second most publishing country, the United Kingdom, in any given time period. Also notable is the role of China, which published its first two papers on wind energy in 1988, surpassed Denmark, Canada, Spain and the Netherlands in the period from 2000-2005 and significantly outperformed even the United States between 2006 and 2013, with 7,020 papers in this period as compared to 4,715 by US authors. Brazil, on the other hand, while always present with a few publications, has had rather few outputs in the form of scientific publications.

1 Based on a keyword search in the Scopus database using the search string TITLE-ABS-KEY ( "Wind power" OR "Wind Energy" ) in combination with affiliated country searches for US, UK, Germany, Japan, China, Denmark, Canada, Spain, Netherlands and Brazil.

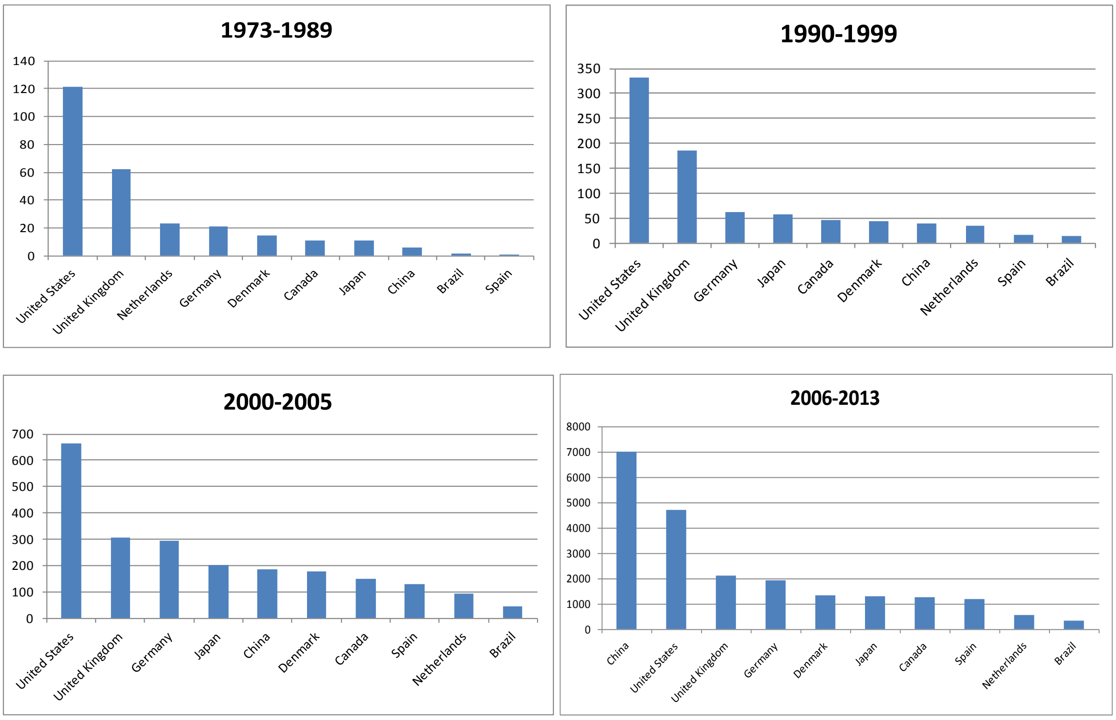


Figure 3: Scientific publications on wind energy (based on a Scopus search)

Patents are considered an intermediate output indicator for innovation activity, since they usually bridge the gap between basic or applied research and the market demonstration stage. From a long-term perspective, patent counts give a very detailed and complete overview of technical knowledge (Kleinknecht et al., 2002, p. 112). In the case of wind energy technology, Figure 4 indicates a similar long-term development as was already seen in scientific publications – after a slow start in the 1980s and '90s, patent applications began increasing rapidly as of 2000, with roughly a three-fold increase from 1990-1999 to 2000-2005 and a more than four-fold increase from 2000-2005 to 2006-2013.

In terms of country ranking, however, the picture painted by patent applications differs somewhat from what would be expected based on R&D expenditures and scientific publications. Figure 4 shows that in contrast to the stark dominance of the US in the first two indicators, it is instead Germany which dominates significantly across all time periods with regard to patent count. It is also interesting to note that China's extreme growth in the number of scientific publications has, to date, not translated to patents. While China did come close to catching up with the United Kingdom from 2006 to 2012, China and Brazil still have the least number of patents in all four time periods. The United Kingdom, on the other hand, does not have as many patent applications as would have been expected based on the first two indicators, much like the United States.

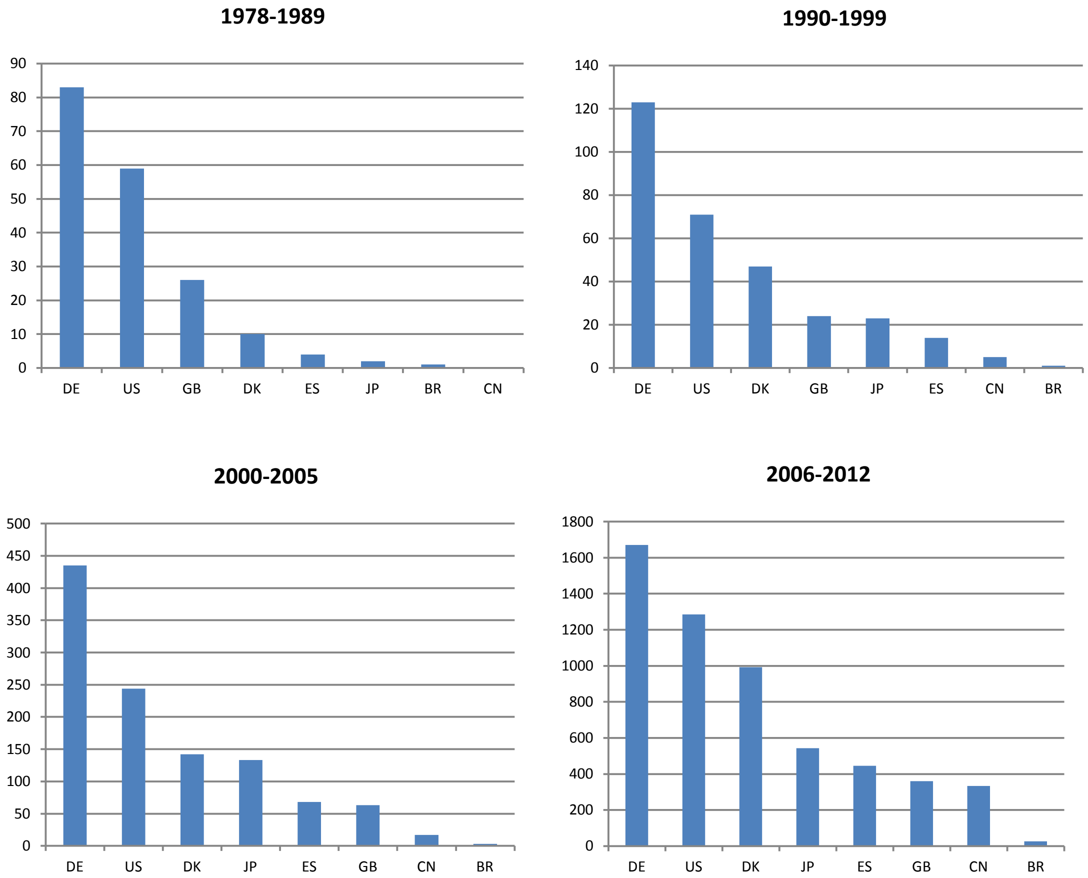


Figure 4: Wind energy patent applications in selected time periods (PATSTAT database, EPO and WIPO; analysis by Fraunhofer ISI)

The three indicators presented above all come from the 'technology push' side of innovation,[2] meaning that they are focused on researching and developing new technologies and changing the available market supply. Once these steps are completed, technologies need to become commercialized and begin to diffuse throughout the market – this is the 'market pull' phase of innovation, where market demand must rise to meet the available supply in order for a new technology to succeed at market penetration. Market diffusion is a complex process that is influenced not only by the prior technology push phase, but also by many other factors, including, in particular, market creation policies.

2 For a more detailed explanation of the 'technology push' and 'market pull' description of the innovation chain in the climate and energy innovation sectors, see Sagar, Bremner, and Grubb (2009).

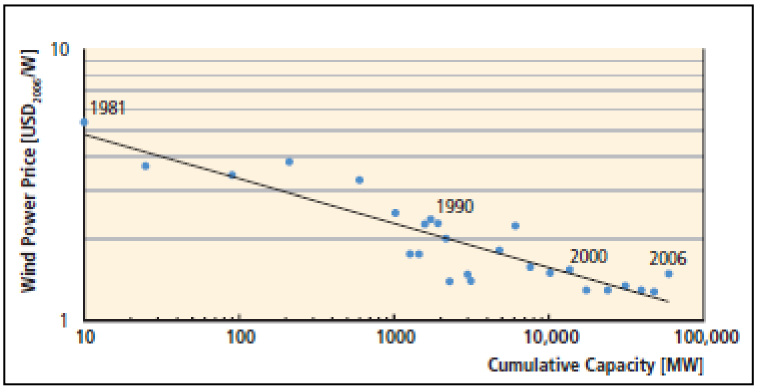


Figure 5: Learning Curve for Wind Turbines (Fischedick et al., 2011, p. 847)

When the market pull phase is successful, the effect can in some cases become self-reinforcing due to the cost-reducing effects of learning curves. Fischedick et al. list six mechanisms through which costs in the renewable energy sector can be reduced: learning by searching, by doing, by using, and by interacting, upsizing of technologies and creating economies of scale (2011, p. 846). All but the first of these mechanisms increase as more wind power capacity is produced and put into use, thus steadily decreasing cost. Figure 5 illustrates the learning curve for wind turbines, which is “the percentage cost reduction for each doubling of the cumulative capacity” (Fischedick et al., 2011, p. 847). It is clear that the costs of wind power have decreased dramatically as the cumulative capacity has increased. Thus, market pull can start the process of market diffusion, which in turn leads to learning curve effects, a reduction in costs and consequently even greater market diffusion.

The current status of this on-going process can be seen in Figure 6, which shows cumulative wind power capacity throughout the world starting in 2005.

It becomes clear that China has installed a huge amount of wind power capacity in this time frame. The United States likewise increased its capacity significantly, while the increase in Germany has been slower. As in all other indicators, Brazil still clearly lags behind the leading countries. In terms of countries’ abilities to meet their electricity demand using wind power, Denmark clearly takes the lead, covering approximately 34% of its electricity demand with wind power. The other frontrunners in wind power innovation all lag far behind with the following approximate rates of wind energy penetration: Germany (12%), UK (8%), Netherlands (5%), US (4.5%), China (3%), Brazil (2%) (US Department of Energy, 2014, p. 8)

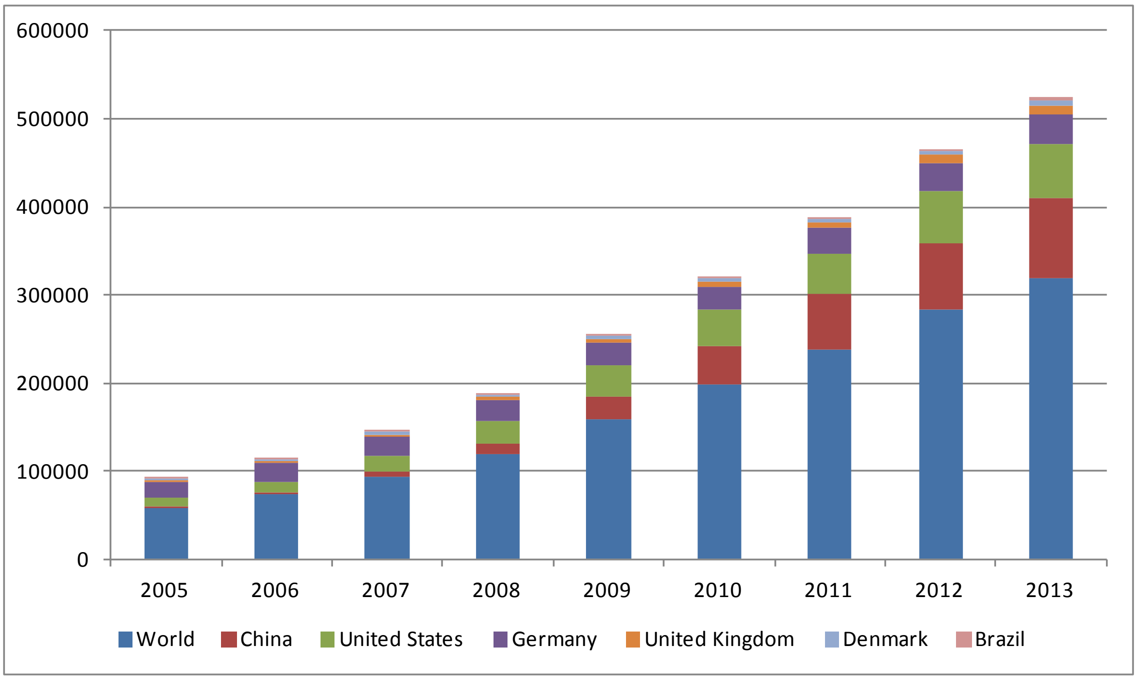


Figure 6: Global Cumulative Wind Power Capacity in MW (based on GWEC, 2014)

Overall, the wind energy sector has been very dynamic, particularly over the past 5-10 years, a trend that can be seen across all indicators discussed above. Looking at the installed wind power capacity in China, Brazil and the rest of the world – countries which have not historically been at the forefront of wind energy research – it appears that the global diffusion with regard to wind energy equipment has been quite successful. However, innovation activities continue to take place in relatively few countries, primarily including the United States, the United Kingdom, Germany, Denmark, and Japan. This shows that while equipment is successfully being transferred to other countries, very little global diffusion of knowledge seems to be taking place. One exception to this is China, which surpassed the United States in scientific publications on wind energy in the period 2006 to 2013. Given that China has likewise increased its number of patents in this sector somewhat – but not nearly as dramatically as its number of publications – it appears that the link between scientific publications and patents is not as close as had been suspected. This implies that there are likely further influencing factors, such as a country's strength in mechanical engineering, that play a significant role in the innovative capacity of a country's wind energy sector. Certainly all countries, regardless of their participation, have benefited from the dynamic innovation process of the recent years as it has led to significant learning curve effects and consequently strongly reduced costs for wind energy technology.

# 3 Theoretical Background

Subsequent to the overview about innovation activity in the global wind energy sector provided in the previous chapter, this chapter presents the theoretical foundations of this study.

Companies that want to enter a foreign market can choose between different entry modes, e. g. export, licensing, joint ventures or wholly owned subsidiaries.[3] On the company-level, each of these entry modes has different implications with regard to investment needs, risks, or the degree of control over foreign operations (Hill, Hwang, & Kim, 1990).[4] This choice, in turn, has important implications for the generation of spillover effects and technology diffusion in the receiving country (see e.g. Keller, 2004). The choice between different technology transfer modes, such as intrafirm transfer to a subsidiary, licensing or market transfer, can be paraphrased as the choice between different boundaries of the firm. The analysis of boundary decisions lies at the heart of the theory of the firm (Foss, 1996). Since the early publications of Oliver Williamson (1975), transaction cost economics (TCE) has been the dominant research paradigm for analyzing boundary decisions of the firm which is why in the following we will draw upon transaction cost economics as the theoretical background of our study.

Please note that our objective here is not to develop a fully-fledged framework for the analysis of spillover effects conditional on the choice of technology transfer mode but rather to introduce important theoretical approaches and concepts that will guide our further analysis and emphasis linkages between the different concepts.

In a nutshell, TCE states that there are fundamental differences between market and intrafirm exchanges in terms of the efficiency of different types of transactions. Transactions are defined as occurring “when a good or service is trans-

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[3] In fact, the available variety of entry modes is in fact much larger, see e. g. Andersen and Gatignon (1986). In order to reduce the complexity of our analysis we will distinguish only between export, licensing, joint ventures and wholly-owned subsidiaries.

[4] As this study is concerned with the issue of international technology transfer, in the following we will use the terms technology transfer mode or channel instead of market entry mode..

ferred across a technologically separable interface” (Williamson, 1981, p. 554). Because human behavior is characterized by bounded rationality[5] and opportunism,[6] transactions conducted in the market place are not free of cost. Instead, agents accrue search and information, bargaining, and/or policing and enforcement costs (Menard & Shirley, 2008; Voigt, 2009) in their attempts to find the desired good and acquire it under the most favorable conditions. During a transaction, there are incentives for both buyer and seller to maximize their share of the quasi rent, which can lead to disingenuous rent-seeking. To avoid this risk, there are two possible forms of governance: either the use of contracts or vertical integration into the firm. Klein et al. assume that “as assets become more specific and more appropriable quasi rents are created (and therefore the possible gains from opportunistic behavior increase[…]), the costs of contracting will generally increase more than the costs of vertical integration” (Klein, Crawford, & Alchian, 1978, p. 298). This is due to the fact that, given the limitations of bounded rationality, it becomes near impossible to cover all possible scenarios in which one of the parties could appropriate the quasi rent. As a result, Williamson posits that market transactions can – depending on the specific characteristics of the transaction – be more expensive than intrafirm transactions. These characteristics therefore determine the degree of organizational interaction that will be most efficient, ranging from a market, or arms-length, interaction to an intrafirm (hierarchical coordination) interaction. With these assumptions in mind, transactions are then evaluated along three dimensions:

- asset specificity;
- frequency of the transaction; and
- uncertainty surrounding the transaction (Williamson, 1981).

Asset specificity is considered the most important of these three aspects and is defined as the "ease with which an asset can be redeployed to alternative uses and by alternative users without loss of productive value” (Williamson, 1991, pp. 79–80). The greater it is, the more likely is an intrafirm exchange, since both buyer and seller are dependent upon each other to a great degree: assuming constant uncertainty and repetition of the transaction, market exchange is favorable for non-specific assets, bilateral contracting is preferable for semi-

[5] “Boundedly rational agents experience limits in formulating and solving complex problems and in processing…information, [but] otherwise remain ‘intendedly rational’” Williamson (1981, p. 553).

[6] Defined by Williamson as „self-interest seeking with guile“ Williamson (1981, p. 554).

specific assets and internalization is the best option for highly specific assets (Williamson, 1981). Williamson argues that the key aspect of asset specificity is that it locks both parties to a transaction in, as the seller cannot easily find another buyer, nor can the buyer find another seller on equally favorable terms (Williamson, 1981, p. 555). With regard to frequency, Klein (2006) distinguishes between three types of frequency found in the literature: 1) the frequency of trade between specific trading partners; 2) the frequency of trade among many trading partners; and 3) the frequency of disturbances in the environment. With regard to the second type, which is of importance here, Williamson states that, first and foremost, specialized governance structures are most beneficial when asset specificity is high. However, in addition to this factor, the question arises "whether the volume of transactions processed through a specialized governance structure utilizes it to capacity […]. The cost of specialized governance structures will be easier to recover for large transactions of a recurring kind" (1985, p. 60). The frequency of interactions, even among different trading partners, is thus a relevant consideration with regard to the investment in specialized, i.e. hierarchical, governance structures. Finally, the preferable amount of organizational interaction is determined by the degree of uncertainty surrounding a transaction.

Anderson and Gatignon distinguish between external and internal uncertainty. External uncertainty is defined as "the volatility (unpredictability) of the firm's environment", often also termed "country risk" in the international context (1986, p. 14). Here, too, asset specificity plays a significant role in how uncertainty should be handled. If asset specificity is low while external uncertainty is high, the authors advise the avoidance of ownership, since it reduces flexibility and binds the firm to an environment that may no longer be as desirable after an environmental shift occurs. If asset specificity is high, on the other hand, flexibility is already strongly reduced given the dependence on a particular partner, leading to the conclusion that "given some degree of asset specificity, control becomes more desirable as uncertainty increases" and ownership thus becomes a progressively more attractive option (Anderson & Gatignon, 1986, p. 14).

Internal uncertainty "exists when the firm cannot accurately assess its agents' performance by objective, readily available out measures" (Anderson & Gatignon, 1986, p. 15). Internal uncertainty plays a particularly relevant role in the international context. The authors posit that, from a transaction cost perspective, a firm's degree of control in a foreign firm should increase with its international experience, as this leads to greater confidence in foreign markets.

However, they concede that this statement may not apply in non-competitive industries, where the inefficiencies that stem from ethnocentrically motivated demands for control are not immediately extinguished by market pressures (Anderson & Gatignon, 1986, pp. 16–17). Socio-cultural distance likewise influences the amount of control that is seen as appropriate from a transaction cost perspective: due to interactions between the amount of control and the degree of asset specificity, in settings with great socio-cultural distance, either low or high levels of control can be appropriate and both are considered more efficient than intermediate levels. The option of high control levels, which lead to a high degree of asset specificity in this context, should only be employed if there are significant advantages to employing the market entrant's management style rather than the local methods. Finally, the value of the brand name influences the appropriate level of control: the greater an asset the brand name is for a company, the higher its level of control should be in foreign markets to ensure the protection of its reputation and standards. A similar argument can be made for further intangible assets such as technological know-how and tacit knowledge in situations where the foreign market has weak enforcement levels of intellectual property rights.

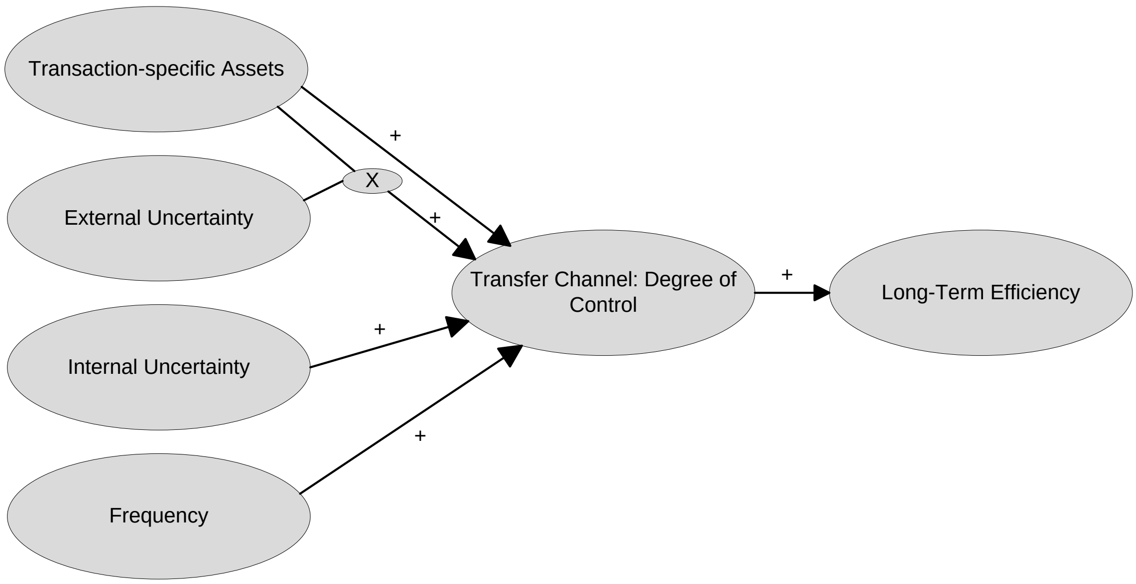


Figure 7: Transaction Costs Framework for Analyzing the Choice of Transfer Channel (based on Anderson & Gatignon, 1986)

A number of authors have already used transaction cost theory to analyze international technology transfer, e. g. Mundaca et al. (2013) perform a meta-analysis on studies dealing with transaction cost of low-carbon technologies and conclude that their manifestation is highly technology and policy-specific.

Among the most influential to our work are two papers by Davidson and McFetridge (1984; 1985), which examine the key characteristics that determine the transfer channel chosen for international technology transfer. They find positive correlations between the probability of internal transfer and particular characteristics of the recipient country, specifically geographic proximity to the transferor and certain demographic attributes, such as language and religion (Davidson & McFetridge, 1985). Moreover, transferors with high R&D intensity, with prior affiliations to the recipient country and those who have previously transferred technology are also more likely to internalize a transfer. Finally, the likelihood of an intrafirm transaction increases "(a) for newer technologies; (b) for technologies with fewer previous transfers; (c) [the close the technology is to] the transferor's principal line of business" (Davidson & McFetridge, 1985, pp. 11–13). They conclude that in the context of technology transfer, the degree of asset specificity and uncertainty surrounding a transaction increases for

- new technologies;
- technologies which make significant progress on the state of the art; and
- for which there were few prior transfers (Davidson & McFetridge, 1984).

Looking at the impact that these characteristics have on the channel that will be chosen for technology transfer, it can be argued that all three aspects increase the measurement costs that accrue to the buyer, since he has few or no experiences to refer back to in verifying the quality of a particular good. Moreover, the more significant the technological advances, the more risk accrues for the seller when transferring his technology to an unfamiliar buyer and/or market. Thus uncertainty surrounding the transaction can have a more significant impact.

Lastly, transferring technologies from developed to developing countries generally implies having to make adjustments to account for the local context, which further increases asset specificity. In sum, then, "the probability of internal transfer is higher the newer and more radical is a technology and the fewer the occasions upon which it has been transferred" (Davidson & McFetridge, 1984, p. 259).

# 4 International Transfer of Wind Energy Technology to China and Brazil

## 4.1 Methodological Approach

Methodologically, a case study approach, see e. g. Yin (2009), was chosen to analyze the international transfer of wind energy technology to China and Brazil. Given the complexity and dynamics of this subject, a case study approach allows us to explore qualitative and unexpected factors of influence. Moreover, we are able to combine information that was gathered from multiple sources, such as expert interviews, statistical data, and documents. The most important empirical data source were 11 personal interviews that were conducted with experts from companies, industry associations, development agencies and public authorities in China and Brazil (Table 1). These experts were carefully selected in order to capture a wide range of views and expertise. The interviews were conducted in person or by telephone, depending on the location and availability of the interviewee. The interviews were semi-structured, using a set of open questions and a short questionnaire with a 5-point Likert scale. The questionnaire assesses the influence of different transaction specific characteristics on the speed and ease of technology transfer. These characteristics were chosen based on the work of Davidson and McFetridge (1984) and were divided into technological, market-related and political/cultural characteristics. Two different interview guidelines were used, adjusted either for experts from companies or for experts from policy-making institutions. The interview guideline design ensured that, depending on the field of work of the interviewee, all important aspects were covered, while keeping the necessary flexibility regarding further questions as part of a natural conversation (Mayer, 2012, p. 37).

| Interview Code | Country | Organization |
|---|---|---|
| C-1 | China | Research Institute |
| C-2 | China | Industry Association |
| C-3 | China | Development Agency |
| C-4 | China | Consultant |
| C-5 | China | Wind Turbine Manufacturer |
| C-6 | China | Wind Turbine Manufacturer |
| B-1 | Brazil | Industry Association |
| B-2 | Brazil | Development Agency |
| B-3 | Brazil | Wind Turbine Manufacturer |
| B-4 | Brazil | Project Developer |
| B-5 | Brazil | Project Developer |

Table 1: List of Interviews

The rest of the chapter is structured as follows: Sections 4.2 (China) and 4.3 (Brazil) provide an in-depth description of the findings of the two case studies, which are then summarized and compared analytically in Section 4.4 using the theoretical foundations laid out in Chapter 3.

## 4.2 China

### 4.2.1 China's Wind Power Market

China is the global leader in the wind power market with 91.4 GW of cumulative installed wind power capacity by the end of 2013. China's wind capacity increased more than a hundredfold from only 0.55 GW in 2003, currently making it the third largest energy source (6 %) in installed capacity after coal (66 %) and hydropower (22 %) (GWEC, 2014, p. 19). In terms of newly installed capacity, China outpaces its global competitors with 16.1 GW capacity connected to the grid in 2013, which accounts for 45.6% of the world's total newly installed capacity and a growth of 24.1% from 2012 (CWEA, 2013, p. 3; GWEC, 2014, p. 18). The takeoff of China's wind power industry was mainly triggered by China's Renewable Energy Law in 2006. Since 2009, the annual growth of wind power capacity has stabilized at an average of 16 GW per year and shows that China is entering a phase of continuous growth. Generated wind power accounts for 2.6 % of China's total energy generation (GWEC, 2014, p. 42).

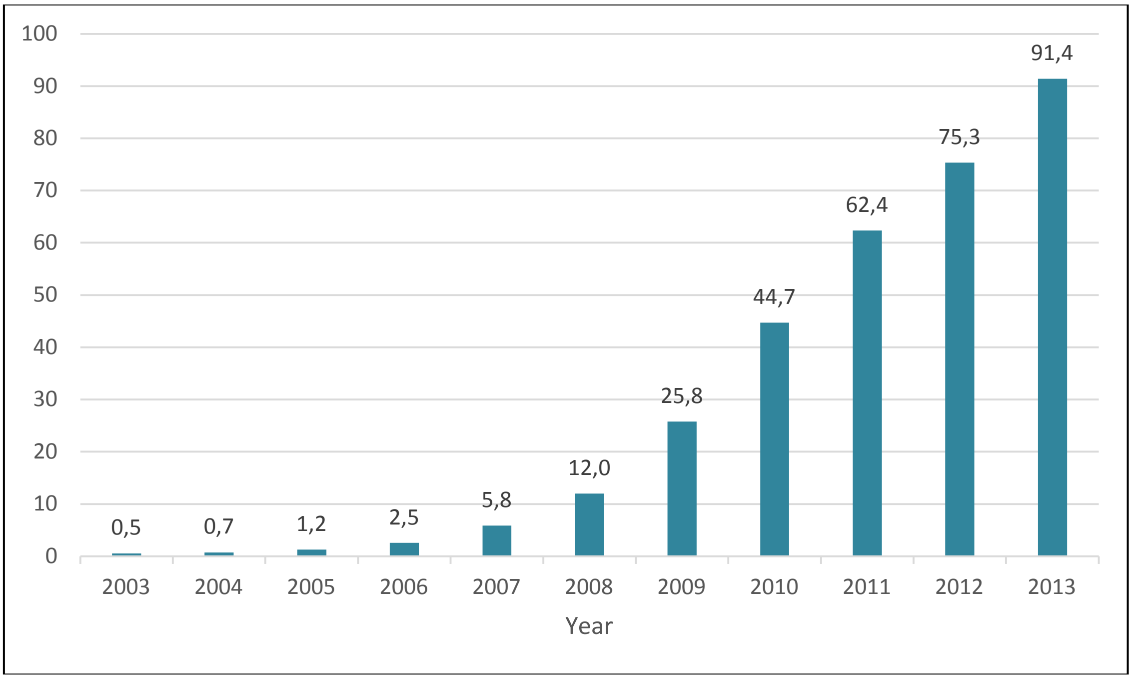


Figure 8: Total Installed Wind Power Capacity in China in GW (CEWA 2013)

The current Chinese wind turbine market is dominated by Chinese manufacturers. In the year 2012, Goldwind was the market leader with a share of 23 % of newly installed capacity, followed by the domestic competitors United Power (15.7 %), Sinovel (9.3 %), and Mingyang (8.7 %). The most important foreign companies in terms of market share were Gamesa (3.8 %) and Vestas (3.2 %) (CWEA 2012).

As in other countries, the trend in China is moving towards turbines with higher performance. Compared to China's fast overall growth in wind power, the progress of offshore wind installations has been rather slow. The share of offshore wind power amounts to only 4.6 % of the total installed capacity (WWEA & World Wind Energy Association, 2014, p. 24).

### 4.2.2 Market Formation Policies

A groundbreaking initiative for the development of the Chinese wind power market was the National Development and Reform Commission's (NDRC) Wind Power Concession Programme that was effective between 2003 and 2009. It introduced a competitive bidding process for government-selected sites, ready for development through domestic and international companies. The projects were relatively large-scale with capacities ranging from 100 to 200 MW. The central government guaranteed financial support, grid connection, preferential tax rates and corresponding infrastructure. The Concession Programme initiated a total of 18 wind projects with a cumulative capacity of about 3.4 GW. These concession projects included the first extensive application of the Local Content Requirements (LCR) of the $9^{th}$ FYP from 1996. The original requirements demanded 40 % locally manufactured components of the purchased wind power equipment for newly developed projects. The concession projects from 2003 increased that share further to 70 %. Consequently foreign wind turbine suppliers established their own manufacturing facilities in China, since there were only few Chinese manufacturers in the market at that time. The NDRC further institutionalized the LCR in 2005 and denied every wind power project with less than 70 % domestically produced equipment (IEA/IRENA, 2014; Lewis, 2013a, pp. 52f).

The Renewable Energy Law of the Peoples Republic of China that came into force in 2006 represents another milestone. The Law introduced nationwide renewable energy targets, a feed-in tariff system for wind energy, an obligatory purchase and connection policy, and a fund for renewable energy development, which pushed the development of renewable energies significantly. In the same year, the $11^{th}$ Five Year Plan was issued by the NDRC including several targets for wind power like the construction of 30 wind farms, each with a capacity of more than 100 MW by 2010, or the goal to increase on-grid wind power capacity to 20 GW by 2015 and to 30 GW by 2020. In addition, the Medium and Long Term Development Plan for Renewable Energy that came into force in 2007, targeted the development and use of renewable energies by implementing preferential financial and tax policies, including funds subsidizing renewable energies as well as the reduction or elimination of taxes for certain projects. It was supposed to increase the share of renewables of the total primary energy consumption by 15% by 2010 (Gallagher, 2014; IEA/IRENA, 2014; Lewis, 2013b)

In 2008 the Ministry of Finance (MOF) issued a funding policy for the commercialization of all locally produced wind power generation equipment. Under the condition that the China General Certification Center (CGC) tested and certified the equipment and that the turbines have been connected to the grid and put into operation, all turbines over 1 MW capacity were rewarded with RMB 600/kW (Lewis, 2013b, p. 56).

By the end of 2009, the Chinese government made amendments to the Renewable Energy Law in order to strengthen renewable energy development. The NDRC added offshore wind to the list of top National Research and Development Priorities in the Renewable Energy Industrial Development Guidelines.

Moreover, the Chinese government announced offshore wind deployment targets of 5 GW by 2015 and 30 GW by 2020 (Lewis, 2013b, p. 53).

In November 2009, Notice No. 2991 of the NDRC fully revoked the existing local content requirement on all wind turbines installed in China. In addition, the Ministry of Finance (MOF), the State Administration of Taxation and the General Administration of Customs removed import duties and value added taxes on key technological wind power equipment in 2010.

The next big strategic policy focusing on the promotion of renewable energies from various resources was the 12$^{th}$ Five Year Plan for National Economic and Social Development running from 2011 to 2015. The plan incorporates binding energy targets, such as decreasing the $CO_2$ emissions per unit of GDP by 17% and the overall energy consumption per unit of GDP by 16% by 2015. Further targets are the construction of 70 GW of wind capacity until 2015 (IEA/IRENA, 2014).

In 2012, the 12$^{th}$ FYP for Renewable Energy outlined new policy targets and indicators for renewable energies. The wind power connected to the grid is supposed to increase to 100 GW, including 5 GW of offshore wind power with an expected annual generation capacity of 190 billion kWh. The goals for the wind power sector were extended by the 12$^{th}$ FYP for National Strategic Emerging Industries, planning to scale up the commercialization of offshore wind power equipment production and adapt the production standards to international levels. Moreover, the Ministry of Science and Technology wants to put a focus on technology innovation planning to develop 3 - 5 MW direct-drive permanent magnet synchronous generator wind turbines as well as a 7 MW prototype. In order to approach the known grid integration problems, the State Council issued a plan to establish an efficient grid operation and management system applicable to wind power development (IEA/IRENA, 2014).

This range of different policies demonstrates China's strong commitment to expand and diffuse wind power technology. Foreign companies and their advanced technologies play a crucial role in the implementation of these leapfrogging strategies. It is interesting to learn how experts from the respective industries and government organizations have perceived the impact of the laws and policies and how the policy measures have influenced the transfer of technology and knowledge. Most of the interviewed experts see national policies as a crucial component with respect to the dissemination of renewable energy. Strategic and long-term policy initiatives, such as the Renewable Energy Law and the

12th FYP have created framework conditions that have made investments in renewable energy for local and international companies attractive. Certain measures within these policy programs have had a positive impact on technology transfer. From the Chinese perspective, the LCR have been a great success and significantly contributed to the formation of the Chinese wind power industry. Although JVs and joint development initiatives were never mandatory in the wind power sector, they were strongly supported by the Chinese government through various financial incentives. Thus, foreign turbine manufacturers found themselves forced to cooperate with Chinese companies in order to access these subsidies. The collaborations led to technology transfer through shared licenses and joint development of wind power equipment. However, after the establishment of Chinese wind turbine manufacturers, such as Goldwind, the preferential treatment of Chinese companies led to predatory competition.

### 4.2.3 Technology Gap and Absorptive Capacity

The expert interviews and the literature highlight the persistence of different technological gaps between China and the global state of the art. The gaps relate to grid integration, wind park operation and maintenance, and offshore wind development (Interviews C 2, C-3, C-4, C-5). Although the gap in on-shore wind power is rather marginal compared to offshore, existing turbines with less than 3.5 MW capacity are still lacking important grid technologies. Furthermore, performance, weight and environmental friendliness of these turbine types are still behind the global competition (IEA, 2012).

With regard to onshore wind, the mentioned gaps relate to problems with grid integration and the overall operation of wind parks. China still lacks important grid technologies like “Low (Zero)-Voltage Ride-through”, which allows wind turbines to continue operating during sudden drops in grid voltages rather than disconnecting from the grid. There are also problems with the implementation of advanced maintenance and operation standards, leading to shortened turbine life cycles and causing higher costs in the long term operation of wind parks (Interview C-3). Another gap exists with regard to innovation and quality of equipment. Although the top Chinese manufacturers are able to produce turbines with a capacity of up to 3.5 MW in mass production, they still lack behind in turbine design and innovation capacity. German manufacturers already supply wind turbine systems with more than 6 MW for offshore use, whereas Chinese companies are still at the prototype level for this capacity, which makes the gap in offshore wind power rather significant. As market trends point towards large-scale systems for the development of offshore wind capacities, some Chinese manufacturers have already started R&D programs for turbine units up to 10 MW. The first turbine systems of this size, however, are expected to reach commercialization after 2020 (IEA, 2012).

With regard to absorptive capacity, the experts assessed China's ability to absorb wind power technology to be medium or even high, because China has been very successful in absorbing wind power technology in the past and has demonstrated its ability to produce this technology at low costs. However, with regard to more applied innovation capacity there still seems to be a gap between China and the leading countries as evident from the number of patents in wind power technology (see Figure 4).

### 4.2.4 Technology Transfer Strategies

As became evident from the expert interviews, the most important strategies for the transfer of wind power technology to China are licensing and joint ventures (Interviews C-1, C-2, C-3, C-4, C-5, C-6). In the early stages, the Chinese wind industry was primarily developed by using licensed technologies from abroad. This led to a rapid development of the industry over a very short period of time (Interview C-5). Companies such as Nordex, Repower, Vensys and Siemens used licensing to enter the Chinese market (Interviews C-4, C-5). Licensing is favored in particular by smaller companies, because they have more to gain from licensing fees than to lose with regard to international competition or IPR infringement (Lewis, 2013b, p. 157). For Chinese turbine manufacturers, license agreements offer the opportunity to acquire basic knowledge of already approved technologies and thus support a rapid gain in market share (Interviews C-4, C-5, C-6). However, most license agreements mainly include production rather than design technology and usually exclude the latest turbine designs (Interview C-5). In addition, the licensed technology is often subject to certain restrictions, such as prohibiting the sale outside the domestic market (Lewis, 2013b, p. 157).

From the perspective of Chinese companies, joint ventures are more attractive than licensing agreements, since this form of cooperation typically involves newer and more complex technologies. Joint development has the advantage that there are no initial concerns about market competition and that each JV partner brings a different set of experiences and knowledge into the partnership. Chinese manufacturers, for example, can use the R&D experience of the German partner to adapt the technology to the Chinese context. Another benefit is that the IPRs of jointly developed technologies are shared among the partners and potential issues can be excluded in arrangements prior to the partnership (Lewis, 2013b, p. 158). These characteristics have made JVs a very successful and effective strategy for equipment and knowledge transfer (Interviews C-2, C-3). In the past, many partnerships between German and Chinese manufacturers evolved. Examples include joint development collaborations of Sewind and Hewind with Aerodyn, Shanghai Electric with Siemens, and Goldwind with Vensys. The cooperation between Goldwind and Vensys was expanded in 2008, when Goldwind acquired a 70% stake in Vensys in order to gain access to advanced knowledge (Goldwind, 2012, p. 13), 13, Interview C-3). The use of acquisitions to gain access to the innovation capacities of Western companies is a rather new strategy of Chinese wind power companies, that is available to established companies with sufficient financial resources (Lewis, 2013b, p. 157; Tan, Zhao, Polycarp, & Bai, 2013). One of the advantages of such acquisitions is the flexibility and freedom in decision-making regarding the use of the technology and respective knowledge that it involves. However, the acquisition can only be successful if the acquiring company is able to integrate the obtained expertise into its own business activities (Lewis, 2013b, p. 158). In the case of Goldwind and Vensys, the M&A model seems to work very well with respect to the exchange of knowledge, as has been proven through the commercialization of new jointly developed turbine designs (Interview C-3).

Licensing is generally considered one of the fastest diffusion channels. However, in the swiftly evolving Chinese market, licensing alone may not be effective, because licensed technology tends to become outdated rapidly. Therefore, it is necessary to include additional agreements that take future technological developments into account. In the past, wind power technology mainly diffused through companies like Goldwind using foreign licenses countrywide. Pursuing this strategy, diffusion outside the company only took place indirectly through personnel fluctuation between companies (Interview C-4). Although licensing offers the opportunity of fast implementation and usage of the technology, JVs additionally support genuine innovation processes, as employees of the Chinese companies are involved in R&D. Technology and knowledge transfer, though, are highly dependent on the success of the JV (Interview C-4).

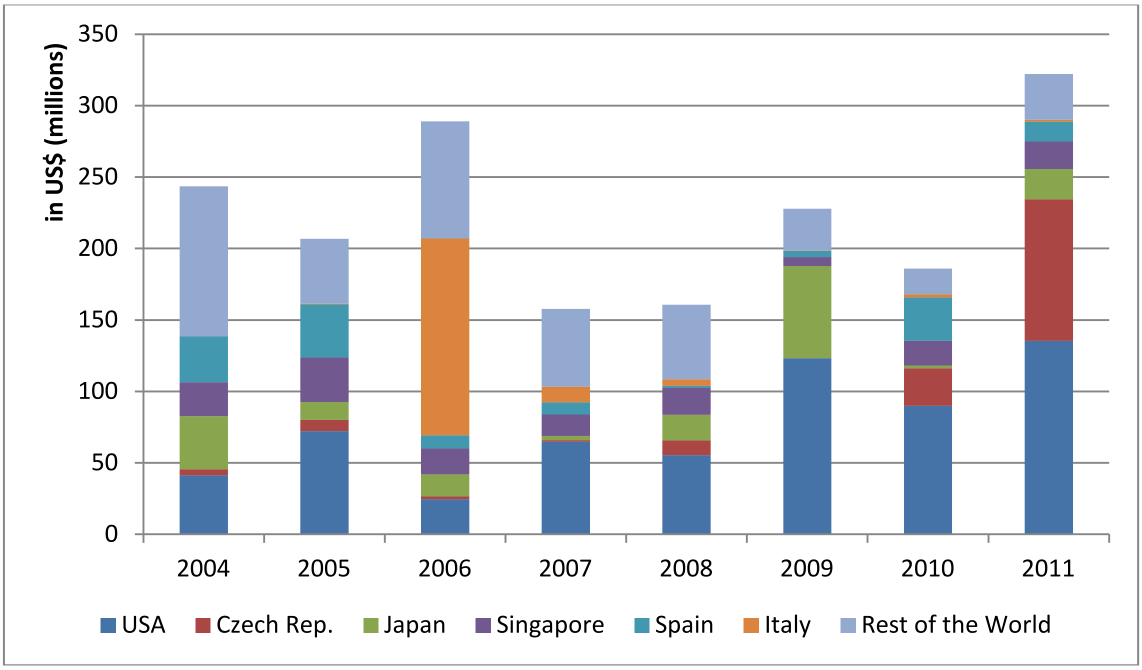


Figure 9: China's Top Import Partners for Wind Technology 2004-2011

Figure 9 shows the top countries from which China received wind technology imports between 2004 and 2011. Throughout this time period, the US was clearly the most significant import partner, while the contribution of other countries varied significantly from year to year.

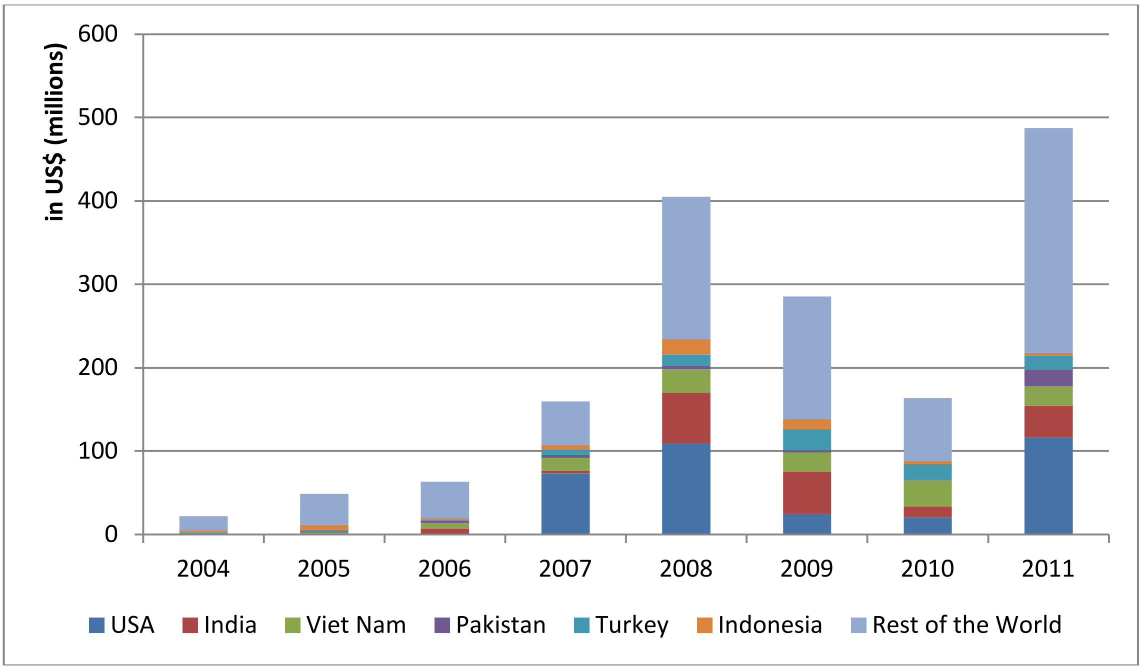


Figure 10: Top Recipient Countries of Chinese Wind Technology Exports 2004-2011, in Mio US$

A similar trend can be seen in the recipient countries of Chinese wind technologies (Figure 10), where only the exports to India and Vietnam show any consistency over the years. Such significant variations in trade partners from year to year may help to explain why international trade does not contribute as significantly to knowledge spillovers as other modes of interaction, since the types of longer-term relationships that are needed for the transfer of tacit knowledge do not have time to form.

### 4.2.5 Drivers and Barriers of Technology Transfer

The key drivers for the transfer of wind power technology to China identified by the interviewees are the market demand for renewable energy that was created by the Renewable Energy Law as well as the government's industrial policy that aimed for the build-up of a domestic wind power industry. Domestic manufacturing policies like the LCR forced foreign manufacturers to invest in local production facilities which resulted in technology transfer and accelerated the diffusion of wind power technology in China. A major barrier to technology transfer that was identified by the expert interviews is the poor quality of governance of the Chinese energy sector. Although China’s policy initiatives can in general be assessed as a driver for technology transfer, implementation and enforcement of regulations were viewed as hindering. The enforcement problem is partly linked to the fragmentation of China's energy bureaucracy (Interviews C-2, C-4). The high number of different actors and their diverging interests impede China's energy governance, due to dissension among the various agencies over the responsibilities for the content of certain laws and regulations (Downs, 2008, p. 42). Since most of these laws and regulations come from the central government and are top-down in nature, it is challenging to implement and enforce them successfully at the local level. In addition, regional governments also lack the knowledge to manage the diverse local interests of the different stakeholders. A more holistic regulatory framework could help to coordinate the various interests and authorities (Interviews C-4, C-5, C-6). Furthermore, the weak protection of IPR and the large geographic and cultural distance between China and e.g. Europe were mentioned as further barriers to technology transfer.

## 4.3 Brazil

### 4.3.1 Brazil's Wind Power Market

Brazil has an estimated wind power potential of 143.5 GW. This potential is concentrated mainly near the coast as well as on the north-eastern and southern parts of the country (CRESESB, 2001, pp. 42 f.). By the end of the year 2013, the cumulative installed wind power capacity in Brazil was 3.46 GW and another 4.7 GW of new wind power was contracted in three wind auctions. In addition to this, Brazil has several wind farms under construction with a total capacity of about 10 GW out of which 7 GW are expected to be connected to the grid by the end of 2015. Government projections in the Decennial Energy Plan estimate an installed capacity of 17.5 GW by the end of 2022 (GWEC, 2014, p. 36). This makes wind power development highly significant for the national energy matrix. Yet, in 2013, Brazil was still not under the top 10 countries of installed wind power capacity (GWEC, 2014). However, this might change in the future given that Brazil is ranked under the top 10 countries in newly installed capacity in 2013, demonstrating the momentum it is currently gaining in wind power development (see Figure 11). The objective of the Brazilian government is to produce 70 % of its energy from renewable sources and to reach 16 GW of installed wind power capacity by 2021 (LARIVE International, 2014).

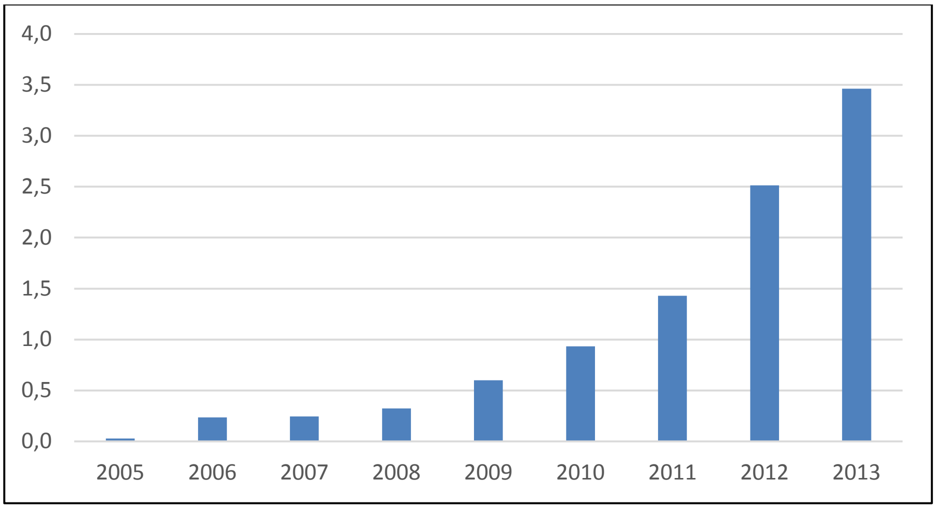


Figure 11: Installed Wind Power Capacity in Brazil in GW (ABEEólica, 2015, p. 4)

The first study on offshore wind power potential in Brazil was conducted in 2008, revealing favorable sites in the south eastern region between Rio de Janeiro and Porto Alegre. However, due to high investment cost and the remaining onshore potential, experts do not expect noteworthy developments of offshore wind power within the next decade (LARIVE International, 2014, p. 8).

The development of the Brazilian wind industry can be roughly divided into three phases:

- The first phase lasted from 1995 to 2002 and was characterized by smaller pioneering projects. It was a time of awareness raising and information diffusion, especially with regard to the complementary relationship between wind and hydropower.[7] Wobben Windpower, a subsidiary of the German wind turbine manufacturer Enercon, was the first multinational company in Brazil that made attempts to cease the market potential and develop the Brazilian wind power market (Interview B-3).
- During the second phase that lasted from 2002 to 2009, the Programme of Incentives for Alternative Electricity Sources (PROINFA) was established, including premium-tariffs for wind, small hydropower and biomass development (Interview B-3).
- In the third phase, which started in 2009, Brazil's wind industry benefited from the global financial crisis. The USA and Europe reduced their investments in renewable energies, so that international turbine manufacturers had to resort to

[7] In the time of the year when there is water scarcity and reduced production of hydropower, the wind is strong and windpower may compensate for the reduced production of hydropower.

alternative markets like China, India or Brazil. In 2009 a competitive auction system was established by the government, which aimed to increase energy security in a cost-efficient way (IRENA/GWEC, 2012). Wind power finally began to win auctions against other renewable energy sources due to increased competition induced by the rising number of international turbine manufacturers that entered the Brazilian market. Moreover, technological advances like increased turbines size and favorable exchange rates lowered the costs for wind power (Interviews B-1, B-3, B-5).

As of 2014, eleven turbine manufacturers were active in the Brazilian market, including Acciona (Spain), Alstom (France), Gamesa (Spain), Goldwind (China), GE Energy (United States), IMPSA Wind (Argentine), Siemens (Germany), Suzlon (India), Vestas (Denmark), WEG Equipamentos Elétricos (Brazil), and Wobben Windpower (Germany) (Larive International 2014). WEG Equipamentos Elétricos, the only Brazilian company, formed a joint venture with the Spanish wind energy company MTOI in 2011.[8]

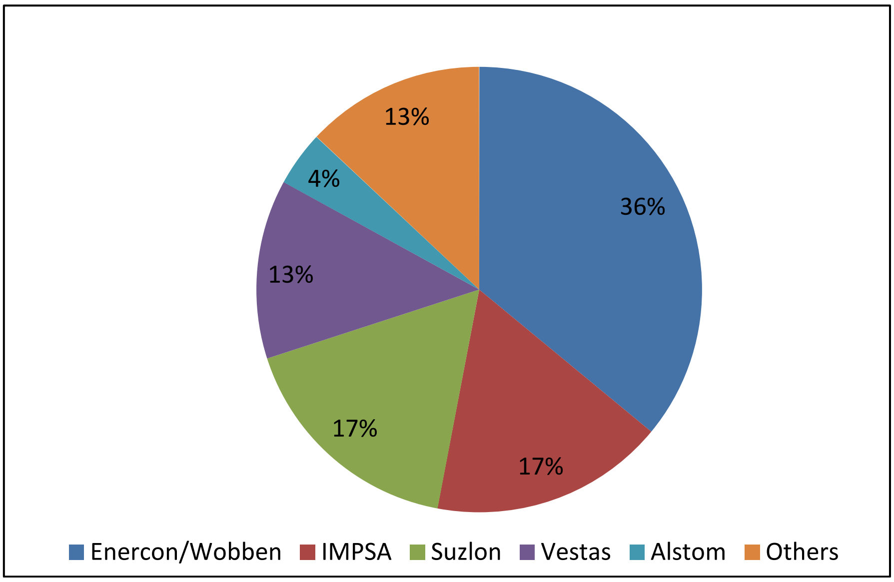


Figure 12: Turbine manufacturers market share in Brazil for projects with Turbine Purchase Agreements and Power Purchase Agreements (windpowermonthly.com 31 July 2014)

Based on the projects that are still in the pipeline, a stronger role for Gamesa, GE and Acciona can be expected in the future (Campbell, 2014). Even though foreign manufacturers dominate the Brazilian turbine market, a more holistic view at the wind power supply chain reveals that Brazilian companies have an

8 http://www.ebmag.com, 13.06.2011

important role to play in certain segments of the supply chain. Tecsis, for example, is the largest manufacturer of rotor blades in Brazil with a production capacity of 1,500 MW/year (LARIVE International, 2014).

### 4.3.2 Market Formation Policies

The first policy directed at wind energy in Brazil, the program PROEÓLICA[9], emerged in 2001 due to scarce rainfall and a crisis in the water dependent power sector. However, the foundation for this policy was laid in the 1990s with the reform of the energy sector. The liberalization and privatization began changing power structures after the centralization promoted by the military regime; the creation of the Independent Producer Law (9.074/1995) and the Auto-Producer Law (9.427/1996 and 9.648/1998) with open access to the grid created new possibilities for private investments and the free choice of energy producer by large consumers generated more competition.

The objective of PROEÓLICA was to build 1,050 MW of installed wind power capacity by the end of 2003. The Brazilian government wanted to reduce its strong dependence on hydropower, using wind power as a complementary renewable energy source in order to stabilize electricity generation in times of water scarcity. Therefore, the public energy company Eletrobrás was supposed to purchase wind energy for 1.2 times the market price in the first year and 1.1 times the market price in the second year (Molly, 2001, pp. 74 ff.). However, PROEÓLICA failed only one year after its implementation, since not a single wind project was commissioned in 2001 (Dutra, 2007, p. 183). A too tight authorization deadline, a lack of clarity about the benefits of the program, and the fact that the executive guidelines were never published, were major reasons for this failure. Additionally, unexpected increases in rainfall, filling the hydropower reservoirs reduced the priority for wind energy (Strauch, 2014, pp. 11 f.).

After the failure of the PROEÓLICA the PROINFA (Incentive Programme for Alternative Electric Energy Sources) started in 2002 (Fiestas, 2011, p. 4). The aim of PROINFA was to diversify the electricity mix by increasing the use of renewable energy source, such as wind, small hydro power (SHP) and biomass (GWEC/ABEEólica, 2011). The PROINFA was divided into two phases. During the first phase, 3,300 MW of renewable energy were contracted for a 20-year period by Eletrobrás in a public bidding process for a minimum of 90 % (wind),

[9] Resolution No. 24 of the Electric Energy Crisis Management Chamber GCE in 5 of July 2001 (http://www.ipef.br/legislacao/bdlegislacao/arquivos/9829.rtf).

70 % (biomass) and 50 % (small hydro) of the average retail price in the previous twelve months. 1,100 MW of the 3,300 MW were to be allocated to wind power, while the rest was allocated to biomass and SHP. To avoid competition among the different energy sources, prices were determined separately for each technology. The second phase of PROINFA was scheduled to come into force after the capacity of 3,300 MW targeted in the first phase had been met. Energy production from wind, SHP and biomass would be expanded to meet 10 % of the national energy demand within 20 years. Since the targets of the first phase were not met in time, the Ministry of Mines and Energy (MME) created the Alternative Sources Bidding (LFA – Leilão de Fontas Alternativas), replacing the second phase of PROINFA (de Castro & Dantas, 2008; www.entrepreneurstoolkit.org, 2011).

In Brazil, power is purchased and sold in three regulatory environments: the Regulated Market (Ambiente de Contratação Regulada – ACR), in which power is purchased through auctions, the free market (Ambiente de Contratação Livre – ACL), where power is purchased directly among market participants, and the short term market (Mercado de Curto Prazo – MCP), where the balance of purchased and effectively used power is regulated in multilateral agreements (Câmara de Comercialização de Energia Elétrica).

There are several kinds of auctions in the regulated market, some for specific aims. The main types are:

- Alternative Sources Auction (Leilão de Fontes Alternativas – LFA or FAR, Fontes Alternativas Renováveis): these auctions are directed at increasing the participation of renewable energy sources in the national mix;
- Structuring Auction (Leilão Estruturante): at these auctions, power is purchased from large strategic projects to assure low cost and a stable energy supply to final clients;
- Reserve Power Auction (Leilão de Energia de Reserva – LER): created to increase the power supply security, purchasing more power than is needed in the system;
- New Power Auction (Leilão de Energia Nova – LEN): meant for the purchase of power from power plants that have not yet been built but are expected to begin supplying power within either three (A-3) or five years (A-5);
- Existing Power Auction (Leilão de Energia Existente): meant for purchases of cheap power from A-1 power plants that are already amortized and where the supply starts within one year) (Câmara de Comercialização de Energia Elétrica).

The power purchase contracts under the PROINFA regime were not made through auctions, but rather through public calls, for which the incentives and the selection procedures are set in law 10.438/2002. Thus, PROINFA is a fully protected purchase environment.

In 2009 a Reserve Power Auction (LER) for wind power only was created, as well as an Alternative Sources Auction (FAR) that also included wind power in 2010. Other LER auctions followed later on and wind gained in competitiveness in relation to other sources. In these auctions, a maximum price per source is defined for the start of the auction, based on cost calculations. The costs for wind power decreased in the last years and have reached grid parity (McIvor, 2011).

Apart from the projects commissioned under PROINFA, 50 additional projects with a cumulative capacity of about 2.4 GW were granted by ANEEL, Brazil's electricity regulatory agency. Wind projects could now attend the New Energy and Alternative Sources biddings (LEN and FAR)[10]. Many investors submitted project tenders, but did not participate either in the LEN A-3 and A-5 bidding processes or in the alternative sources bidding process in 2008, signalling that there is interest from wind power developers, but that they needed differentiated treatment (EPE, 2009, p. 8). Therefore, a specific wind power auction was prepared for the end of 2009, defined by the Ministry of Mines and Energy[11]. Between 2004 and 2010 the first PROINFA wind parks were installed. Public biddings for other energy sources were made, but wind power still had no competitiveness. However, in 2009 wind power began to win biddings, because of

- Technological development: larger rotor blades and higher towers;
- Favorable exchange rates;
- Increased competition due to new market entrants (Interview B-3).

In 2009 there was the first auction at 180 R$/MWh and 1.8 GW were contracted. In 2010 there were 2 auctions with 2 GW contracted at 140 R$/MWh. At that time, Wobben Windpower and Impsa were already present in Brazil and Suzlon was about to enter the market. In 2010 more manufacturers entered the Brazilian market. In 2011 a new auction was made and 2.7 GW were contracted at

[10] New Sources Tender: Leilão de Energias Novas (LEN); Alternative Sources Tender: Leilão de Energias Alternativas (FAR)

[11] MME Ordinance n. 147/2009 Art. 1°, § II (Portaria do Ministério de Minas e Energia N° 147 de 30 de Março de 2009).

100 R$/MWh. Wind power became the second most competitive energy source next to large hydropower. The government viewed wind power as an alternative to hydro power and competitive in relation to small hydropower, whose costs were at about 140 R$/MWh (Interview B-1).

Prices were higher in the past because manufacturers expected higher margins, but they had to adapt to the Brazilian market (Interview B-5). The increase in wind turbines size reduced costs as well. Today the price of wind turbines in Brazil is comparable to the USA and India, for example; the cost of a wind turbine per MW installed capacity came down from 4 million USD to 1.5 million USD (Interview B-5). In recent years, wind power loses only to large hydropower in costs, according to the wind power association (Interview B-1). Brazil has now has the cheapest wind power in the world, because of the competitive auction model and the high capacity factor, which for Brazil is on average 38, in some places 46, while in Europe it is 28 (Interview B-5).

For the first phase of PROINFA, the so-called nationalization indices were introduced, putting a 60 % local content requirement on equipment and a 90 % rate on services. The regulations specified which parts of technical equipment had to be locally sourced. Until 2013 wind turbines had to have at least 60 % national content, and since December 2013 at least 80 % (Interview B-1, B-3). The Brazilian government even plans to increase the nationalization requirement to 100 % by 2015 (Buist, 2014).

Another stipulation pertaining to the wind-only auctions prohibits the import of wind turbines with a capacity below 1.5 MW. In the guidelines that regulated the public biddings, however, no nationalization indices are mentioned (GWEC/ABEEólica, 2011). Nevertheless, compliance with local content requirement offers companies access to low-interest loans and funding from the Brazilian Development Bank (BNDES), and thus attracted a number of manufacturers from abroad (Fiestas, 2011, p. 12). From 2014, the BNDES requires that gearbox, generator and doubly fed induction generator must be produced locally. For direct drive models, at least three of the four main elements (towers, blades, nacelles and hub) must be produced or assembled in Brazil (LARIVE International, 2014).

### 4.3.3 Technology Gap and Absorptive Capacity

When the first wind parks were installed in the 1990s, there was a major technological gap between the technologically leading countries and Brazil (Interview B-5). Today the wind power technologies employed in Brazil are close to the global state-of-the-art (Interviews B-1, B-3, B-4, B-5), with the exception of offshore technologies (Interview B-4). Almost all wind power technologies employed in Brazil come from abroad or foreign turbine manufacturers with manufacturing sites in Brazil (Interview B-4, LARIVE International, 2014, p. 17. The challenge is to adapt the foreign technology to the Brazilian context. The wind and climate conditions in Brazil are different from Germany or Europe. In Brazil, there are no turbulences and mostly unidirectional winds, whereas turbines in Europe are optimized for fluctuating wind speeds, turbulences and extreme temperature conditions (Interview B-1). Some manufacturers conducted studies in Brazil, but the majority of technology development takes place at the manufacturer's home countries, where development centers are located (Interview B-3). Due to this competitive market in Brazil some manufacturers launch new technologies first on the Brazilian market (Interview B-3). In Brazil there are different requirements for technology: While there is a general trend towards larger rotors, which are more expensive and suited for space concerns; Brazil emphasizes high capacity factors, which are lower for large rotors, and therefore favors smaller rotors (Interview B-3).

The fact that wind power technology is not developed in Brazil results in a rather large gap in innovation performance between Brazil and those countries leading the global wind power technology development. This is also supported by patent and publication data.

### 4.3.4 Technology Transfer Strategies

According to the wind energy experts that took part in our study, the transfer of technology from multinational wind power companies to their subsidiaries in Brazil is the most important transfer channel. As mentioned earlier, the growth of the Brazilian wind power market has attracted a number of international wind turbine manufacturers. In order to comply with the local content requirements stipulated by PROINFA as well as the financing requirements of BNDES, many of these companies have chosen to invest in their own production facilities in Brazil. Wobben Windpower, for example, currently has three production sites: Sorocaba (São Paulo), Pecém (Ceará) and, since 2012, in Parazinho (Rio Grande do Norte), where the company produces the turbine models E-48 (800 kW) and E-70 (2,000 kW) as well as rotor blades and concrete towers. The annual production capacity is 500 MW/year. Moreover, according to information provided by GWEC/ABEEólica (2011), Impsa and Gamesa have production capacities of 600 MW and 400 MW respectively, which resulted in a total capacity of 1,500 MW/year. Due to their success in recent tenders, General Electric, Alstrom, Vestas, Siemens, Suzlon, and Guodian United Power had announced new investments in production facilities (GWEC/ABEEólica, 2011). According to a representative of a company that entered the Brazilian market by a wholly-owned subsidiary, the availability of trained staff was a problem at the beginning of the venture, which however could be solved by staff training (Interview B-3).

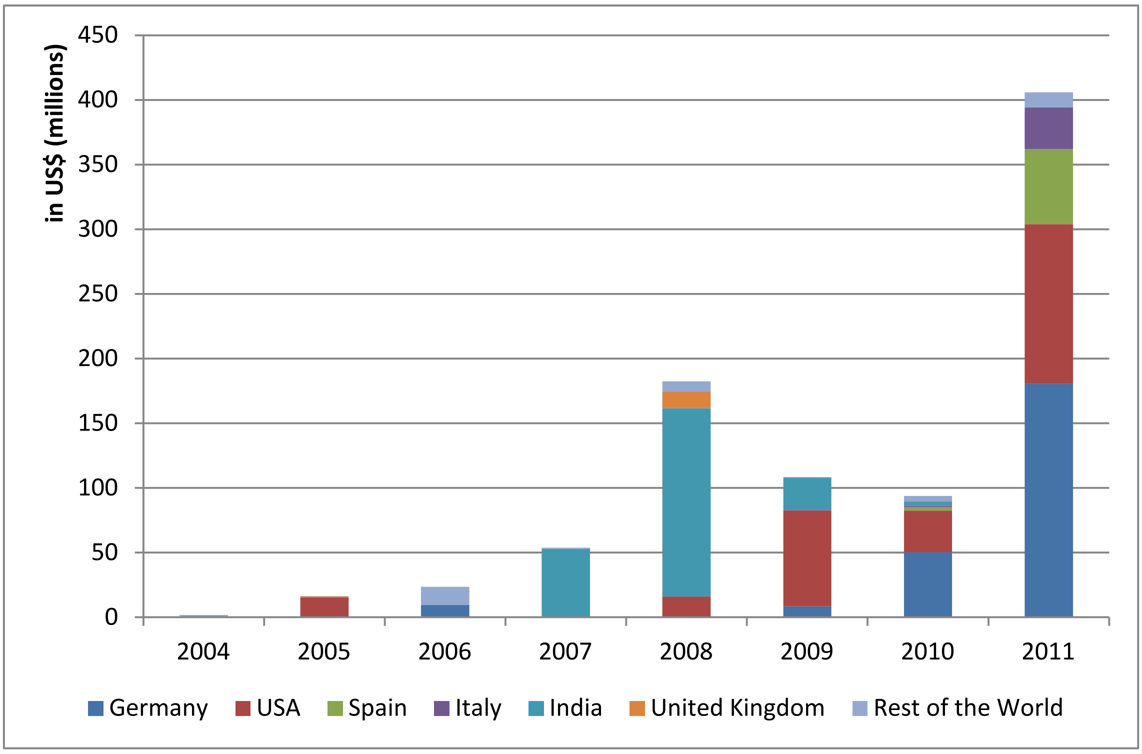


Figure 13: Brazil's Top Import Partners for Wind Energy Technology

Trade has played a rather small role in the development of the Brazilian wind technology sector. Looking at the wind technology import data since 2004 in Figure 13, it becomes clear that the amount of imported technology is strongly variable from year to year. Germany was initially a strong player in Brazil, especially due to early action by Wobben Windpower. Due to uncertainties about government support, the national content requirements, and complex tax structures, other companies refrained from investing in Brazil at that point in time. However, after 2008 a number of factors came together to make the Brazilian market more attractive: the financial crisis and slowdown in the wind power markets in Europe, the installation of PROINFA parks in Brazil, as well as the planning of tenders with premium prices. Consequently a number of foreign companies turned their attention to Brazil. This development caused the very uneven distribution of import partners in the last years that can be seen in Figure 13.

A similar trend can be observed with regard to Brazilian exports of wind technology (Figure 14). While the United States received some amount of wind technology from Brazil in most years since 2004, the value exported there is far below US$ 10 million. The United Kingdom, Argentina, the Netherlands and Costa Rica all imported larger amounts from Brazil in one or two years, but do not show up as export partners at all in other years. One explanation for this inconsistency is that wind power technology tends to be developed and installed in very large projects. These require a significant amount of technology while they are being carried out, but nothing thereafter.

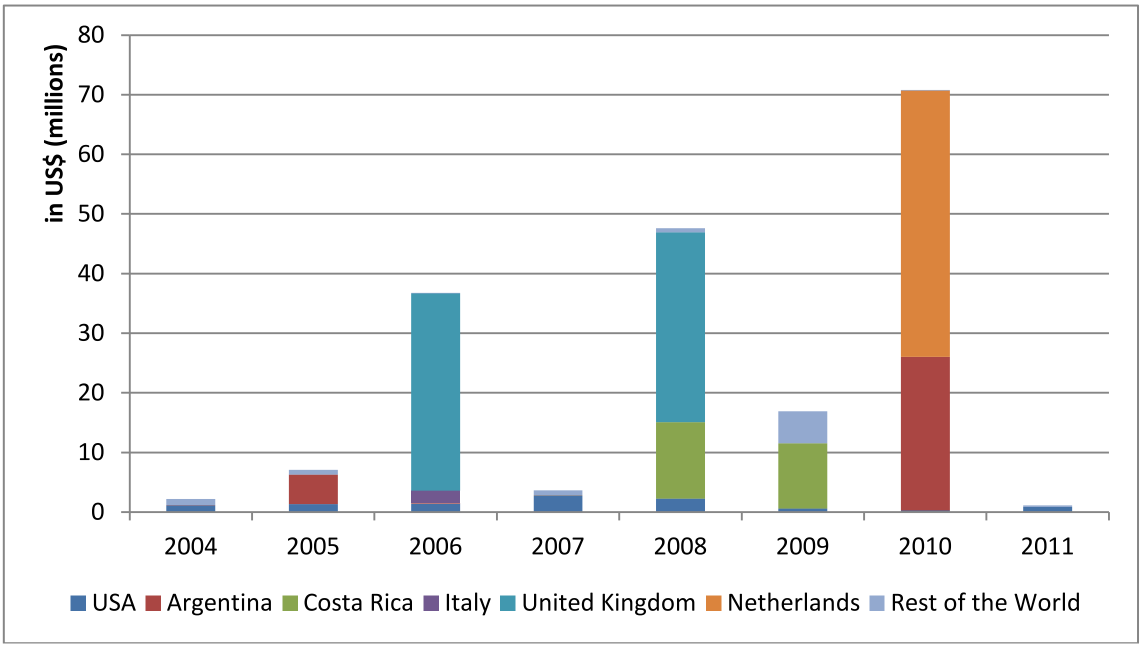


Figure 14: Top Recipients of Brazilian Wind Technology Exports

### 4.3.5 Drivers and Barriers of Technology Transfer

The interviews highlighted that commercial viability of wind energy, the use of state-of-the-art technology, strong competition and the local content requirements were perceived as the most important drivers for technology transfer to Brazil. The commercial viability is in particular due to Brazil's high capacity factors and the fact that technological advancements in the global wind power industry have helped to bring down the costs (see chapter 2). Given the expected increases in electricity demand and the government's ambition to diversify Brazil's energy matrix, wind energy is seen as an alternative to established energy sources. In this situation, wind power has to compete with other renewable energy sources, in particular small hydro power and biomass, but its success in recent public biddings suggest that wind power is competitive vis-à-vis these technologies and that new wind power capacity will be added in the next years. Wind power's commercial viability is closely related to the intensive competition between the leading international wind power companies and the use of state-of-the-art technologies, because, as outlined in chapter 2, technological development has been directed at cost reductions. According to one interviewee, some manufacturers launch their new technologies first in Brazil due to the competitive nature of the Brazilian market (Interview B-3). Furthermore, the local content criteria stipulated by government policies and the financing requirement of BNDES are perceived as drivers for technology transfer because it induces foreign manufacturers to establish production facilities in Brazil. The potential spillover effects emanating from such FDI have been briefly discussed in chapter 3. Given the fact that Brazil's own wind turbine industry and the related research infrastructure are in its infancy, it seems to be most likely that spillover effects will occur through forward and backward linkages in the supply chain and workforce migration.

Important barriers to technology transfer that were identified by the experts are the lack of a complementary infrastructure and the low governance quality of the energy sector. The lack of a complementary infrastructure refers in particular to bottlenecks in the wind power supply chain, e. g. pertaining to steel plates for the construction of towers, which resulted from the fact that the government and BNDES stipulated local content requirements without taking into account that the wind power supply chain in Brazil was not fully established. According to the experts, weak governance quality becomes apparent in management mistakes within government institutions impeding the implementation and enforcement of government policies. Another example regarding weak legislation is Law No. 12.783/2013, which affected existing energy contracts and created uncertainty among investors regarding energy prices. The unpredictability of energy prices defined by EPE in the regulated market causes uncertainties for business planning, as does the unpredictability of tenders, which in the last months have been more directed at natural gas power plants and solar energy (Azzopardi, 2015; GWEC/ABEEólica, 2011). The tax scheme is considered as a bureaucratic hurdle as there are too many different taxes and changes are undertaken frequently.

## 4.4 Country Comparison of Technology Transfer Strategies and Spillover Effects

The first objective of this chapter is to compare the different strategies chosen for the transfer of wind power technology to China and to Brazil as well as to better understand the strategic choices made by technology providers. A transaction costs analysis framework is used to elaborate the reasons for the different outcomes of the two cases: While the case study on China arrived at the conclusion that a variety of transfer channels are used and hybrid governance modes, such as licensing and joint ventures, are favored in particular, the Brazilian case revealed that transfers within MNE to their subsidiaries are by far the dominant transfer channel.

The second objective, which is closely related to the first one, is to assess the extent of spillover effects and compare the diffusion of wind power equipment and knowledge within these two countries. The generation of spillover effects is partly conditional on the transfer channel; however, in order to do justice to the analysis of spillover effects, a change in perspective is required. While the choice of transfer channel is analyzed from the viewpoint of the technology provider, the assessment of spillover effects requires a much more aggregated analysis that also takes into account aspects such as technological capabilities and other characteristics of the recipient country.

With regard to the first objective, a matter of particular importance to the transfer of environmental technologies in general and wind power technology in particular is that the choice of the most efficient transfer channel can be considerably restricted. Two classes of restrictions have been identified by the TCE literature (Anderson & Gatignon, 1986):

- Government restrictions
- Production cost factors, e. g. labor or transportation costs

Both case studies revealed that government restrictions have a considerable impact on the choice of transfer channel, which is due both to the strong involvement of the receiving countries' governments in market creation activities for renewable energies and to their control over energy markets and infrastructures. Important government restrictions that have been at least temporarily in place in China are local content requirements (1996-2009), taxes on imported wind power equipment (until 2010) and subsidies for domestic wind power production. Although these restrictions together provide strong incentives for foreign producers of wind power equipment to locate their production in China, the empirically observed diversity of transfer channels seems to suggest that companies nevertheless have a choice to make. Likewise, for Brazil, local content requirements stipulated by the government and by the BNDES, as well as import restrictions, can limit the available choice of transfer channels. Production cost factors, in contrast, have not been identified by the two cases as being of particular relevance in this context, although transportation costs can be considerable in the wind power sector.

In the following, a transaction costs framework is used to synthesize arguments that help to explain the outcomes observed in the two case studies. As described in Section 3, the choice of the most efficient transfer mode is influenced by the following characteristics of a transaction: asset specificity, frequency, and uncertainty. Uncertainty can be further divided into external and internal uncertainty, whereby the former describes the uncertainty related to the company's external environment and the latter refers to the uncertainty resulting from the behavior of the company's agents in the foreign market.

### 4.4.1 China

*Asset specificity*

Asset specificity can manifest itself in three ways: site, physical asset and human asset specificity. Following the prescriptions of TCE, transactions pertaining to highly specific assets are most efficiently conducted within the boundaries of the firm, whereas market exchanges are the most efficient solution for non-specific assets.

Based on the insights gained from the case study, the transfer of wind power technology to China apparently involves semi-specific physical and human assets. Physical equipment and the embodied technological knowledge transferred to China can be classified as semi-specific if existing turbine models are adapted to meet the requirements of the Chinese market, but could, in principle, be sold to other markets in the world as well. For example, adaptation can be required with regard to wind and climatic conditions as well as turbine price. If, however, wind turbine models would be specifically developed to meet the needs of the Chinese market and could not be sold to other markets, these should be classified as specific assets. Specificity of human asset can, for example, result from market knowledge, personal contacts, cultural knowledge, and language skills. As the specificity of the physical and human assets involved in the transfer of wind power technology to China can be considered to be medium or even high, *licensing* or *joint ventures* would be recommended as transfer channels.

*Frequency*

The frequency of a transactions is interpreted here in the sense that a standardized transaction is repeatedly conducted (see Section 3). Provided that the expected number of transactions is sufficiently high, the costs associated with a hierarchical governance mode (e.g. transfer to a wholly-owned subsidiary) will be easier to recover. Given China's vast wind energy potential and the government's strong commitment to the future development of wind power, which is underscored by various policy initiatives, a high frequency of transactions can be expected as long as the company’s technology is competitive vis-à-vis other domestic or foreign companies. Thus, there is a higher likelihood that the benefits resulting from investments in transfer channels with high resource commitments,such as *joint ventures or wholly-owned subsidiaries*, will exceed the costs.

*Uncertainty*

With regard to the transfer of wind power technology to China, the external uncertainty is assessed to be high due to a combination of market und political risks. Although the general policy framework for the development of wind power in China is long-term and stable, the government's high degree of control over the wind power sector is paired with its ambition to acquire cutting-edge foreign technology and to build a domestic wind power sector that is competitive on the world market.

As a consequence, foreign wind power companies are faced with fierce competition from a number of domestic competitors that currently dominate the Chinese market, and market shares of foreign companies have plummeted in recent years. As of 2012, Gamesa and Vestas, the two most successful foreign companies in China in that year, had a market share of only 3.8 % and 3.2 % of the newly added capacity, respectively.

Likewise, internal uncertainty can be considered high, in particular because of the insufficient protection of the technology provider's intellectual property rights in China and the need to safeguard against the undesired leakage of technological knowledge to competitors. Internal uncertainty can increase further in cases where the cultural distance is significant and where the company faces difficulties retaining experienced staff.

*Impact on Transfer Channel and Knowledge Spillover*

It can be concluded that the diversity of transfer channels that was empirically observed by the case study mirrors the ambiguous results of transaction cost analysis. Whereas the high external and internal uncertainty associated with technology transfer to China supports the choice of market exchange or licensing, the expected high frequency of transactions and the involvement of semi-specific or even specific assets are reasons to favor the choice of licensing, joint ventures or even wholly-owned subsidiaries. Given this inconclusive outcome, government policies that support local production and, thus, favor joint ventures or subsidiaries as channels for technology transfer, can be a decisive factor.

Furthermore, the observed diversity of transfer channels can also be explained by the fact that wind power companies differ in size and international experience. Large multinational companies with a long-standing history of business activity in China, such as e.g. Siemens, will assess the country risk differently and perhaps more accurately than smaller, internationally inexperienced competitors that lack adequate resources for risk assessment and mitigation.

The starting point for the assessment of spillover effects is the finding that their extent is partially dependent on the transfer channel used (Keller, 2004). Furthermore, the transfer of technology is associated with transfer costs incurred by the technology provider, but the technology recipient, on the other hand, has to invest in learning efforts that likewise incur learning costs (Blomström & Wang, 1992; Teece, 1977). These learning efforts contribute to the build-up of absorptive capacity.

The innovation indicators discussed in Section 2 suggest that the innovation capacity of China for wind power technology still lags behind the world's leading countries, although patent and in particular publication data suggest that China is catching-up rapidly. Nevertheless, these findings highlight that absorptive capacity is based on more than just the ability to innovate; otherwise the success of Chinese companies in the wind technology sector would not be possible. This could be an indicator of the importance of a „learning through imitation“ model in the technology absorption process.

Based on the assumption that a certain degree of absorptive capacity can be understood as a prerequisite for spillover effects to take place, joint ventures probably generate the highest spillover effects due of the close personal interactions between foreign and domestic technological personnel that foster mutual learning and allow for the transfer of tacit knowledge. However, some interviewees indicated that Western companies might be reluctant to transfer their latest technological knowledge to joint ventures in China and prefer a transfer to wholly-owned subsidiaries – or not to transfer at all –, precisely because of China's high absorptive capacity and the competitiveness of domestic companies. Thus, absorptive capacity acts as a double-edged sword in some cases. Wholly-owned subsidiaries can generate spillover effects as well, e. g. through staff turnover and vertical linkages to suppliers and customers, although these spillover effects are probably weaker and more dispersed than those generated by joint ventures. Licensing usually involves older technologies and more explicit forms of knowledge, but these spillover effects were nevertheless assessed to be highly relevant in the early development stages of the Chinese wind power sector and the rapid rise of Chinese wind power companies. Imports of wind power equipment were not identified to be relevant in this context.

### 4.4.2 Brazil

*Asset specificity*

With regard to asset specificity, some of the interview partners suggested that the adaptation of wind power technology to the Brazilian market is an important issue, because Brazil's wind and climatic situation differs significantly from Europe and because the country also presents a distinct set of market requirements. The wind situation in Brazil is characterized by mostly unidirectional wind with no turbulences, whereas in Europe, wind turbines are designed for fluctuating wind speeds, turbulences and extreme temperature conditions. Moreover, because of the emphasis on high capacity factors and less concern about space, the global trend towards the use of bigger rotors does not apply that much in Brazil. Therefore, similar to China, the specificity of physical and human assets involved in the transfer of wind power technology to Brazil is assessed to be medium or even high. As a result *licensing*, *joint ventures* or *wholly-owned subsidiaries* would be recommended by TCE as appropriate transfer channels.

*Frequency*

The frequency of expected transactions can be considered to be high because of Brazil's large untapped wind energy potential and high average capacity factors that allow for a production of wind energy at low costs. Furthermore, Brazil is a large emerging economy with a rising energy demand and the government has the ambition to diversify Brazil's energy matrix. These factors suggest that there will be a high demand for wind energy in the future and further market development. The frequency argument is augmented by the fact that wind power companies from Europe consider Brazil as a manufacturing base for the supply of South and Latin America. Similar to the Chinese case, the high frequency of transactions favors investment in transfer channels with high resource commitments, such as *joint ventures or wholly-owned subsidiaries.*

*Uncertainty*

The external uncertainty associated with the transfer of wind power technology to Brazil can be assessed to be medium or even high, in particular because of the competitive pressure resulting from public biddings. Competition within the wind power market is driven by the fact that most of the world's leading wind power companies have entered the Brazilian market and invested in production facilities or have at least committed themselves to do so. Apart from the intense competition within the Brazilian wind power market, wind power has to compete directly with other renewable energy sources in public biddings. This competition, in particular from hydropower, represents an additional source of external uncertainty. Even though the wind power industry in Brazil criticizes the lack of long-term political goals for the development of wind power and some of the interviewees pointed out deficits pertaining to the overall governance of the energy sector, the political risk of transferring wind power equipment and/or knowledge is assessed to be medium, because of the priority that the government has given to the development of the wind power sector in recent years and the relative stability of the political framework. Although cultural differences and language barriers were regarded as obstacles by some of the interviewees, the case study did not provide much evidence that risks stemming from the inability to monitor the behavior of the company's agents, i.e. internal uncertainty, are of particular relevance. This might, however, be due to the fact that most foreign companies have chosen to set up wholly-owned subsidiaries and are thus able to exert hierarchical control over their agents.

*Impact on Transfer Channel and Knowledge Spillover*

Altogether, the uncertainty relating to the transfer of wind power equipment to Brazil can be assessed to be rather medium than high, a result that would favor the use of hybrid governance modes, such as *licensing* or even *joint ventures.*

The transaction cost analysis for Brazil suggests that transfer channels that require high resource commitments might be more appropriate than those with low resource commitments, in particular because of the high frequency of transactions and the need to adapt technology and business practices to the Brazilian context. Although the uncertainty stemming from competition within the Brazilian wind power market is considerable and probably higher than in most other countries, the overall uncertainty situation would not support arguments speaking strongly against transfer modes with high resource commitments. In conclusion, the empirical finding that technology transfer from multinationals to their wholly-owned subsidiaries in Brazil is the most important strategy is supported by transaction cost analysis. However, this empirical outcome is certainly influenced by government restrictions pertaining to local content requirements, financial incentives that favor local production, and the lack of potential joint venture partners or licensees in Brazil.

Based on these results, the analysis of spillover effects can be focused on those generated by firm-internal transfers to wholly-owned subsidiaries. In most cases, these investments can be characterized as greenfield investments that generate spillover effects mainly through workforce migration as well as through vertical linkages along the supply chain. Compared to China, the capacity of Brazil to absorb wind power technology is assessed to be much lower due to the missing domestic industry and the low research activity in this field, in particular with regard to applied research. Furthermore, the weak linkages between industry and the research sector reduce the chances for large spillover effects to take place.

### 4.4.3 Country Comparison

Table 2 shows both similarities and important differences with regard to the international transfer and diffusion of wind power technology to China and Brazil. First of all, the diffusion of wind power technology gained momentum much earlier and much more forcefully in China. Brazil's currently installed wind power capacity of 3.5 GW was already achieved in China in 2006. As of today, China is the country with the largest amount of installed wind power capacity in the world, whereas Brazil is not among the top 10 countries in the world. However, this gap is put into perspective when the diffusion of wind power technology is evaluated in terms of wind power's share of domestic electricity demand, which turns out to be fairly equal in China and Brazil. Focusing on onshore wind power equipment, the case studies highlighted that the technological gap between the two countries and the global state of the art is only marginal, although the case study on China identified persistent gaps with regard to grid integration, as well as wind park operations and maintenance. However, when referring to offshore wind power, the technological gap between China and Brazil and the world's leading countries in this field was considered to be large. Moreover, a considerable gap persists with regard to technological knowledge and innovation capacity, which is discussed in greater detail below.

| | China | Brazil |
|---|---|---|
| **Installed wind power capacity in 2013** | 91.4 GW | 3.5 GW |
| **Wind power as a share of total domestic electricity demand in 2013** | 3% | 2% |
| **Policy Framework** | Renewable Energy Law, 12th Five Year Plan, Medi-um and Long Term Devel-opment Plan for Renewa-ble Energy, MOF funding policy | PROINFA, New Energy and Alternative Sources Biddings, 2010-2019 Plan for Energy Expansion |
| **Key transfer channels** | Licensing, joint venture | Wholly-owned subsidiary |
| **Absorptive capacity** | Medium | Low |
| **Spillover effects** | Medium-high | Low |
| **Main drivers for technology transfer** | Market creation policies, commercial viability of wind power, LCR | Market creation policies, commercial viability of wind power, high degree of competition, LCR |
| **Main barriers for technology transfer** | Weak governance in energy sector, weak protection of IPR, geographic and cultural distance | Weak governance in energy sector, lack of complementary infrastructure |

Table 2: Comparison of the Chinese and Brazilian Wind Energy Sectors

The fact that the technological gap pertaining to onshore wind power equipment was closed within a relatively short period of time can be regarded as a success of international technology transfer. For China as well as Brazil, the regulatory framework for the development of the wind power sector can be seen as the most important driving force for this development. Both countries were successful in creating market demand for wind energy, although the political approach of the Chinese government towards the wind power sector is considered to be more ambitious and comprehensive. Most importantly the Chinese government combines market formation policies with industrial and research policy initiatives that are targeted at the build-up of a domestic wind power industry. In contrast, the Brazilian government's approach is much more narrowly directed at developing wind energy as a cost-efficient alternative to other energy sources, although domestic production of wind power equipment is likewise strongly encouraged by local content requirements.

With regard to the technology transfer strategies employed by multinational wind power companies, Brazil and China were found to differ significantly. For Brazil, firm internal transfers to subsidiaries were identified to be the most important channel; for China, hybrid transfer channels (e. g. licensing, joint venture) were more widely used. Joint ventures in particular are strongly encouraged by the Chinese government. The spillover effects generated by these hybrid transfer channels are medium or even high in the case of China, but only low in the case of Brazil. This difference results partly from the use of different transfer channels, but even more importantly, from the varying levels of absorptive capacity. Employing innovation indicators, i.e. patents and scientific publications, as a measuring tool, the level of China's absorptive capacity is mid-level, while the absorptive capacity of Brazil is judged to be low.

As mentioned above, market formation policies were identified as the most important drivers for technology transfer in both cases. The process of market formation was strongly supported by the increasing commercial viability of wind power and the increasing competitiveness vis-à-vis other energy sources. Furthermore, the use of local content requirements in China and Brazil was considered as a driver for technology transfer. Pertaining to the situation in Brazil only, the high degree of competition between international wind power companies was considered to be a driver of technology transfer.

With regard to both, China and Brazil, the weak governance quality of the energy sector was seen as a significant barrier to technology transfer. In China, for example, deficits with regard to the implementation and enforcement of regulations as well as the fragmentation of the energy bureaucracy were bemoaned. A barrier pertaining to the situation in Brazil is the lack of a complementary infrastructure that refers in particular to bottlenecks in the wind power supply chain. For China, two other barriers where identified: the weak protection of IPR and the large cultural and geographic distance (from a European perspective). Both barriers are particularly pertinent for small and medium-sized enterprises that lack the necessary international experience and financial resources to compensate for such circumstances.

# 5 Conclusion

The case studies presented above were focused on the wind energy technology sectors of China and Brazil. Due to time constraints, only a limited number of experts could be interviewed. Moreover, the conclusions presented here are focused on the situation of newly industrializing countries, in particular with large markets, and therefore cannot be generalized for all developing countries.

These case studies show that the technological gap with regard to onshore wind power equipment is relatively small as compared to market leaders; offshore technologies, however, are much less well-developed in these markets and lag behind the market leaders.

The importance of national market creation policies posited by Gallagher (2014, p. 176) can be confirmed as a necessary prerequisite of international technology transfer in this analysis, although it was only sufficient to lead to the larger-scale transfer of equipment and not the underlying knowledge. The formation of autonomous national innovation capacities that could not only absorb, but further advance, existing knowledge requires a more stringent political framework that encourages investments in research and the creation of a strong domestic industry that is able to incorporate spillover effects. The development of such policies is one area where a significant difference can be seen between China and Brazil, the former being more advanced in this regard.

Once the appropriate political framework conditions for market creation have been created, decision-making processes within multinational enterprises become increasingly relevant. A company's choice of transfer channel, combined with the country's absorptive capacity in the background, can have a significant effect on the amount of spillover effects that take place. For both countries, the likelihood of high interaction frequency and semi-specific or even specific assets suggest choosing a resource-intensive transfer channel, such as a joint venture or wholly-owned subsidiary. These channels are likely to lead to spillover effects. However, uncertainty is high in both countries due to very competitive markets and local content requirements, and is increased further in China due to weak IPR protection and great cultural distance. Thus, for China, hybrid transfer channels like joint ventures or even licensing can be preferable.

The case of China also shows that policies and regulations, if they are too favorable for domestic companies and conversely too hostile for foreign firms, can endanger the continuity of technology transfer. While local content requirements in China were a useful tool to help form a domestic wind power industry, over time the competition became so significant on the Chinese market that foreign companies such as Nordex have left the country. Thus, when international firms no longer see a realistic chance for success, there is a real danger that they might leave, cutting the recipient country off from newer technological advancements being developed abroad. This example underscores the importance of fair competition and the protection of IPR in ensuring the continuity of international technology transfer to recipient countries.

The issue of uncertainty is less prominent in Brazil, both because the cultural distance is perceived to be less significant (from a European perspective) and because while the wind energy market is competitive, the country has much less ambitious industrial policies in place. However, future Brazilian wind energy firms face the risk of a market-stealing effect: due to the significant inflow of foreign direct investment in the sector, Brazilian companies may face significant barriers and fierce competition from foreign companies if they try to enter the domestic market at a later point in time.

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