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The Spatial Evolution of the Global Wind Turbine Industry: The influence of Pre- and Post-entry Experiences as well as National Factors

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Abstract

We apply Klepper (2007) heritage theory for the spatial evolution of the wind turbine industry on the global level. In contrast to other industries that were investigated with the heritage theory, like automobiles, semiconductors, tyres, or lasers, the wind turbine industry strongly depends on technological progress in related field. Due to this "bricolage" quality, we expect better performance of firms that are able to combine different knowledge and are in a spatial context that facilitates the combination of different knowledge. We found out that entries from related fields performed better than spin-offs and a strong influence of national factors.

Introduction

Where and how regional industries concentrate is a highly contested field with many, often contradictory, explanations. Most approaches consider agglomeration economies that start to work at some point in time as responsible for the formation of large concentrations (Krugman 1991, Storper and Walker 1989). Recently, Steven Klepper presented a distinct approach on this topic. He focuses on the fact those regions where a concentration will emerge are shaped by a particular form of formation, namely spin-offs (Klepper 2007, Romanelli and Feldman 2006). This pattern led Klepper (2007) to argue that clusters might arise without the necessity of agglomeration economies. Instead, the inheritance of routines from incumbent firms to their spin-offs is the crucial process in cluster emergence. In this line of argumentation, better firms grow stronger than other firms. Due to their growth, they will sooner be able to generate spin-offs that again grow above average rate. As spin-offs tend to locate near their incubator, large concentrations come into being without economies of agglomeration, with the largest concentration located in the region with the best firm.

This hypothesis was tested for different industries like automobiles (Klepper 2007, Boschma and Wenting 2007), tyres (Buenstorf and Klepper 2009), or fashion (Wenting 2008).[1] All studies showed comparable results. Entries with a background in the respective or related industries show higher survival rates compared to entries without a related experience. Spin-offs exhibit the best performance and concentrations emerged mostly a those places, where pervasive spin-off processes occurred.

The paper to be presented is a further empirical contribution of how firm specific characteristics affect the evolution of regional industries. Yet, it deviates in one important aspects from existing studies, namely in the developmental logic of the industry under investigation. While most of the existing studies focus on clearly delimitable industries that formed around a particular technology, the paper has with the wind turbine industry an object of investigation that that formed due to processes of technological convergence and thus depends strongly on technological progress in several related fields (Cooke 2010), which Garud and Karnoe 2003) termed “bricolage”. Additionally, the industry shows another spatial pattern. Instead of building highly concentrated clusters with neat geographical boundaries, most of the firms and production in the wind turbine industry is located within a core region that ranges from Denmark via northern Germany to the Netherlands. Furthermore, this spatial pattern leads to the necessity to analyse the industry on the global level.

[1] For an overview see Klepper (2009).

Do to the many clear results of existent studies we do not expect completely different processes in the wind turbine industry, but deviations in small, but important details. In accordance with existent studies, we therefore expect better survival rates for firms with pre-entry experience in the wind turbine industry or related industries. Due to the dependence of the industry on progress in related fields and connection of different technologies, we expect deviations in two ways. On the firm level, we expect a less dedicated importance of spin-offs and a better performance of diversifying firms. Considering the recombinatory characteristics of the industry, we additionally expect a larger influence of spatial externalities.

The Heritage Theory: Assumptions and Empirical Results

The heritage theory of bases upon three observations: first, experienced firms and founder, i.e. entries from the same or related industries, perform better than inexperienced firms (Klepper 2001), with spin-offs exhibiting the best performance. The second is that clusters are found in regions where spin-off processes occur. The third is that in those regions, where a cluster is, inexperienced firms perform even worse than inexperienced firms in other regions, therefore at best indicating a kind of negative agglomeration economies.

Upon these results, Klepper establishes a theory to explain regional concentrations upon firm specific factors instead of regional prerequisites or agglomeration economies. His theory bases on three different lines (Klepper 2007, Buenstorf and Klepper 2009). The first is firm routines. In this line of argumentation, the capabilities of firms are important. Firms with experience in related fields are better equipped than entries without experience from the respective or related industries. Furthermore, firms with better routines grow stronger than firms with inferior routines. Firms with better routines sooner get the adequate size to generate spin-offs that again exhibit above average growth. The second line of argumentation is that firms with better routines also attract the better employees. This further leads to an improvement of routines and faster growth, faster spin-offs. The third line of argumentation is that spin-offs stay at the place of the parent firm, whereby subsequent spin-off processes results in concentrations. As a result of these processes, concentrations can emerge at those places where firms due to their superior routines spawn most spin-offs, without any necessity of static or dynamic agglomeration economies.

Klepper's (2007) study on Detroit is a good example for this reasoning. The concentration of automobile firms occurred with Detroit at the place with most spin-offs. In contrast, entries without experience in automobile or related industries performed worse in Detroit than in other regions. He argues that if agglomeration factors would play a role, they would have had an impact on all firms, independent of type of origin. The bad performance of Detroit inexperienced firms compared to inexperienced firms in other places would let assume that if agglomeration economies really plays a role, this role is a negative one.

Several studies empirically support this reasoning (for an overview see Klepper 2009). These studies share a common research design as they on the one hand differentiate entries according to their experience and have different variables to measure (potential) agglomeration economies.

Pre-entry experience is measured by type of entry: spin-offs have founders from the same industry; experienced entrepreneurs have worked in a related industry; experienced firms have diversified from a related industry; and inexperienced firms account for the remaining entries. Some authors like Boschma and Wenting (2007) combine the categories experienced entrepreneurs and diversifiers, as both types of entries refer to experiences gained related fields. Wenting (2008) also includes number of places and firms, where the founder of a spin-off previously has worked as further refinement of pre-entry experience.

Agglomeration economies are measured in most studies by a dummy variable for the region in which the largest agglomeration occurs. The idea is that if there are agglomeration economies in the places with these large concentrations, they should be grasped by the dummy variable. Examples of this approach are the study of Klepper (2007) on the US automobile industry with a dummy for Detroit as largest concentration. Wenting (2008) in analysing the evolution of the fashion industries in Paris, London, Milano and New York additionally includes number of fashion firms in the same place as proxy for localisation economies. Boschma and Wenting (2007) measure agglomeration economies in their study on the British automobile industry in Great Britain in the form of related industries in the regions.

All studies found out that pre-entry experience was a crucial factor for firm survival, whereby spin-offs survived longer than experienced firms, which again survived longer then inexperienced entries. As a result, the largest concentrations formed in those places, where the most spinoffs occurred. In contrast, the agglomeration dummy had no significant effect on firm survival and the emergence of the large concentration could mostly be explained by firm specific qualities. Agglomeration economies only positively affected firm survival in some examples, like related industries in the early days of an industry (Boschma and Wenting 2007). For banks in the Netherlands, the agglomeration dummy for Amsterdam as largest concentration of banks was not significant, but some reasons, spin-offs in the Amsterdam region survived longer than spin-offs in other regions (Boschma and Ledder 2010). The only study that found out the agglomeration economies as together with pre-entry experience influencing regional concentrations is from Boschma and Weterings (2005) on the software industry.

At all, the studies point strongly supports the assumption that large concentrations rather form on the basis of firm specific capabilities than on agglomeration economies or regional processes. However, there are some limitations. All surveyed industries describe delimitable industries where most progress takes place within the industry, and not in related industries. However, recent accounts let assume that a large extent of contemporary regional development stems from industries that are the result of technological convergence of regional industries, where new regional industries form at the interface of existing regional industries (Cooke 2010). Additionally, the weak support of the heritage theory by the software industry, which is the youngest industry under investigation, also points out that temporally changing socio-economic factors might affect the importance of externalities (Boyer and Durand 1997, Chesbrough 2003). Furthermore, it might be the case that agglomeration economies for some reason might only affect spin-offs, an assumption already made by Klepper (2007).

Despite these limitations, proves on the heritage theory are so compelling that the question arises regarding its generalisation. Such an investigation would require the application of the framework of the heritage theory on an industry that strongly differs from the already observed industries. The wind energy converter (WEC) industry is adequate for this task. It shares with other industries the tendencies to concentrate, but it deviates from existent studies, as it emerged in the 70s and therefore is quite younger than most of the observed industries and depends on heterogeneous knowledge base that is strongly affected by technological progress in related fields.

The Wind Energy Converting (WEC) Industry

The utilisation of wind as a source of electricity dates back to the end of the 19^{th} century, when Charles Brush build the first known turbine converting wind into electricity (Heymann 1995, Gilles 2008). However, the origin of modern wind energy, i.e. building wind turbines in industrial means, is a quite recent development. In the 70s during the oil crisis, the established power sector met increasing criticism. A new energy market emerged consisting of people striving for an environmental friendly way of energy self supply, many of them farmers. Additionally, many European countries as well as the United Stated launched extensive support programs for technology development and to encourage entrepreneurs and firms to start WEC manufacturing.

While early attempts were aimed to establish functioning designs, technological progresses in the form of higher efficiency and reducing costs were achieved by an up-scaling of kW capacity since the 80s. While in the 80s the common WEC-capacity was mostly below 100 kW, it increased to 930 kW till end of the 90s (Iset 2006) and to 1,6 MW in 2009 (Btm 2010), with the most advanced WECs having a capacity 7,5 MW. The ongoing trend towards up-scaling was later accompanied by continuously optimizations in grid products and sound reductions, expansions of rotor diameters and towers, product diversification, like hot or cold climate versions heights as well as business expansion into offshore wind energy.

During this development, the industry was strongly transformed. While it was a craftsmanship dominated industry with strong connections to agriculture in early days, it developed to a distinct industry with inputs from mechanical engineering and today relates to sectors such as steel industry for tower production, advanced casting industry for bearings, shafts, bugs, flanges etc, electrical engineering for generators and converters as well as carbon fibre treatment for rotor blades and nacelle covers. WEC also became a distinct topic in science and university research with distinct research centres (e.g. RisøDTU in Risø/DK, IWES in Bremerhaven/GER and CENER in Sarriguren/Spain). Despite these steps towards achieving technological progress by generating an analytical knowledge base, current R&D spending is still at about 2% of turnover. However, these expenditures mostly cover R&D investments of the WEC manufacturers that mostly invest into R&D activities regarding the system architecture. Yet, the wind turbines are assembled of many different components, provided by specialised suppliers. The technological advancements of these components are decisive for the technological progress of the whole system. Technological progress of the wind turbine industry therefore heavily depends on the technological progress of suppliers from related fields. The investment of wind turbine firm into R&D therefore covers only a small part of the technological progress within the field and shows the large dependence on related fields.

The industry also exhibits a distinct spatial pattern. As the product is ultimately assembled at the wind farm and parts of the products are of considerable size, transportation to the place of demand plays a considerable role (Kammer 2010). As a result, the spatial dynamics of the industry are currently stronger orientated stronger towards sales markets than on low cost production areas or distinct places of knowledge production. These industry qualities aggravate strong concentrations and lead to the development of a core region in Europe that stretches over wide areas and ranges from Jutland in Denmark to northern and eastern Germany, whereby several cities like Hamburg, Husum, Rendburg, Aurich or Århus stand out as important centres, but none of them functions as hub for the entire sector.

Early firms in the WEC industry emerged in Denmark and the USA. The industry in Denmark was shaped by craftsmen that pioneered a highly successful WEC concept that subsequently was termed "Danish-design" (Heymann 1995, Oelker 2005). Cooke (2008) describes how early firms drew their technological inspiration from local marine engineering and agriculture, which led to rotor blades shaped like ploughs and ship propellers. The early Danish design was a rather simple and heavy construction. It was created in a trial and error process to endure the rough winds at the Danish costs and achieved broad acceptance due to its reliability (Karnøe 1999). Since industrial production of WEC could not be accomplished by the craftsmen dominated industry, their designs were picked up by medium size companies from agriculture machinery and equipment production like Vestas, Nordtank, Nordex or Danregn/Bonus. These firms provided the manufacturing capability and financial capacity to industrialise the production and development.

The industry in the USA followed a different approach. It developed and adopted a light-weight model, which combined high efficiency by fast rotation and sparse material: the light weight model. Supported by a DOE national research programme, technological development, especially for large scale turbines, was put forward by large engineering companies from the start. This rather sophisticated model of turbine design was a science driven attempt to leapfrog the Danish technology (Garud and Karnoe 2003). But unsteady operation and high failures aggravated the further diffusion of this technology (Van Est 1999).

The two designs directly competed during the Californian wind rush. In the 80s, 12.000 WEC, which represented 95% of global WEC production (Garud and Karnoe 2003), were installed in California. In the early 80s, the Danish market share was 2,6% in 1982 and grew rapidly to 71% in 1986. At the end of the Californian wind rush, about half of the installed turbines came from Denmark (Stoerring 2007). The burst of the bubble in 1986/7 caused the exit of nearly all US WEC manufacturers. While the industry was formed mainly by Danish and US firms in its early days, the German and Spanish industries grew to considerable scale during the 90s, and contemporary developments mostly take place in China and India.

Today, the core business of every WEC manufacturer is the assembly of nacelles and installation of turbines in the wind farm. A WEC contains up to 8.000 different components and wind turbine firms exhibit large differences in degree of vertical integration. Make or buy decisions refer to products like blades, gearboxes, generators, or towers. This leads to complex supply chains, when the degree of vertical integration of the manufacturer is low. As an industry, WEC gained increasing importance. It is estimated that the wind industry employs half a million people worldwide with a global turnover of 45bn. €. The capacity of growth of installed wind energy converters (WEC) from nearly 24 GW in 2008 to 38 GW in 2009 (Gwec 2010) reflects the dynamics of the industry. This growth is accompanied by a large number of new entrants and change of spatial pattern.

Due to these qualities of the industries, we expect the following results regarding the interplay between pre-entry experiences and agglomeration economies. First, as the industry depends on technological progress in related fields, we expect those firms showing better performance that have the capacity to integrate and absorb technological progress in different fields. Therefore, we expect the highest survival rates for experienced firms, i.e. firms that diversified from related fields. Second, as the nearness to market is an important factor in the industry, we expect that spatial factors play a role, yet in the form of early markets of considerable size with sophisticated customers (Porter 2000). As legislative frameworks and political support heavily affected the emergence of this green energy industry, we expect strong national influences. Third, literature suggests that the chosen technology affects the survival of firms, as exemplified by the competition between the Danish- and the light-design. To account for the ongoing structural changes in the industry we assume that also the particular technology chosen at time of entry affects the survival of the firm.

Development of the Global WEC Industry

Firms have tried to convert wind into electricity for a long time. Jacobs Wind Electric Company for example started in the USA already in 1922. With Allgaier, there also was an early entrant in Germany in 1948. In these early days, the production of wind turbine converters was rather craftsmanship than industrial process. Since the 70s, the production became an industry with a distinct profile. Due to these properties, and as data on the early phase are hardly available, we start with the analysis of WEC producers in the 70s.

Data on firms in the wind turbine industry were collected from various sources. Data on early industry entrants, such as their backgrounds and time of entry, was drawn from literature (e.g. Gipe 1995, Heymann 1995, Oelker 2005, Righter 1996, Van Est 1999, Gilles 2008, Karnøe and Jørgensen 1995) and internet documentation (www.windsofchange.dk). Information on entries at a later stage was gathered form general Media, specific industry magazines (Windpower Monthly, Neue Energie, North American Windpower) or company documents (Windblatt, WindpowerUpdate, VestasInside). Data on entry and exit of a company as well as the process of sectors consolidation were supplemented by not standardized telephone interviews (about 15) and general discussions with industry members on fair (about 6). Classification of technology was done under consideration of descriptions of above listed literature and drawn from picture documentation on www.windsofchange.dk.

For 32 out of 187 companies, data on year of entry or exit (in 13 cases), pre-entry experience (in 16 cases) or their used technologies (in 3 cases) were completed. Assumptions on year of entry and exit were based on the available firm information (e.g. technology, home country, entry date or exit reason etc.) in connection with the then dominating market trends. For example, when no further sign of activity was found for Danish and US firms after the Californian wind rush, we assume that they exited during the end of the bubble. Generally, the level of data quality increases over time and further increases if the firm is still alive.[2]

To compare the WEC industry with other studies, we apply survival analysis, i.e. we measure firm performance by years of production. We define the start of production as entry into the WEC industry. In accord with Boschma and Wenting (2007) as well as Wenting (2008) we distinguish between three types of entries: spin-offs, which are new firms where the founder has experience in the wind turbine industry; experienced firms, i.e. firms diversifying from related industries or where the founder(s) have experience in related fields. We defined related fields as those industries where most entries come from, i.e. handcraft, agricultural machinery, electrical engineering, mechanical engineering, designing activities, aerospace and steel industry. There were also 10 firms with an origin in ship building. We omitted ship building from related fields, as research suggest that the relation between ship building and wind turbines is not a technological one, but refers to infrastructure: shipyards provide infrastructure of the size necessary for the assembly of newer and larger wind turbines.

We define the year a firm ceased to produce wind turbines as exit. An exit could take place in several ways. The first is simply by bankruptcy. The second reason is the acquisition by another firm. However, if the acquirer had no activities in the wind turbine industry before and uses the acquisition to diversify into the industry, the acquisition is not classified as exit (Klepper 2007). The third reason for exit is the re-location from one country to another. In this case, we classified the firm as exit when it ceased its production in its origin country and as spin-off when the firm started its production in the new country. We classified firms as still alive, when an exit did not occur till 2009.

At all, we compiled a data base of 187 firms. As expected for a convergence industry, we found a large number of diversifiers and a small number of spin-offs. 82 firms entered the wind turbine industry from related fields. 23 firms spun off from firms already active in the industry. 82 firms were classified as inexperienced firms. 117 firms exited the industry, i.e. 70

[2] There are some differences between the complete and completed data sets, for example regarding the age of firms. These differences could be expected as data are especially missing when firms were active only for some years. These differences were not significant.

firms were still alive in 2009. Compared to other studies, the small number of spin-offs is obvious.

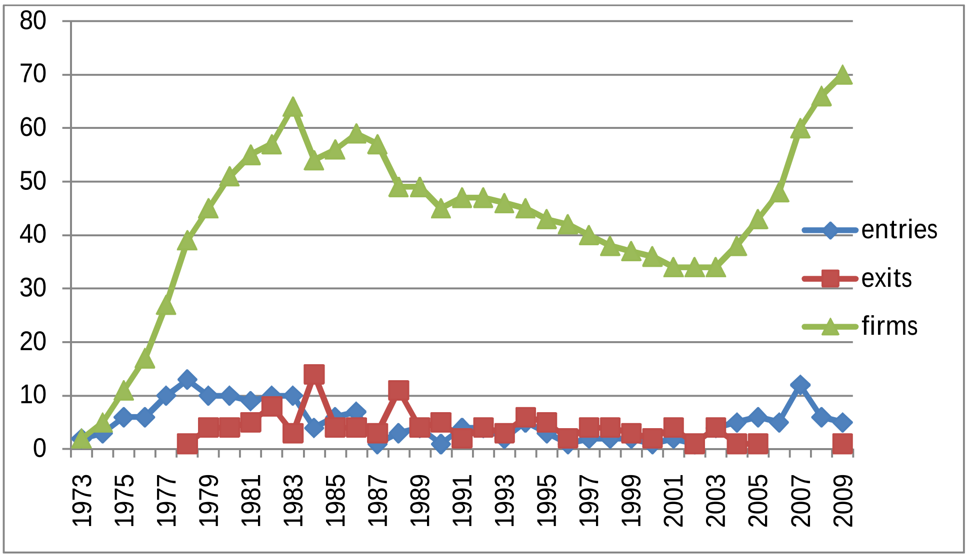

Figure 1: Development of Firm Numbers

The beginning of the industry was marked by several entries since 1973, among them large firms like General Electric[3]. The industry boomed on a global level till 1983 with a peak of 64 firms. This boom phase was followed by a shake out that lasts till 2002, when a second boom phase followed. There are two differences compared to studies previous studies on the spatial evolution of industries. The first is that the boom phase and the shake-out phase last longer than in comparable studies. The second difference is that there is a second boom phase starting from 2003.

The smother curve is caused by the analysis of the industry on the global instead of the national level. This aggregation mitigates the more distinguished dynamics on the national level. 102 of the 187 entries are distributed over three countries: Denmark had 33 entries, USA 30 entries and Germany 39 entries. Figure 1 shows that the firm numbers on the national level show more pronounced booms and shakeouts, but they take place during different points in time. While the peak of US-based firms did last from 1977 till 1983, Danish firms had their peak in 1983 and German based firms between 1991 and 1995. Additionally, these three countries cover 19 of the 23 spin-offs in the sample (see table 1). The aggregate of these different national pattern results in a smoother global pattern. The second deviation from existing studies, i.e. the second boom phase, is caused by a global restructuring of the industry. This boom mostly takes place in emerging markets like India or China, where the growing economies have a large demand for electricity, equally from which kind of source.

[3] GE exited the industry later and again entered the industry by acquiring Zond.

	Denmark	USA	Germany	rest	Total
Spinoff	7	5	7	4	23
Experienced	12	11	20	39	82
Inexperienced	14	14	12	42	82
Total	33	30	39	85	187

Table 1: Pre-experience of Entries in Denmark, USA, and Germany

	Entry1973-1983	Entry1984-2009	total
Spinoff	5	18	23
Experienced	40	42	82
inexperienced	44	38	82
Total	89	98	187

Table 2: Temporal Pattern of Pre-entry Experience

Table 2 illustrates the entry pattern over three cohorts. The Figure shows that with the exception of lower entry rates of spin-offs in the first cohort, a change of entry pattern cannot be observed. However, the changing background of the experienced firms, i.e. firms that diversified from related industries, exhibits the technological transformation of the industry. Figure 2 shows that the entries of the first cohort stem from a large range of fields, while in the second cohort most experienced entries had a background in mechanical engineering. The large number of firms from shipbuilding reflects the increasing size of wind turbines over time.

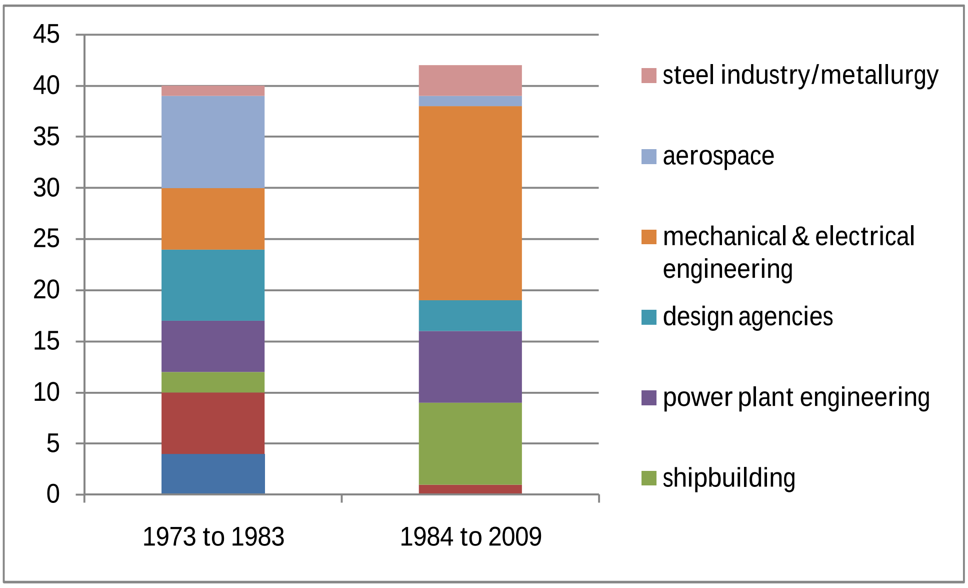

Figure 2: Temporal Pattern of Related Industries

Survival Analysis

We apply Kaplan-Mayer tables for the survival rates of firms depending on their type of entry. Firms that still exist as well as firms that were acquired by another wind turbine firm and ceased to produce under an own brand were censored. Figure 3 shows that there are no clear differences in survival rate of different types of firms on the global level. However, the analysis of the survival pattern in USA, Denmark and Germany show that the unclear global pattern might stem from differences on the national level. In Denmark, for example, experienced firms show the longest survival rates, while spin-offs exhibit the best performance in the USA and Germany. This figure gives a first indication on the importance of national differences in the evolutionary pattern of the wind turbine industry.

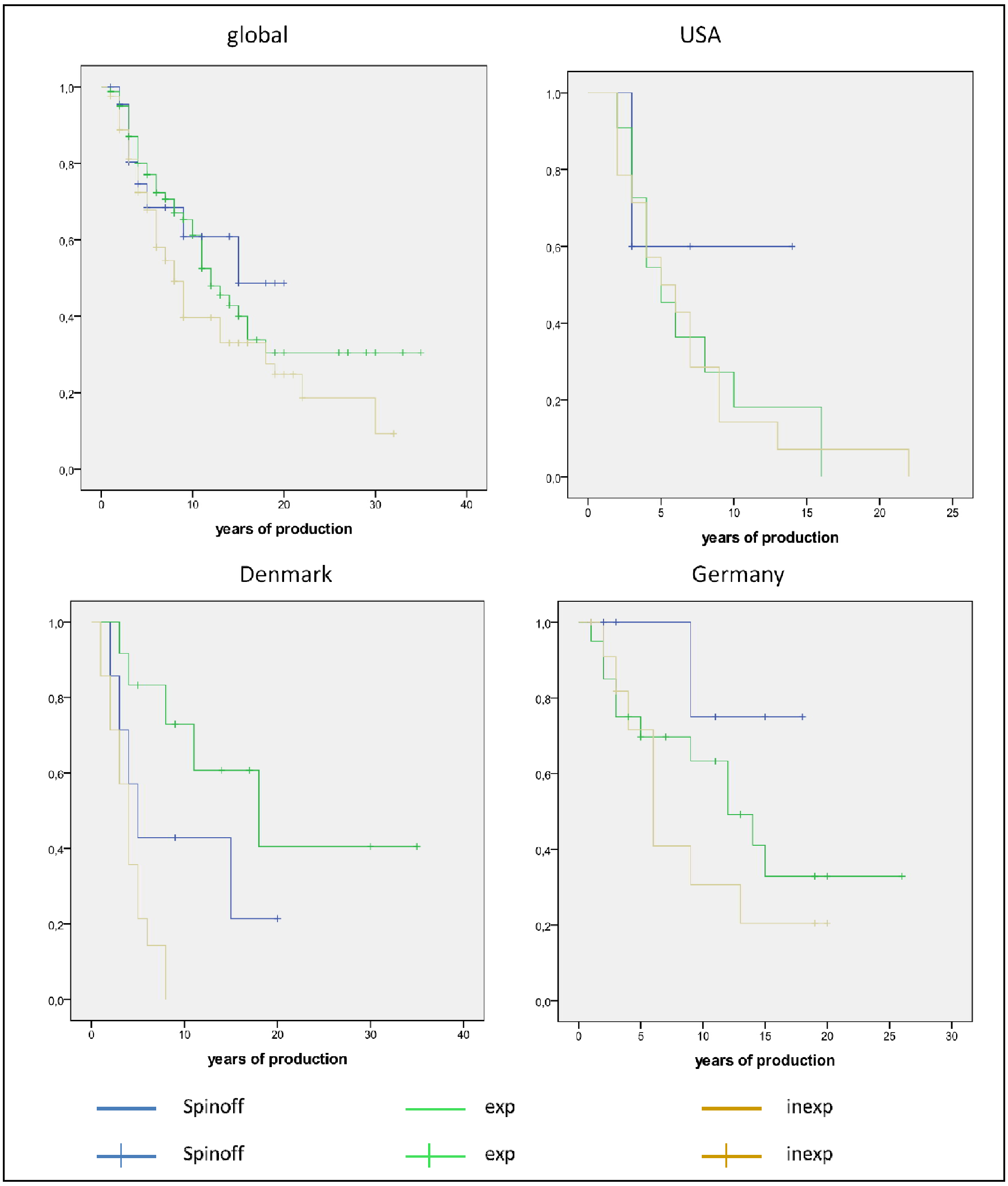

Figure 3: Survival Rates of Firms According to Spatial Context and Experience

For the further analysis, we apply Cox-regression. This procedure is applied in the relevant literature and enables the integration of cases that are still active and therefore have an unclear survival time. Although the lines of the Kaplan-Mayer tables for the global industries intersect, which actually violates the conditions to apply Cox regression, we apply this measure due to the clearer pattern on the national levels.

In addition to years of production and pre-entry experience (SPINOFF, EXP), we include we include two other variables on the firm level. The first regards the applied technological designs. As illustrated by the competition between the light weight and Danish design during the Californian wind rush (Stoerring 2007), the applied design was an important factor for firm survival. We build dummies for the light-weight (DESLIGHT) and Danish design (DESDK) as well as for the standard drive train (DESSTAND), which is an advancement of the Danish design and the currently dominant design. There are still other designs, which are applied by too few firms to count as a distinct category. One example for this is the Darrieus design, which consists of turbines rotating with a vertical axis and was applied by five firms. Betting on the right technological trajectory strongly affects survival rates, (Kenney and Von Burg 1999, Bresnahan et al. 2001). Therefore, we expect positive effects by the Danish and Standard design. The second firm variable contributes to assess post-entry learning. The WEC industry has a diverse knowledge base and it can be assumed that firms benefit when they are able to combine, absorb, and integrate technological progresses in different fields. We use acquisitions of other firms as proxy for this capability.[4] There are three types of acquisition relevant in the sample: WEC firms acquire other WEC firms in the same country, WEC firms acquire other WEC firms in other countries, and WEC firms that were acquired by firms from outside the industry. Phene et al. (2006) show that firm's success by collaboration is higher when two firms are either in the same field but in different countries or in related fields in different countries, while collaboration within the same field and the same country has a lesser effect. Therefore, we combine the number of acquisitions of firms in other countries and from other industries into one variable (ACQUI). We additionally test if acquisitions of WEC firms in the same country affect survival as well (ACQUIIND). Following Phene et al. (2006), we expect a positive influence of ACQUI on firm survival.

In accordance with existing literature (Klepper 2009), we build a dummy to assess spatial influences for firms being in the core region of the WEC industry ranging from Denmark over northern Germany till the Netherlands (CORE). This core region consists of at all 71 firms. To assess the influence of national effects, we employ dummy variables on the

[4] We are aware of the endogeneity problem by using post-entry changes in Cox regression and will change the method to multi nominal logit regression in the next version of the paper.

country level for Denmark (DK), USA (USA) and Germany (GER). The majority of entries are distributed over these three countries. Furthermore, wind energy as green energy strongly depends on national legislation and support.

To generally consider changes in the socio-economic environment, we built dummies for the first of the three entry cohorts illustrated in Table1 (COHORT73TO83). It is generally expected that early entrants survive longer than later entrants (Klepper 2007). However, the burst of the Californian wind rush falls into the first cohort; therefore we expect shorter survival rates for early entries.

Eight models were elaborated upon these variables. The first model only consists of dummy variables for spin-offs and experienced firms. The coefficients in Table 2 show that hazard rates for firms decrease when it is a spin-off or experienced firms. However, only the rates for experienced firms are significant, which is most probably the result of the small numbers of spin-offs.

Model 2 tests for temporal effects on survival rates. We included a dummy for the first cohort into the model. In contrast to other studies that show longer survival rates for early entrants, the opposite is the case for the WEC industry. The reason for this might lie in the Californian wind rush. Most of these firms are Danish or US firms that were active during the bubble and exited when the bubble burst. But the increased hazard rates might also be a result of the data available. Firms that only existed a few years are easy to detect in countries with an already established industry with specialized institutions to monitor the industry, while they might stay unnoticed in more peripheral areas.

The third model includes with ACQUI and ACQUIIND some additional firm related variables. Both variables have a negative influence on hazard rates, with ACQUI a stronger one, as expected. But in this model, no effect is significant.

The fourth model includes the applied technological design at time of entry. The model shows that especially DESLIGHT increased hazard rates. This increase is certainly a result of the burst of the Californian wind rush, where nearly all firms that applied this design went bankrupt. The increased hazard rate by the Danish design might have the same cause. In contrast, applying the standard design, which diffused widely, had no significant effect on survival rates. In this model, DESLIGHT is the only significant variable.

Model 5 includes the country dummies. The country dummies are all significant and increase hazard rates, i.e. entering the WEC industry in one of these countries decreases the length of survival. It seems that an increase in turnover of firms is responsible for the strength of these countries in the wind turbine industry. This reflects results on the regional level that agglomerations are accompanied by a high degree of firm turnover (Wagner and Sternberg

2004). Additionally, model 5 is the first model where pre-entry variables SPINOFF and EXP are both significant. As already illustrated in Figure 1, the national institutional environment strongly affects the how pre-entry experience affects survival.

In model 6, the country dummies are exchanged with a dummy variable for firms in the core region of the global wind turbine industry. In contrast to the country dummies, this variable negatively affects survival rates, but is not significant. In this model, mostly pre-entry experience explains survival rate and not being located in a particular global region.

Models 7 and 8 include variables regarding all dimensions to further elaborate the interdependencies of the different variables. We include ACQUI, as acquiring firms in other countries and other industries had a stronger effect on survival rates than ACQUIIND. Regarding applied technologies, we include DESLIGHT, as especially this variable measures the increased hazard rate caused by betting on the wrong technological trajectory. The difference between models 7 and eight is that model 7 includes country dummies, while the spatial dummy in model 8 refers to the core region of the global wind turbine industry. The interesting point is that pre-entry experience becomes insignificant when using the dummy for the core region instead of the country dummies, which might be a result of the strong national influences on survival pattern. At all, model 7 with the country dummies explains most of the patterns. It shows that national influences are relevant as expected as well as the choice of technology. Furthermore, as expected for this industry, experienced firms exhibited better survival than spin-offs. What could not be proved was the influence of post-entry experience in the form of acquisitions. Three reasons might apply for this. The first lies in methodological difficulties by using Cox-regression for post-entry experiences (see also Footnote 4). The second is the small numbers available for acquisitions from other industries and other countries. A problem that also would be solved by using the appropriate method. The third reason might be that the assessment was wrong.

Concluding, pre-entry experience was insignificant when also spatial dummies were integrated into the models. The only exception was the model 2, which includes COHORT73-83. However, firms in this cohort were mostly firms from Denmark, the USA or Germany. This temporal variable therefore reflects to some extent the country variables.[5] Furthermore, entries from related industries seemed to perform better than spin-offs as well as firms that have chosen the right technology. This might indicate that in an industry that strongly depends on technological progress in neighboring fields, suffered from several changes of technological designs and spatial configurations as well as an early bubble and general dynamic capabil-

[5] The results should be taken with care, as the data base is still under construction.

ities (Teece et al. 1997) are more important to cope with these changes are important than industry specific routines.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model7	Model 8
Spinoff	-0,511	-0,289	-0,301	-0,209	-0,923**	-0,668*	-0,430	-0,135
Exp	-0,368*	-0,376*	-0,353	-0,345	-0,532**	-0,473**	-,613***	-0,422*
Cohort73to83		0,914***					0,347	0,532**
Acqui			-0,425				-0,542	-0,324
Acquiind			-0,101					
Deslight				1,088***			1,183***	1,118***
DesDK				0,192				
DesStand				-0,351				
DK					1,338***		1,615***	
USA					1,518***		0.729***	
Ger					0,779**		0,729**	
Core						0,360		0,568**
Number of Cases	187 (93 cens.)	187 (93 cens.)	187 (93 cens.)	187 (93 cens.)	187 (93 cens.)	187 (93 cens)	187 (93 cens.)	187 (93 cens.)
Chi-square	3,802	19,732 ***	5,529	39,921 ***	41,165 ***	6,419 *	64,861 ***	50,509 ***
-2 log likelih-ood	843,070	826,468	840,520	813,061	808,527	840,427	784,156	802,463

Table 3 Cox-Regression Results (significancy: 10%*, 5%, 1%***)**

Conclusion

The starting point of the study was the insights on the evolution of concentrations gained by Klepper's heritage theory, i.e. that firm based qualities, mostly in the form of pre-entry experience, can explain the emergence of large concentrations. In nearly all studies that applied the heritage theory, the results strongly point towards a stronger influence of firm-based qualities for the establishing of large concentrations than standard explanations by agglomeration economies. While it was stated in all these studies that the heritage theory intended to give alternative explanations for the case under study, the question arises if this theory is generalisable.

The intention of the study was to apply the heritage framework on an industry that differs from the previously investigated industries in one important way: it is an industry that results from the technological convergence of other industries. As such, the WEC industry strongly depends on technological progress in related fields. Beside several technological changes, the industry underwent also changing spatial restructuring on the global level.

The preliminary results show that in contrast to other studies spin-offs are yet an important element, but of lesser importance for spatial evolution of the wind turbine industray. Additionally, firms that entered in countries which formed spatial concentrations in the WEC industry showed lower survival rates than in other countries.

The results are preliminary and underlie several qualifications. The first of all is that the data base still is under construction. The seconds refers to the variables applied in the study. There are some indications that several industries that we termed as related and entries from those industries as experienced firms did not have a positive effect on firm survival. Examples for this are aerospace and shipbuilding. The third limitation is the method. Multinominal-logit regression would the endogeneity problem of some variables like ACQUI and ACQUIIND, i.e. do firms perform different because they acquire other firms or do they acquire other firms because they perform better.

Despite these qualifications, the preliminary results indicate that the dependence of the WEC industry on progress in other field results in firm and spatial dynamics different from those in the automobile, banking, tire or semiconductor industry. Further and deeper analysis of this industry would lead to a better understanding of the interplay between the qualities of firms as well as their environment for the spatial evolution of industries.

References

Boschma, R. and Ledder, F. (2010): The Evolution of the Banking Cluster in Amsterdam, 1850-1993: A Survival Analysis. In: Emerging Clusters - Theoretical, Empirical and Political Perspectives on the Initial Stage of Cluster Evolution, ed. D. Fornahl, S. Henn and M.-P. Menzel. Edward Elgar, Cheltenham UK; Northampton, MA USA, 191-213.

Boschma, R. and Wenting, R. (2007): The Spatial Evolution of the British Automobile Industry: Does Location Matter? In: Industrial and Corporate Change 16(2), 213-238.

Boschma, R. A. and Weterings, A. B. R. (2005): The Effect of Regional Differences on the Performance of Software Firms in the Netherlands. In: Journal of Economic Geography 5(5), 567-588.

Boyer, R. and Durand, J.-P., Editors (1997): After Fordism. MacMillan Pres Ltd., London.

Bresnahan, T., Gambardella, A. and Saxenian, A. (2001): ‘Old Economy’ Inputs for ‘New Economy’ Outcomes: Cluster Formation in the New Silicon Valleys. In: Industrial and Corporate Change 10(4), 835-860.

Btm. (2010): International Wind Energy Development, World Market Update 2009. Ringkøbing: BTM Consult.

Buenstorf, G. and Klepper, S. (2009): Heritage and Agglomeration: The Akron Tyre Cluster Revisited. In: Economic Journal 119(537), 705-733.

Chesbrough, H. W. (2003): The Era of Open Innovation. In: Mit Sloan Management Review 44(3), 35-41.

Cooke, P. (2008): Regional Innovation Systems, Clean Technology & Jacobian Cluster-Platform Policies. In: Regional Science Policy & Practice 1(1), 23-45.

Cooke, P. (2010): Jacobian Cluster Emergence: Wider Insights From "Green Innovation" Convergence on a Schumpeterian 'Failure'. In: Emerging Clusters - Theoretical, Empirical and Political Perspectives on the Initial Stage of Cluster Evolution, ed. D. Fornahl, S. Henn and M.-P. Menzel. Edward Elgar, Cheltenham UK; Northampton, MA USA, 17-42.

Garud, R. and Karnoe, P. (2003): Bricolage Versus Breakthrough: Distributed and Embedded Agency in Technology Entrepreneurship. In: Research Policy 32(2), 277-300.

Gilles, P. (2008): Windpower. Zürich: Schiffer.

Gipe, P. (1995): Wind Energy Comes of Age. New York: Wiley.

Gwec. (2010): Global Wind 2009 Report. Bruxelles: GWEC.

Heymann, M. (1995): Die Geschichte Der Windenergienutzung : 1890 - 1990. Frankfurt: Campus.

Iset. (2006): Windenergiereport Deutschland 2005. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Kassel.

Kammer, J. (2010): Windenergie: Die Strukturen Einer Wachstumsindustrie Und Die Ausbildung Eines Globalen Standortmusters. University of Hamburg: PhD-thesis.

Karnøe, P. (1999): When Low-Tech Becomes High-Tech: The Social Construction of Technological Learning Processes in the Danish and the American Wind Turbine Industry. In: Mobilizing Resources and Generating Competencies: The Remarkable Success of Small and Medium-Sized Enterprises in the Danish Business System, ed. P. Karnøe, P. H. Kristensen and P. H. Andersen. Copenhagen Business School Press, Copenhagen, 139-185.

Karnøe, P. and Jørgensen, U. (1995): Samfunnsmoessig Vaerdi Af Vindkraft, Delrapport 4: Dansk Vindmølleindustris Internationale Position Og Udviklingsbetingelser Copenhagen: AKF Forlaget.

Kenney, M. and Von Burg, U. (1999): Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128. In: Industrial and Corporate Change 8(1), 67-103.

Klepper, S. (2001): Employee Startups in High-Tech Industries. In: Industrial and Corporate Change 10(3), 639-674.

Klepper, S. (2007): Disagreements, Spinoffs, and the Evolution of Detroit as the Capital of the Us Automobile Industry. In: Management Science 53(4), 616-631.

Klepper, S. (2009): Spinoffs: A Review and Synthesis. In: European Management Review 6(3), 159-171.

Krugman, P. (1991): Geography and Trade. Cambridge MA: MIT Press.

Oelker, J. (2005): Windgesichter : Aufbruch Der Windenergie in Deutschland. Dresden: Sonnenbuch-Verlag.

Phene, A., Fladmoe-Lindquist, K. and Marsh, L. (2006): Breakthrough Innovations in the Us Biotechnology Industry: The Effects of Technological Space and Geographic Origin. In: Strategic Management Journal 27(4), 369-388.

Porter, M. E. (2000): Location, Competition, and Economic Development: Local Clusters in a Global Economy. In: Economic Development Quarterly 14(1), 15-34.

Righter, R. (1996): Wind Energy in America: A History. Norman: University of Oklahoma Press.

Romanelli, E. and Feldman, M. (2006): Anatomy of Cluster Development: Emergence and Convergence in the Us Human Biotherapeutics, 1976–2003. In: Cluster Genesis: Technology-Based Industrial Development, ed. P. Braunerhjelm and M. Feldman. Oxford University Press, Oxdord, 87-112.

Stoerring, D. (2007): Emergence and Growth of High Technology Clusters. University of Aalborg: PhD thesis.

Storper, M. and Walker, R. (1989): The Capitalist Imperative: Territory, Technology, and Industrial Growth. Cambridge MA: Basil Blackwell.

Teece, D. J., Pisano, G. and Shuen, A. (1997): Dynamic Capabilities and Strategic Management. In: Strategic Management Journal 18(7), 509-533.

Van Est, R. (1999): Wind of Change. A Comparative Study of the Politics of Wind Energy Innovation in California and Denmark. Utrecht: International Books.

Wagner, J. and Sternberg, R. (2004): Start-up Activities, Individual Characteristics, and the Regional Milieu: Lessons for Entrepreneurship Support Policies from German Micro Data. In: Annals of Regional Science 38(2), 219-240.

Wenting, R. (2008): Spinoff Dynamics and the Spatial Formation of the Fashion Design Industry, 1858-2005. In: Journal of Economic Geography 8(5), 593-614.