Leadership in wind turbine manufacturing of early adopter countries & early entrant firms

(working paper, extended abstract)

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Abstract

The greatest prospects for survival and industry leadership in a new growth industry largely accrues to early entrants. This has been described at the level of the firm in the literature on industry lifecycles, and at the level of countries in the literature on lead markets. Here, we perform a case study of the global wind turbine manufacturing industry at both country and firm level. We find that turbine markets were indeed dominated by the earliest of manufacturing firms for some time, but that waves of new entrants from the second half the nineties onwards have taken increasingly large shares of the market. These successful late entrant firms, however, did all originate from early entrant or early follower countries. Late entrants from late adopter countries have been altogether unsuccessful. It appears that the accumulated localized experience in early adopter countries provides a beneficial development environment for domestic manufacturers, in early as well as later phases of global industry development.

1. Introduction

Global policy efforts for stimulating the deployment of renewable energy are primarily focused on mitigating climate change, but regularly also feature components of stimulus for innovation, job creation and industry growth. Such growth in these new sectors can make up for stalling growth, or losses, in incumbent, conventional energy industries. Contribution to growth can be particularly large if domestic industries manage to become leading suppliers for the technologies involved in global markets. The economic growth potential of these new areas has been recognized, and policy makers across the globe have launched policy programs in attempts to capture this potential. By year end 2015, a total of 89 countries have deployed wind turbines, and 26 of these have at least one domestic turbine manufacturer. The number of countries that have with domestic turbine manufacturing industries has developed relatively linearly over time, with plenty of newcomers since the global market started to grow rapidly in circa the year 2000 (Figure 1).

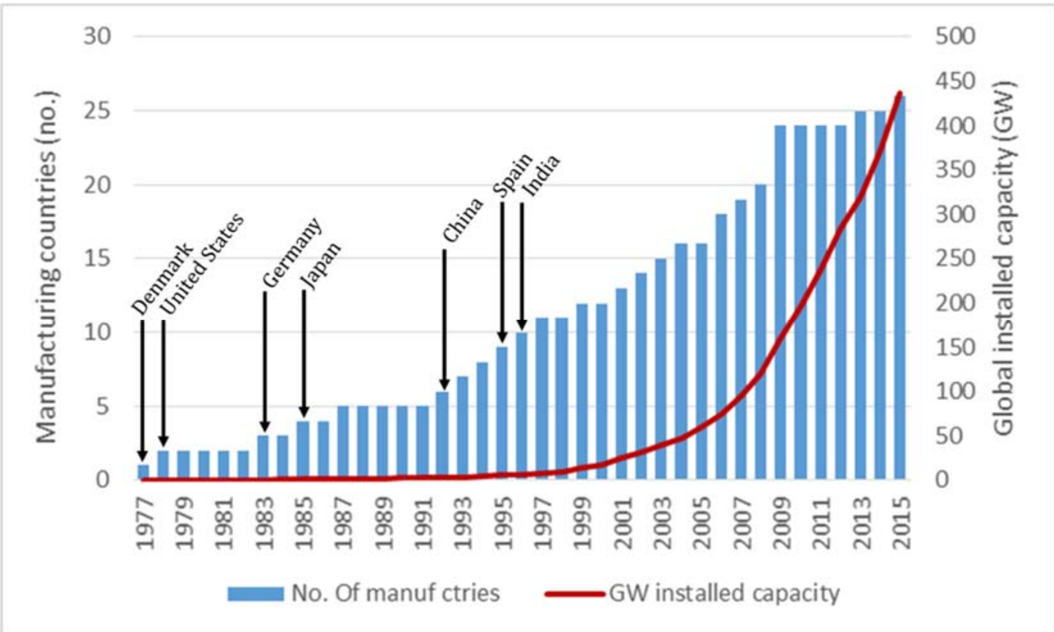


Figure 1. **Timing of country entry into wind turbine manufacturing**

The literature on industry life-cycles has described patterns of firm-level entry, exit, survival, innovation and growth towards leadership positions in new industries. Key insights include that the greatest prospects for survival and industry leadership accrued to firms that entered early, or could be traced back to early entrants through mergers, acquisitions or similar mechanisms, or brought experience from related fields. With increasing industry maturity, entry becomes harder or even impossible, with increasingly short survival times and smaller market shares for later entrants. The literature on industry life-cycles has regarded international competition, but usually with reference to the entry and success of foreign manufacturers in a single national market that is the object of analysis in individual case-studies.

The literature on lead markets has had more attention for comparing the success of manufacturers from different countries in global markets. A key conclusion from this literature is that the creation of strong domestic demand, in a highly competitive market to create selective pressure, might accrue first mover advantages to domestic firms, ultimately improving their chances at outcompeting manufacturers from other countries in global export markets. The relevance of locational advantages have similarly been highlighted in analyses of 'cluster life-cycles', where it is argued that firms or industries benefit from clusters through the presence of 'a local pool of skilled labour, local supplier linkages, and local knowledge spillovers', amongst others (Potter & Watts, 2011: p417).

Here, we perform a case study of the timing of entry and leadership of turbine manufacturers at the national and firm level. We find that early entry both at the national and at the firm level is strongly connected with market share leadership. However, although turbine markets were dominated by the earliest of manufacturers for some time, waves of new entrants from the second half the nineties onwards have taken increasingly large shares of the market. The successful late entrant firms, did all originate from early entrant or early follower countries. It appears the domestic context provides a beneficial development environment for the manufacturing industry, even at later phases of global market and industry development.

2. Method and data

The literature on industry lifecycles and on lead markets share the notion that early entry is a key factor in successfulness, referring either to the entry of individual firms in national markets, or to national industries in a global market.

Early entry by itself is likely not a sufficient condition, as (national level) analyses of lead markets or innovation systems have also stressed the need for R&D and market creation (Griliches, 1985)(Bergek & Jacobsson, 2003; Edler & Georghiou, 2007). Such domestic markets can provide a learning environment that can function as a springboard for success in export markets (Beise, 2005; Fagerberg, 1995; Porter, 1990). Concerning R&D, much attention has been given to identifying and explaining differences in the effectiveness with which countries manage to turn R&D activity into commercial, industrial applications (Guellec & Potterie; Rousseau & Rousseau, 1998).

When assessing successfulness, we will therefore not only look at total market shares, but also at the effectiveness of creation of domestic manufacturing industries, given a level of domestic R&D activity or domestic market creation.

2.1. Data collection

Analyses and graphs in this paper are based on a database that measures the activity of national innovation systems with three output variables: knowledge production, market creation, and manufacturing output. At the firm level, data is available on the timing of entry and exit as well as annual manufacturing output.

2.1.1. Knowledge production

Knowledge production is measured as citations to patents. This data was collected from PATSTAT Online, version of Autumn 2016 (EPO, 2017) We selected all patents tagged with CPC code Y02E10/70 ('Wind energy'), and subsidiary classes, which includes technologies relating to complete wind turbine sets as well as components, grid connection procedures etc.. The resulting dataset contained 109,162 wind power patent applications, in 65,001 DOCDB families, with inventors from 105 countries, and which received 342,967 citations in total, by year end 2015. Determining what country these citations should be counted towards was a three step process. First, based the country of residence of the inventors, weighted in case of multiple nationalities. Second, if inventor information was missing, based on the nationality of the applicant. Third, if both inventor and applicant info was missing, which is common for patents from a number of Asian countries (China, Japan, Korea in particular), the location of the office of the first national phase filing (within each family) was used. If the first filing was with a supranational bureau such as the EP or WO, the country code within the application number was used.

The citation count data required two fixes. First, for the last few years, the data appears to be incomplete. There is a drop-off in wind patent applications since 2010, as reported in other sources, but there is a drop-off in total applications as well, which differs from reports by patenting authorities. We correct the total number of wind power patent applications upwards, by the same factor as required to result in a linear growth trend in total number of patent applicants for the period 2009-2015 (as reported by WIPO; @ref). This requires a correction factor of 1.04 for 2013, 1.14 for 2014 and 1.63 for 2015. We assume that the number of citations per application remains constant and weigh citations in years 2013 to 2015 by those same factors (see also Figure A.1). Second, citation practices differ across patenting authorities, with the USPTO in particular including much longer lists of references to earlier patents. Michel and Bettels found that applications filed with the USPTO cite circa 3.5 times as many publications as other bureaus (Michel & Bettels, 2001), and we find the same difference in our set of wind power patent applications (Figure A.2). We correct for this by weighting citations from applications filed with the USPTO by a factor of 1/3.5.

2.1.2. Market creation

Market creation is measured as MW of wind turbines installed in the domestic market, with data sourced from Eurostat (EC, 2015) for European countries, UN Data (United Nations, 2015) for the remainder, with updates for 2014 and/or 2015 from the BP review (BP, 2015) and from 'The Wind Power' global database of wind farms (The Wind Power, 2016), and figures for years prior to 1990 from the Earth Policy Institute (Earth Policy Institute, 2015).

2.1.3. Manufacturing output

Manufacturing output is measured as MW of wind turbines installed. Data is sourced from 'The Wind Power' global database of wind farms (The Wind Power, 2016), with entries for China, Denmark, Germany, Sweden, the Netherlands and the US replaced with data from more complete national datasets (Bundesnetzagentur, 2017; CWEA, 2016; Diffendorfer, Kramer, Ancona, & Garrity, 2015; Energistyrelsen, 2016; Vindlov, 2017; Wind Energie Nieuws, 2017). Each of these databases lists info on at least 1) the country the wind farm is located in; 2) the capacity of wind turbines installed; 3) the year of operational start; and 4) the brand of the turbine manufacturer. The combined dataset included 42,692 wind farms, with complete info on location, year, capacity and equipment manufacturer for 424.1 GW of installations, or 95.6% of the reported global total of 443.8 GW, by year end 2015.

Manufacturer level entry and exit is measured as the first and last years of installations of turbines. The length of time between establishment of a firm and its first turbine installation is thus ignored. This is likely a period of many years for newly created firms, whilst it could be a very short period for firms working on the basis of an acquisition or a licensed design.

With regard to installations, manufacturer exit and brand nationality, we consider acquisitions, mergers and joint ventures. For example, when Siemens bought Bonus, we consider that 1) Bonus exits in the year following acquisition; 2) new Bonus branded turbines are assigned to its owner, Siemens; and 3) the nationality assigned to a turbine brand is that of its owner; new installations of Bonus turbines after the acquisition are considered to be German, not Danish manufacture. Note that all of this applies to new installations following acquisition; the existing stock keeps its original brand name and nationality labels. In case of mergers and joint ventures, new installations are assigned to each (parent) company weighted by ownership share in the jointly owned business (if no information on exact shares was available, a 50-50% split was assumed). In the case of mergers, only one of the companies (the younger of the two) was considered to exit, and the newly formed entity was assigned the entry year of the older of the two merger partners. For joint ventures, entry and exit was determined for the separate entity itself.

The dataset is limited to utility scale turbines, here defined as turbines exceeding 30 kW. Smaller turbines form a marginal share in total installations in the original dataset, but are produced by a relatively large number of manufacturers. Their inclusion is problematic in particular because such turbines and their manufacturers are included in some, but not all of the national datasets. This would lead to bias when comparing numbers of manufacturers from different countries. The Danish dataset in particular is very complete, with several hundreds of records of individual turbines of a capacity of only several kW. Although 30 kW is hardly a utility scale turbine by present day standards, this cut-off makes sure we preserve relatively common smaller turbine sizes in the late seventies and early eighties.

3. Results

A total of 89 countries have deployed wind turbines, and 26 of these have at least one domestic turbine manufacturer. Out of these 26, seven countries dominate turbine manufacturing, having produced 98.3% of installed capacity by year end 2015 (Figure 2). Manufacturing output has more overlap with domestic market sizes than it does with R&D activity (Figure 2). Further, the seven leading countries were all early adopters or early followers in the establishment of domestic manufacturing industries (Figure 1).

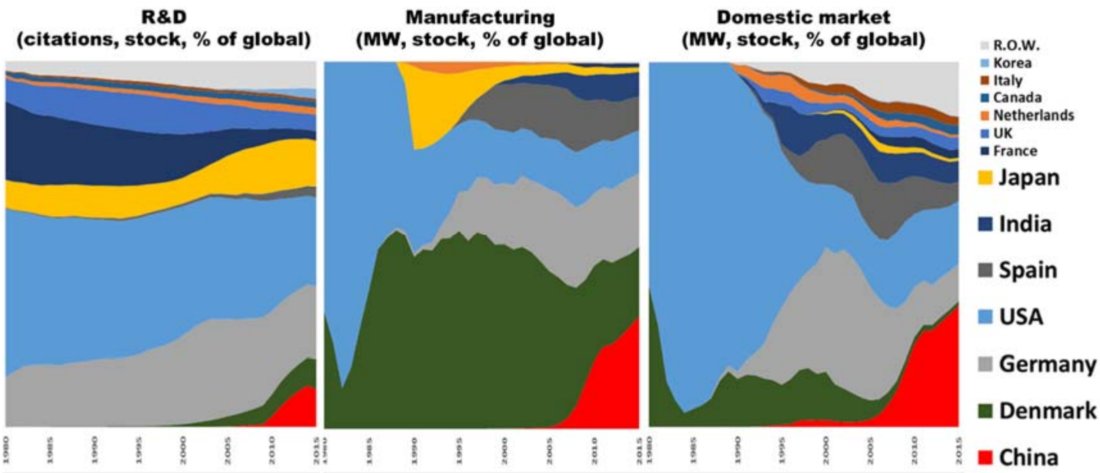


Figure 2. **Wind turbine R&D, manufacturing and markets, by nationality, 1977-2015**

3.1. Firm level entry and leadership

The total number of manufacturers of utility scale wind turbines included in our database is 220. The number of active manufactures peaked in 2010, at around 95 manufacturers, but has since fallen to about 55. The rapid growth and fall in recent years is mostly attributable to an industry growth and consolidation in China (Figure 3).

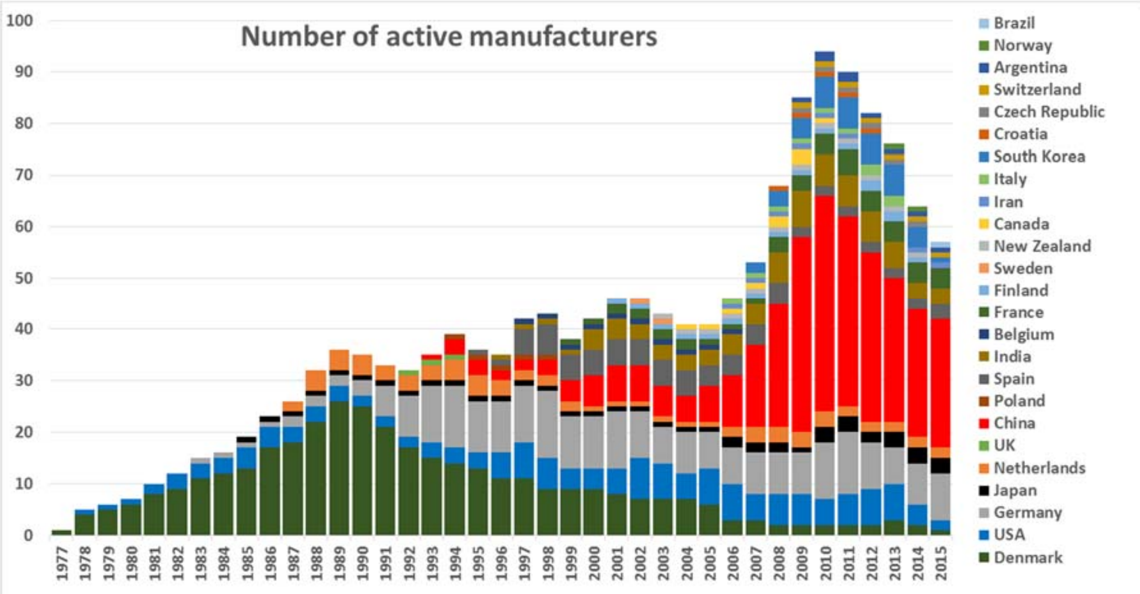
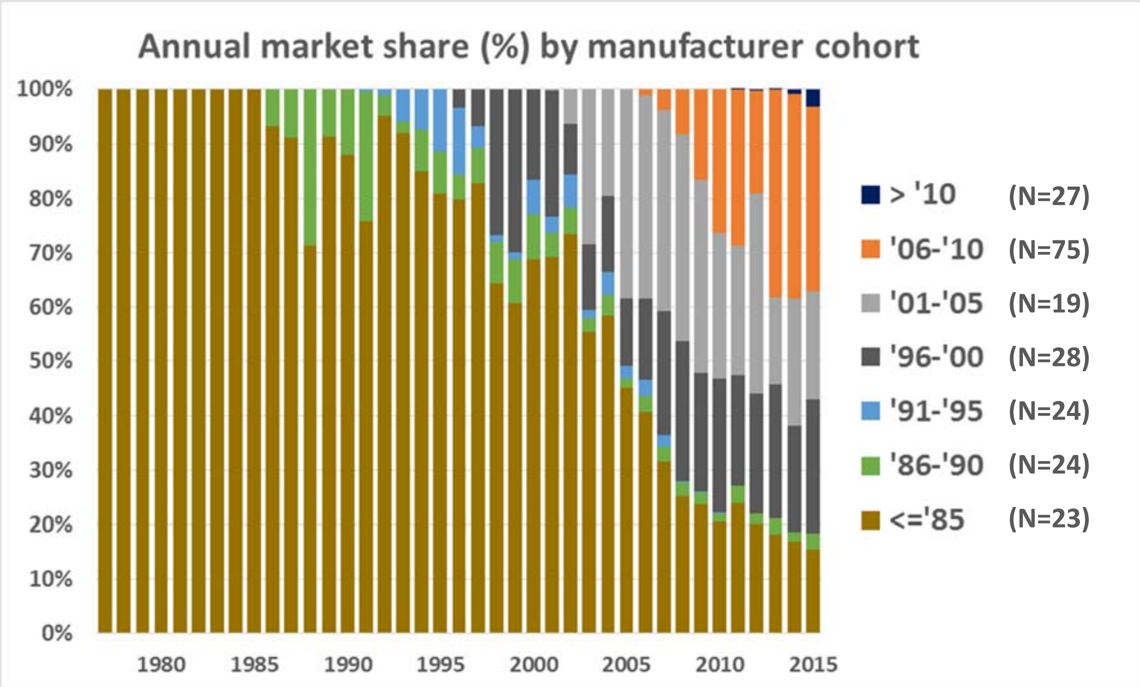


Figure 3. **Number of active manufacturers, by country and year**

Turbine markets have long been dominated by the earliest of manufacturers from Denmark, the US, Germany, and for a much smaller share, from Japan (Figure 4, top). Manufacturers that entered into the industry prior to 1985 managed to retain the bulk of the market with the rise of large groups of competitors in the second half of the eighties and first half of the nineties. Three waves of entrants from the second half the nineties and first and second half of the noughties, however, have eaten away at the market share of the early entrants. Market shares in recent years are divided up roughly equally between several cohorts of firms entering the industry at relatively early and relatively later periods.

If we look at the nationality of these firms, however, the picture is different (Figure 4, bottom). The two parts of Figure 4 together highlight that there is plenty of potential for late-entrant firms to capture market share, but that this potential predominantly exists for firms that hail from countries that were amongst the first to grow a domestic wind turbine manufacturing industry. Vice versa, although these early adopter countries managed to retain industry leadership, it was not necessarily the earliest of manufacturing firms from these countries that retained their large market shares. Within these countries, individual firms have exchanged position a number of times (@to be added).



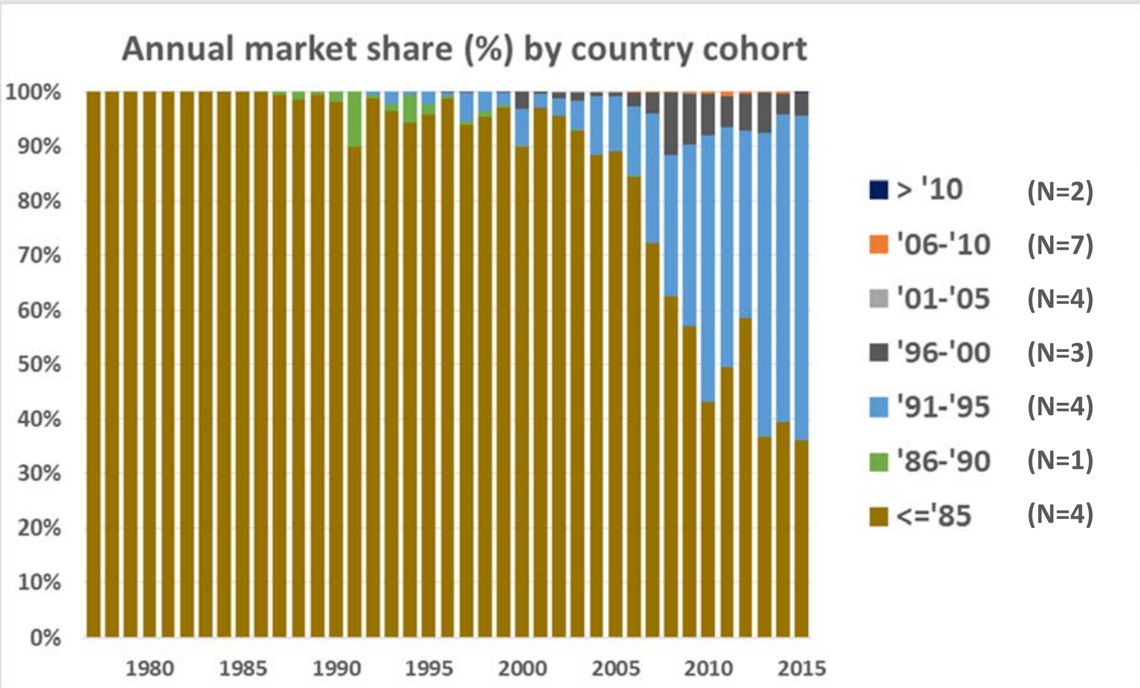


Figure 4. **Global wind turbine market share (annual), by manufacturer cohort (top) and country cohort (bottom).**

Cohorts in terms of years manufacturer or country entry into wind turbine manufacturing, here measured as the first year of installation of a turbine with a brand name or nationality

4. Conclusion & discussion

Results from our case study of the wind turbine manufacturing industry are very much in line with the claims of the lead market literature. Early establishment of a domestic manufacturing industry is a strong determinant of survival and leadership of domestic brands in the more mature turbine markets that developed decades later. The creation of early, and rapidly growing domestic market demand for wind turbines was also found to be strongly connected to future leadership, whilst high volumes of R&D activity were less of a determinant for such leadership.

When comparing the leadership of individual firms, results are only moderately in line with claims of the industry lifecycle literature. Although turbine markets were indeed dominated by the earliest of manufacturers for some time, waves of new entrants from the second half the nineties onwards have taken increasingly large shares of the market. These successful late entrant firms, however, did all originate from early entrant or early follower countries.

These results suggest that there is multi-scalarity in industry life cycles: the maturity of the firm, as well as of the domestic environment it is located in, help determine a firms chances of survival and leadership at the global level. Firms with equal years of entry into the industry have strongly improved chances of survival and leadership if the countries they hail from had earlier entry into the global innovation system. It is likely that accumulated localized experience in early adopter countries, in aspects such as 'a local pool of skilled labour, local supplier linkages, and local knowledge spillovers' (Potter & Watts, 2011: p417), provides a beneficial development environment for domestic manufacturers, in early as well as later phases of global industry development.

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Appendix A

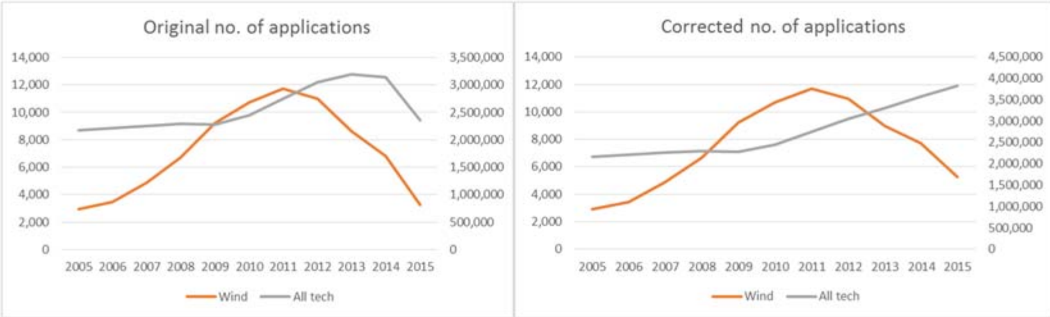

Figure A.1 Number of applications reported in Patstat database version of August 2016 (left) and our correction (right).

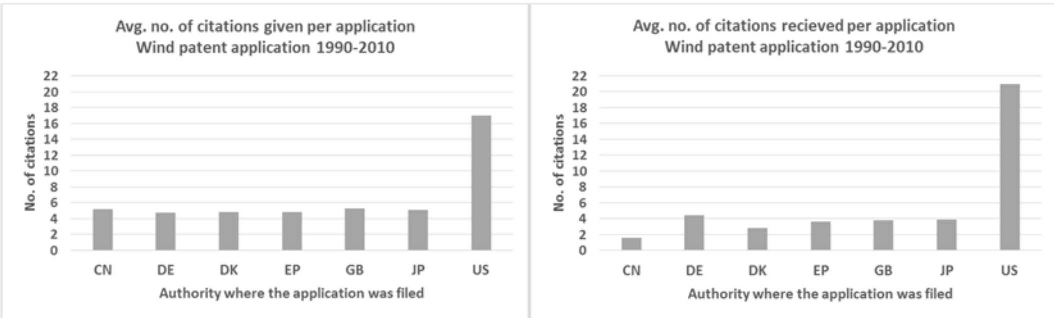

Figure A.2 Average number of citations given and received, by authority where the application was filed.