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1/2018

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April 2018

Publisher:
Helmholtz-Zentrum für Umweltforschung GmbH – UFZ
Permoserstr. 15
04318 Leipzig

ISSN 1436-140X

The Regional Heterogeneity of Wind Power Deployment: An Empirical Investigation of Land-use Policies in Germany and Sweden*

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Abstract

The purpose of this paper is to investigate the impacts of land-use policies on wind power deployment at the regional levels in Germany and Sweden, respectively. We use data on added wind capacity at the German district level and the Swedish municipality level over the time period 2008-2012. These data are analysed with a model specification permitting the probability of having any capacity addition (1/0) during this period to be independent of the level of the installed capacity (in MW). The results confirm that the regional variations in wind power deployment can to a significant extent be attributed to land-use policies, not least in the form of priority areas and the designation of restricted areas. The quantitative results display interesting differences across the two countries, not least concerning the role of priority areas, which is found to be much more profound in the German case. The assignment of protected areas appears instead to have constituted a more stringent policy tool in Sweden. Furthermore, cross-country differences in the relevance of various explanatory variables are also found to be related to geographical patterns, the overall extent of wind power deployment, as well as the design of the support schemes for wind power. Overall, the results highlight the need for better understanding of the critical role of land-use policies for future renewable energy development in various national and institutional contexts.

Key words: wind power; regional distribution; land-use policy; Germany; Sweden.

* Financial support from the German Helmholtz Association (Grant HA-303), the German Ministry of Education and Research (Grant 01UU1703), and the Swedish Energy Agency is gratefully acknowledged. Any remaining errors reside solely with the authors.

1 Introduction

Wind power is widely considered an important technological option to decarbonize the electric power sector (IPCC, 2011). Consequently, wind power is increasingly deployed in most countries across the world. Yet, the level and growth of wind power deployment vary strongly across countries (GWEC, 2016). This heterogeneity can be explained by differences in natural and geographic endowments, which affect both the availability of sites for and the profitability of wind power deployment (e.g., Gosens, 2017; Mann et al., 2012), as well as by the economic strength of a region, i.e., the availability of capital for investment (e.g., Carley et al., 2017; Jenner et al., 2013). Importantly, however, the spatial patterns of wind power deployment have also been driven by variations in the political framework. Two types of policies are particularly important: First, public support schemes for renewable energy sources (RES), such as feed-in tariffs or renewable portfolio standards, have had a significant impact on the profitability of wind power deployment. Second, land-use policies, such as priority areas, protected areas, etc., affect the availability of sites for such deployment.

Significant scientific efforts have been undertaken to understand the impact of RES support schemes on wind power deployment empirically – at a global scale (Carley et al., 2017; Dijkgraaf et al., 2018) as well as for important markets such as the USA (Bowen and Lacombe, 2017; Hitaj, 2013; Maguire and Munasib, 2016; Menz and Vachon, 2006; Shrimali et al., 2015a; Shrimali et al., 2015b; Staid and Guikema, 2013), Europe (Jenner et al., 2013; Nelson, 2008), and China (Xia and Song, 2017). These studies suggest that feed-in tariffs have been important drivers of wind power deployment, while results are more mixed for renewable portfolio standards. In contrast, far less is known empirically as to whether and to what extent the spatial heterogeneity of wind power deployment is driven also by various types of land-use policies regulating the availability of sites. This paper contributes to closing this research gap (see also below). We here employ an econometric approach with the purpose to investigate – and compare – the impacts of land-use policies on wind power deployment at the regional levels in Germany and Sweden.

Land-use policy, specified in planning and environmental permitting law, determines at which sites wind turbines can actually be installed, and how they must be designed (e.g., maximum allowable height) and operated (e.g., allowable operation hours). It may take effect through general regulations, such as the designation of priority or exclusion areas for wind power, or minimum distances of wind turbines to human settlements. Moreover, it typically specifies which criteria that need to be met when an operation permit is to be issued to a specific wind power project. So far, the importance of land-use policies for wind power deployment has been emphasized primarily using qualitative approaches based on case study methodology (e.g., Aitken et al., 2008; Cowell, 2010; Ferguson-Martin and Hill, 2011; González et al., 2016; Hajto et al., 2017; Hull, 1995; Köppel et al., 2014; Larsson and Emmelin, 2016; Masurowski et al., 2016; Ohl and Eichhorn, 2010; Petterson et al., 2010; Toke et al., 2008; Veidemane and Nikodemus, 2015). This literature stresses that land-use policy, and thus land availability, may vary a lot between regions within a country (federal states, counties, municipalities) – and could therefore be an important driver of heterogeneous wind power deployment at the regional level. In our paper, we test this hypothesis quantitatively.

Understanding the role of regional land-use policy for land availability is important. On the one hand, it is a means to incorporate social and environmental impacts at the regional scale into siting decisions for wind turbines. On the other hand, it could constitute a significant constraint to wind power deployment and in this way jeopardize the attainment of national and supranational RES deployment targets. Our empirical analysis will help to shed light on how important this trade-off is in practice. Of course, our quantitative approach is not a substitute but rather a complement for qualitative case studies; it helps to shed additional light on the general significance and magnitude of land use policy impacts.

To our knowledge, only few studies are available that investigate quantitatively how regional land-use policy could affect wind power deployment (see Ek et al., 2013; Goetzke and Rave, 2016; Hitaj, 2013; Hitaj et al., 2014). While these provide some insights on the importance of land-use policy, the results are overall mixed and inconclusive. Inter alia, this is due to the fact that this research has important limitations. Importantly, the studies only consider proxy variables that are assumed to be related to the willingness and ability of regional authorities to provide the necessary sites for wind power. These variables include: (a) the level of economic development of a region (assuming that regions in economic decline may be more interested in developing new green industries); (b) previously installed capacity in a region (assuming that higher capacities in the recent past indicate higher political willingness and institutional capacity); and (c) political preferences in a region (e.g., assuming that green and/or leftish voters are more supportive of wind power deployment). Most likely, though, these proxies also capture influences other than regional land-use policy. For example, previously installed capacity may not only indicate a strong political preference for wind power (positive relationship), but also to the presence of fewer sites available for additional wind turbines (negative relationship) (e.g., Goetzke and Rave, 2016). Moreover, the mixed results reported in previous research also follow from the use of different variable specifications, econometric approaches and national contexts (Germany, Sweden, USA etc.).

We add to this literature in two main ways: First, we include variables that measure regional land-use policy and the corresponding availability of sites for wind power deployment more directly – most notably the size of priority areas for wind power deployment and nature protection areas (i.e., exclusion areas for wind power) issued by regional authorities. We here also consider the length of green party participation in regional government, which we argue is a better indicator of pro-wind preferences of regional governments than green votes. Second, and equally important, we apply a consistent empirical framework (i.e., identical econometric approach, closely related variables) to explain regional wind power deployment in two countries, Germany and Sweden. This allows us an informed discussion on whether any cross-country differences in the relevance of variables will be related to: (a) the underlying contextual heterogeneity, e.g., geographical patterns, such as Germany being more densely populated than Sweden; (b) the overall extent of wind power deployment, such as Germany being a pioneer and Sweden being a follower; (c) the national RES support scheme, i.e., feed-in tariff in Germany and RES quota with tradable green certificates in Sweden; or (d) the degree of decentralization in land-use policy, such as Sweden having a more decentralized territorial planning system than Germany.

Our empirical analysis employs data on newly installed wind power capacity at the German district and the Swedish municipality levels over the time period 2008-2012. This dependent variable is linked to variables that address how supportive – or constraining - regional land-use policies have been in the two countries in terms of land availability (size of priority areas and exclusion areas, previously installed capacity, constituency of the governing party, regional benefits and costs of wind power deployment). We also include a number of control variables (i.e., wind speed, population density, size of region). Due to the presence of limit (censored) observations, the econometric analyses rely on the so-called Tobit model (Tobin, 1958) and the more general Cragg specification (Cragg, 1971). The latter specification permits the factors determining the probability of a limit observation, i.e., having any capacity addition during the relevant period, to be different from the determinants of the (truncated) regression model for the non-limit data, i.e., the level of the installed capacity in MW.

The remainder of the paper is organized as follows: Section 2 briefly introduces the political frameworks for wind power deployment in Germany and Sweden, respectively. Section 3 introduces our empirical approach, including the conceptual framework, data and model specification. Our results are presented and discussed in Sections 4 and 5, while Section 6 concludes the paper.

2 Political Framework for Wind Power Deployment in Germany and Sweden

2.1 General Context

Figure 1 displays the development of total wind power capacity in Germany and Sweden, respectively, over the time period 1990-2016. This illustrates that Germany is a forerunner in terms of wind power generation,[1] while the Swedish expansion has taken place with essentially a 10- to 15-year time lag. In 2016 the total installed wind power capacity (MW) was more than seven times higher in Germany compared to Sweden. Moreover, from a land use perspective it is useful to note that the density of wind power capacity in terms of MW/km^2 is almost ten times as high in Germany.

One key explanation behind these varying developments is the variation in the profitability of wind power investments across the two countries. This is driven by the difference in RES support schemes

[1] Until the year 2007 Germany was the world leader in terms of installed wind power capacity; after that both the USA and China have reported higher capacities of wind power.

and levels, and the consistency with which these national wind power policies have been implemented. The early Swedish wind power policy relied on a feed-in premium, the so-called environmental bonus, which was low and provided little long-term certainty for investors (e.g., Åstrand and Neij, 2006). In 2003, Sweden introduced a technology-neutral green certificate system for renewable electricity with the aim to secure a pre-determined market share for renewable energy sources. RES generators are awarded a certificate for every MWh they generate, and users are obliged by law to purchase certificates that correspond to a certain percentage of their electricity use. Since 2006 the green certificates have been issued over a 15-year period, thus creating relatively favourable investment conditions for wind power, and with support levels ranging around Euro 20-25 per MWh. The most significant expansions in Swedish wind power capacity therefore occurred after this year (see Figure 1). Importantly for our analysis, the Swedish RES support scheme is spatially uniform, i.e., there is no regional differentiation of certificate prices (Bergek and Jacobsson, 2010).

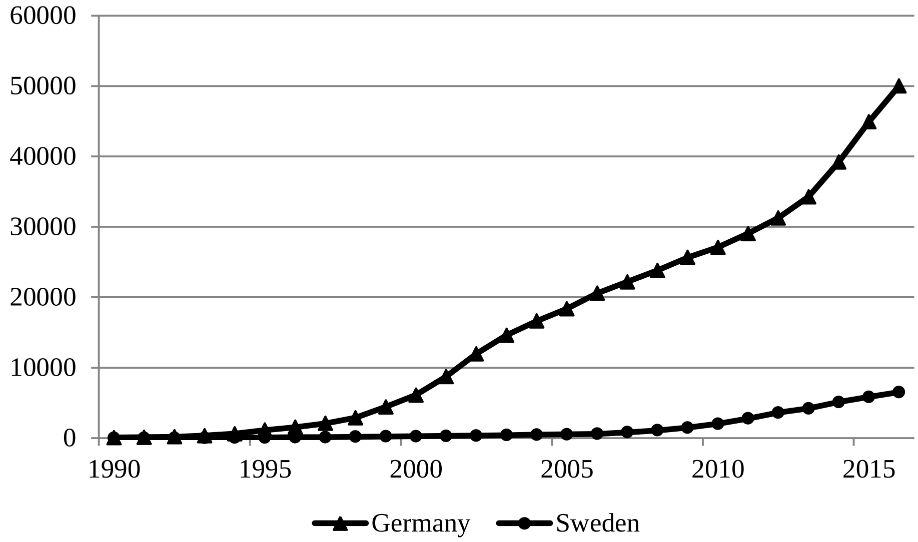

Figure 1: Installed Wind Power Capacity (MW) in Germany and Sweden, 1990-2016

Sources: Deutsches Windenergie-Institut (DEWI) and the Swedish Energy Agency.

In Germany the capacity of wind power started to increase significantly in the beginning of the 1990s, in particular with the implementation of the Law on Feeding Electricity into Grid (StrEG) in 1991. It introduced a technology-specific feed-in premium guaranteed over the first 20 years of the lifetime of the plant. The support scheme was further strengthened in 2000, when the premium was replaced by a fixed feed-in tariff. This introduction increased investment certainty and was one important driver behind the strong expansion of wind power deployment in the following almost two decades (Goetzke and Rave, 2016). In contrast to the Swedish scheme, the German feed-in tariff is not spatially uniform. The so-called reference yield model introduced in 2000 provides for higher (lower) support levels at sites where the expected wind yield is below (above) that of a legally defined reference site. This thus implies a regional differentiation of support levels as a function of windiness. Yet, even though the German reference yield model partly levelizes regional differences in profitability, overall profitability of investments still increases with windiness (Hitaj et al., 2014).

Differences in the levels and growth of wind power deployment between Germany and Sweden can thus be explained by differences in the timing of the RES support schemes and the extent to which policies have reduced investment risks. In addition, support levels have been significantly higher in Germany compared to Sweden. That is, wind power investments have been simply more profitable in Germany than in Sweden. For instance, while the price for a Swedish certificate averaged around Euro 20 per MWh in 2012 (the final year of the period under consideration in the present paper), even the basic tariff in Germany was more than twice as high.[2]

2.2 Importance of Land-use Policy

The land-use policy frameworks regulating the availability of sites for wind power deployment differ between Germany and Sweden. Most notably perhaps, the Swedish planning system stands out as highly decentralized. In cases where the competition for land use is intense, the municipalities must in some way assent to (i.e., plan for) the establishment of wind turbines in order for the installation to take place. However, since all Swedish municipalities have a de facto planning monopoly, they can block wind power by simply ignoring to plan for it. In more remote areas (with less intense land use restrictions) this so-called detailed plan is not required, but as of 2008 the municipalities have been given an explicit veto right with respect to wind power. This implies that no new wind power projects can take place without municipal consent; the new veto was even applied retroactively to pending cases (Petterson and Söderholm, 2011).

The strong municipal position in Sweden leaves substantial room for discretion, in selected cases, making it difficult for wind power investors to access interesting locations in the first place. Khan (2003) even reports that various municipal planning requirements, e.g., the way in which citizens' perceptions are consulted in the planning process, may have been attributed to differences in the attitudes of specific local officials.

Furthermore, at the national level certain geographical areas may be designated as being of "national interest" for wind power. However, in Sweden this is a relatively weak policy tool. For instance, if a specific area is of national interest for other purposes as well (e.g., nature conservation, national defence, reindeer husbandry, mining etc.), the legal rules overall provide little guidance on how to weigh these various interests against each other (Söderholm et al., 2007; Pettersson, 2008).

In Germany the land-use policy system is instead more vertically integrated. It builds on a multi-level governance structure with subsidiarity and counter-current principles for spatial planning (AEE,

[2] See also the extensive archive provided by the RES LEGAL Europe website, http://www.res-legal.eu/archive/.

2012). The national level only decides on the framework regulation, e.g., the requirement that wind power developments should be privileged in non-developed areas (in contrast to most other developments). The strongest competencies are assigned to the federal states and their planning regions. Each federal state can determine a minimum share of its land area that should be designated for wind power. In addition, federal states also issue guidelines for planning and permitting procedures for the lower governance levels. Planning regions (consisting of several municipalities) within the federal states translate these guidelines into spatially explicit priority areas for wind power. The decision on where to establish these priority areas also needs to account for aspects of nature conservation (e.g., pre-existing nature protection areas) and immission control (e.g., distance to human settlements).

Municipalities, e.g., districts or towns, are responsible for setting up yet more specific municipal development plans as well as for permitting individual developments. Their decisions must be in line with the superordinated plans. For example, a German municipality can typically only permit wind power developments, which are located within a priority area defined in the regional plan (BBSR, 2014).[3] The analysis of German land-use policy thus cannot be restricted to the municipal level; it also needs to account for decisions taken at the level of planning regions and federal states.

3 Empirical Approach

3.1 Conceptual Framework

We empirically aim to understand what drives the amount of *additionally installed capacity within a region* (district in Germany, municipality in Sweden) over the time period 2008-2012. Our conceptual analytical framework is displayed in Figure 2. We here assume that the dependent variable hinges on two underlying parameters: the profitability of wind power generation and the availability of sites for installing wind turbines in a region. The specific variables employed to address these impacts are introduced and motivated below, while Section 3.2 provides information about how the variables have been operationalized and what data sources have been used.

Regional land-use policy directly affects the availability of sites. Two instruments of regional land-use policy can be readily measured quantitatively: priority areas for wind power development (or “areas of national interest” in Sweden), and exclusion areas that impose restrictions on wind power development (particularly protected areas for nature conservation). We therefore include both variables in our empirical investigation. We assume that installed wind power capacity in a region increases with the *size of priority areas*, and decreases with the *size of exclusion areas*. However, including only the sizes of priority and exclusion areas would not fully capture all relevant dimensions of regional land-

[3] The stringency of the priority areas set up in the regional plans actually varies from recommendation to binding prescriptions.

use policy.[4] First, the size of such an area will typically be a function of underlying regional political preferences. Moreover, land-use policy is not only restricted to priority and exclusion areas. It also materializes through the use of other instruments, such as guidelines for the permitting of individual wind power developments. Such impacts, though, are difficult to include in quantitative assessments. For this reason, we consider additional variables, which are assumed to measure the general political preferences and the institutional capacity to facilitate wind power development at the regional scale.

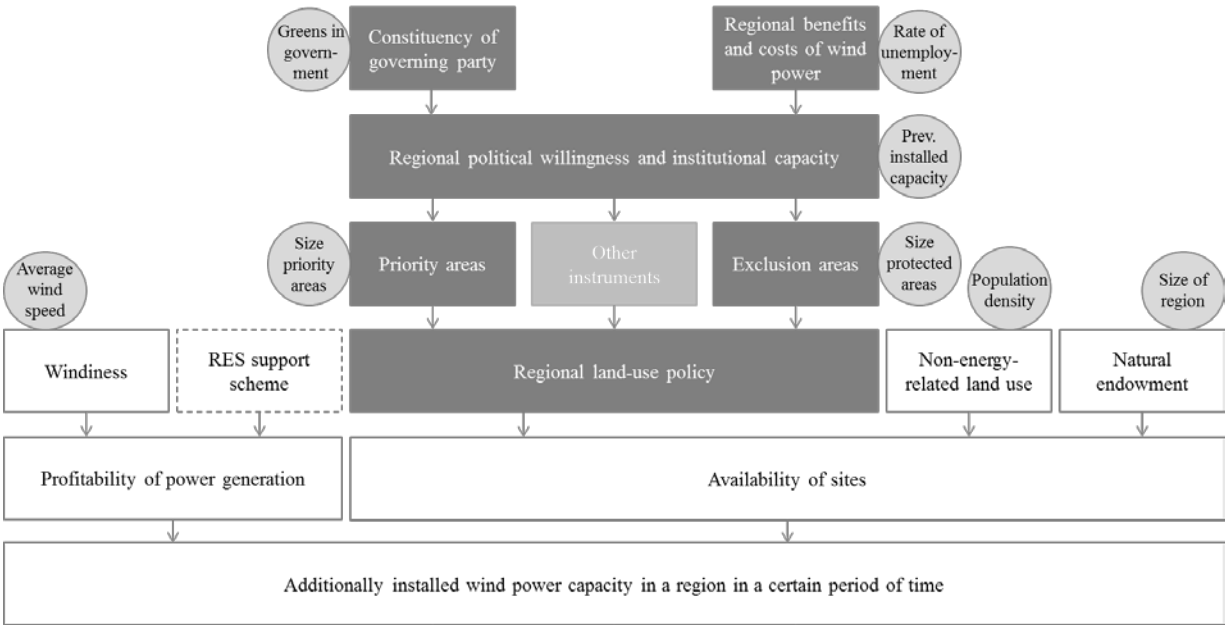

Figure 2: Drivers of Regional Heterogeneity of Wind Power Deployment

Note: Rectangles represent general explanatory factors, while circles represent the corresponding specific variables included in the econometric model.

In order to capture regional political preferences and institutional capacity we include the *amount of total capacity installed prior to the period under consideration*, before 2008, in a region (federal state in Germany, and municipality in Sweden). We assume that a positive relationship between previously and newly installed wind power capacity may point to: (a) a generally high political willingness to facilitate wind power development within a region; (b) good relations between the local authorities and wind power investors that have resulted from previous project developments; and/or (c) a high level of acquired institutional capacity in terms of experience with and knowledge of planning and permitting wind power developments (Ek et al., 2013). This notwithstanding, the eventual sign of the relationship is *a priori* unclear. A high level of previous investments may also impair new investments within a region because suitable and profitable sites have become scarcer as a result (saturation effect, see, for instance, Goetzke and Rave, 2016).

[4] Indeed, leaving out variables would also lead to bias in the econometric estimations when the excluded variable is correlated with the dependent variable and one or more included independent variables (e.g., Greene, 1993).

Furthermore, the willingness to facilitate wind power deployment in a given region will depend on the constituency of the governing parties (for a general discussion, see Kirchgässner and Schneider, 2003). We assume that the newly installed wind power capacity will be positively correlated with the *length of green party participation in the government* (federal state in Germany, municipality in Sweden). We believe this approach better reflects the actual impact of green political positions on regional land-use policy than the share of green votes in general elections. The latter variable – which has been used in previous studies (e.g., Goetzke and Rave, 2016; Hitaj et al., 2014) – only measures general attitudes of the population. In contrast, our variable reflects the presence of green priorities among the regional policy-makers that are actually in power.

Finally, the willingness to support wind power in a region could also depend on the regional benefits and costs that may be attributed to wind power (e.g., Ek and Matti, 2015). To capture such effects at least partly, we include the *rate of unemployment* in a region. In line with previous work (Ek et al., 2013; Goetzke and Rave, 2016), we assume that regions characterized by economic decline, out-migration and high rates of unemployment will be particularly interested in attracting new investments by a supportive land-use policy framework. Indeed, many national governments view RES deployment as a key vehicle for job creation and regional growth (see, for instance, the Swedish Government Bill 2005/06:143).

Obviously, in order to correctly identify the impact of variables related to land-use policy, we need to control for other drivers of regional heterogeneity in wind power deployment. The regional availability of sites for wind power development will also be driven by the intensity of other competing land uses (e.g., human settlements, transport infrastructure), as well as the general natural endowment of suitable sites. We therefore include *population density* and the *size of the region* as controls for these aspects. In addition, regional heterogeneity of wind power deployment hinges on differences in the profitability of investments, and these differences are in turn primarily driven by regional variations in windiness. We consequently include *average wind speed* in a region as a control.

Certainly, the profitability of wind power expansions will also depend on the RES support scheme in place. Yet, we assume that the incentives set out by the respective support schemes are spatially uniform, and for this reason we omit this variable from our econometric approach. This holds perfectly true for the Swedish certificate scheme. It applies with certain restrictions to the German feed-in tariff scheme as well. Despite the reference yield model used, the profitability of wind power deployment at a specific site is still highly correlated with windiness. This was also confirmed in preliminary model estimations incorporating feed-in tariff levels in the German data sample. In the light of this, and given our ambition to keep the econometric framework as consistent as possible across the two countries, the German feed-in tariff levels have been left out of the model estimations. Still, we do comment on the relationship between wind speeds and the reference yield model when discussing the results.

3.2 Data

Our empirical investigation builds on econometric model specifications in which *additionally installed wind power capacity* (in MW) over the time period 2008-2012 represents the dependent variable. The focus on this time period is motivated by the availability of data, e.g., the access to information about Green party coalitions, average wind speeds and land use restrictions in Sweden. In addition, the chosen time span represents a period of significant wind power expansion in both countries, but with substantial regional variation. For Germany the data cover the 402 districts (*Landkreise*), while in the Swedish case they cover the country's 290 municipalities (*kommun*). The German wind power capacity data have been collected from (DGS, 2014). All wind power plants issued by the four German transmission system operators (i.e., 50Hertz, Amprion, TransnetBW, and Tennet) are included in this data set as are nominal capacities, the construction years and the corresponding spatial information in the form of GPS coordinates (or municipality codes). By relying on this information the reported wind power capacities have been aggregated to the district and federal state levels, respectively. Swedish wind power capacities at the municipal level are reported by the Swedish Energy Agency (Energimyndigheten, 2013). For both countries, the data exclude offshore wind power.

Figure 3 shows how additionally installed wind power capacity during the time period 2008-2012 has been distributed across the various regions in the two countries. It provides a clear illustration of how much more wind power-intensive Germany is compared to Sweden, as well as of how wind power activity varies a lot across regions in both countries. Tables 1 and 2 provide some descriptive statistics for our dependent variables as well as the included explanatory variables for the German and Swedish samples, respectively. Appendix A provides correlation rate matrices for the data samples, and these display overall low linear correlation coefficients across the various independent variables.

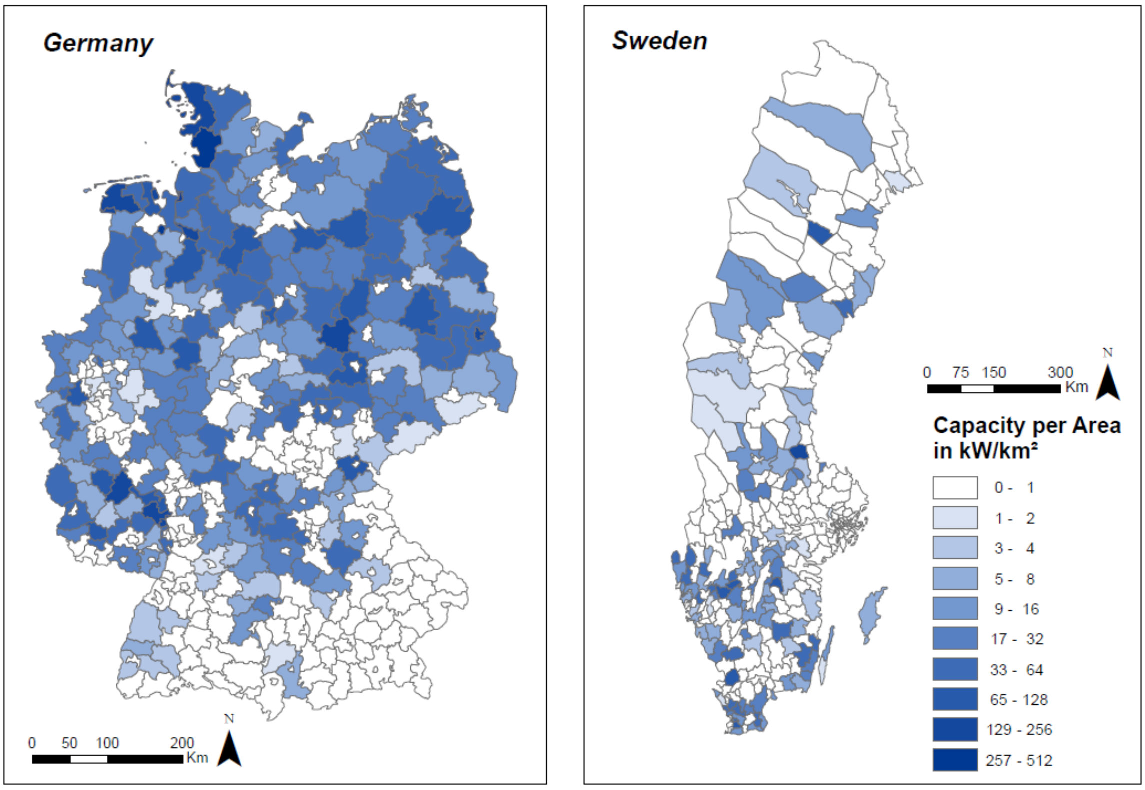

Figure 3: Additionally Installed Onshore Wind Power Capacity by Region (kW/km²), 2008-2012

Sources: DGS (2014) and Energimyndigheten (2013).

Table 1: Descriptive Statistics for the German Data (Districts)

	N	Mean	St. Dev.	Min	Max
Dependent variable					
Additionally installed capacity over the period 2008-2012 in MW	402	22.95	56.14	0	725.74
Variables measuring regional land-use policy					
Priority areas in % per planning region area (2012)	209	0.54	0.79	0	3.75
Protected areas in % per district area (2012)	402	3.65	6.22	0	71.49
Variables addressing the political willingness to facilitate wind power deployment at the regional level					
Total installed capacity within Federal States prior to 2008 in MW	402	1,648.92	1,676.01	0	5,524.17
Participation of the Green Party in Federal State government between 2000 and 2012	402	1.36	2.93	0	10
Unemployment rate in % (2012)	402	3.36	1.63	0.68	9.19
Control variables					
Population density, inhabitants per km² (2012)	402	514.40	670.84	36.855	4,465.45
Land area in km²	402	889.86	722.58	35.60	5,495.40
Wind speed in m/s (1980-2001)	402	5.33	0.54	3.78	7.77

Table 2: Descriptive Statistics for the Swedish Data (Municipalities)

	N	Mean	St. Dev.	Min	Max
Dependent variable					
Additionally installed capacity over the period 2008-2012 in MW	290	9.60	21.13	0.00	156.80
Variables measuring regional land-use policy					
Priority areas in % per municipality area (2010)	290	1.54	3.63	0.00	41.92
Protected areas in % per municipality area (2008)	290	5.88	11.53	0.00	100.00
Variables addressing the political willingness to facilitate wind power deployment at the regional level					
Total installed capacity within a municipality prior to 2008 in MW	290	20.12	29.12	1	101
Participation of the Green Party in municipality government between 2000 and 2012	290	2.35	3.24	0	11
Unemployment rate in % (2010)	290	6.08	1.70	2.50	13.10
Control variables					
Population density, inhabitants per km² (2010)	290	135.01	464.32	0.20	4,410.40
Land area in km²	290	1,833.55	2,843.26	8.82	20,714.70
Wind speed in m/s (2007)	290	6.16	0.62	4.59	7.69

For Germany, the data on the *size of priority areas* for wind power deployment, i.e., the percentage share out of total land area, stem from the Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR, 2014). Yet, detailed information on such areas was only available for a more limited sample of planning regions representing 209 German districts. Typically, several districts form one planning region. Consequently, the information provided for an individual planning region was equally attributed to all districts belonging to this region. In the Swedish case, data on the share of areas of national interest for wind power at the municipality level were provided by the Swedish Energy Agency (Energimyndigheten, 2010).

The German data on the *size of protected areas* for nature conservation were drawn from the Leibniz Institute of Ecological Urban and Regional Development (IÖR, 2015). Specifically, this variable measures the percentage share of so-called "landscape protection" areas per total district area. We focus on this category since landscape protection areas are established by federal states, and thus represent regional land-use policy. In contrast, other categories like nature protection areas or national parks lie within the responsibility of the national government and/or even the European Union. The Swedish data have been drawn from Statistics Sweden (SCB, 2015), and similarly display the share of protected nature areas out of total land area (in %). This includes national parks and reserves, nature management areas, wildlife sanctuaries, and habitat protection areas (on forest and agricultural land).

Data for the *total installed capacity within a region prior to 2008* (MW) were taken from the same sources as those for additionally installed capacity. For Germany, these data are aggregated for each federal state and then applied uniformly as a measure for all districts located in that state. This is because, in the German case, we use this variable as a proxy for federal state policy rather than municipal policy.

By employing information from the German statistical online data platform (DESTATIS, 2015) and the Swedish Association of Local Authorities and Regions (SKL, 2014), we constructed a variable measuring the *length of green party participation in the government* of a federal state (Germany) and a municipality (Sweden). Specifically, we considered the number of years over the period 2000-2012 in which the two countries' green parties formed part of the respective relevant governing coalitions. This operationalization allows for lagged impacts of green party influence on wind power deployment; this is potentially important given the sometimes long lead times for new wind power investments.

The data on *unemployment rate*, *population density* and *size of region* (each at the district level for Germany and municipality level for Sweden) were collected from the German statistical online data platform (DESTATIS, 2015) and Statistics Sweden (SCB, 2010a, b, c). For *average wind speed* data we rely on the information provided by the German Weather Service (DWD, 2015) and the Swedish Energy Agency (Energimyndigheten, 2013). In Germany this information is available in the form of average wind speeds in m/s at different heights over the period 1980-2001 and for a 1000 meter cell resolution. In the Swedish case we use average wind speeds in m/s between 2007 and 2010 at a height of 72 meters for a 1000 meter cell resolution. In both cases we have aggregated these data within a geographical information system (GIS) to the German districts (for an assumed hub height of 80 meters) and the Swedish municipalities, respectively.

Since the German data set is incomplete with respect to priority areas at the district level, we consider three data samples in the econometric analyses: the two full data samples comprising of 402 German districts and 290 Swedish municipalities, respectively, and a more limited German sample consisting of 209 districts.

3.3 Model Specifications

Our dependent variable, added wind power capacity (MW) over the period 2008-2012 equals zero for a significant fraction of the observations, and conventional regression methods fail to account for the qualitative difference between limit (zero) observations and non-limit (continuous) observations. For this reason it is useful to build on the censored regression model proposed by Tobin (1958). In this so-called Tobit model we allow latent wind power capacity additions, y_i^*, depend on the vector X_i comprising the independent variables discussed in Sections 3.1-3.2, so that:

$$y_i^* = \boldsymbol{X}_i\boldsymbol{\beta} + \epsilon_i, \;\; \epsilon_i \sim N(0, \sigma^2) \tag{1}$$

for all districts/municipalities i=1,….,N. Since corner solutions may exist, the observed independent variable is:

$$y_i = \begin{cases} y_i^* & if\ y_i^* > 0 \\ 0 & if\ y_i^* \leq 0 \end{cases} \tag{2}$$

Moreover, in the empirical estimations we also apply a $\log(y_i + 1)$ transformation of y_i, this since the error terms have to be uniformly distributed.

Still, for our purposes the original Tobit model is rather restrictive in that the same set of parameters are assumed to determine both the probability of having any wind power capacity additions in the first place as well as the amount of capacity additions (in MW) in the second stage.[5] This is not necessarily a reasonable assumption in our empirical setting. For instance, the probability of observing wind power capacity additions in a particular region could be more strongly related to political preferences as well as previous experiences of wind power, in particular in contexts in which the local government has a lot of discretionary power over wind power development (e.g., compare Sweden to Germany). However, the amount of capacity installed – once having decided to permit such development – could be more strongly linked to, for instance, different land use policies, wind conditions etc.

In contrast to previous research (with the exception of Ek et al., 2013), we therefore also consider a more general model specification based on Cragg (1971). In this model the determinants of the probability of a limit observation are allowed to be different from the determinants of the model for the non-limit data, and for which the Tobit model represents a special case. Cragg's double-hurdle model is a combination of the univariate probit model and the truncated regression model.[6] The first of these steps, the probit, can be formulated as:

$$\text{Prob}\ [y_i^* > 0] = \boldsymbol{\phi}(\boldsymbol{\lambda}'\boldsymbol{X}_i), \qquad Z_i = 1 \text{ if } y_i^* > 0 \tag{3}$$

$$\text{Prob}\ [y_i^* \leq 0] = 1 - \boldsymbol{\phi}(\boldsymbol{\lambda}'\boldsymbol{X}_i), \quad Z_i = 0 \text{ if } y_i^* \leq 0$$

This is followed by the regression equation for the non-limit observations:

$$\text{E}[y_i | z_i = 1] = \boldsymbol{X}_i\boldsymbol{\beta}' + \sigma\lambda_i, \tag{4}$$

The Tobit model here represents the special case in which $\boldsymbol{\lambda} = \boldsymbol{\beta}/\sigma$. Greene (1993) outlines a test of this restriction through separate estimations of the likelihood values L of the Tobit model (*TO*), the

[5] Lin and Schmidt (1984) note that in the Tobit model, a variable that increases the probability of an observation being a non-limit observation also increases the mean of the variable.

[6] It should be acknowledged that while our model specification allows for one set of parameters to determine the probability of having any wind power capacity additions and another set to determine the amounts (in MW) of such additions, we do also assume that all explanatory variables are independent (exogenous). The conceptual framework we used for identifying these variables (Figure 2) suggests that a nested model specification could be relevant for our purposes, e.g., where land-use policy is the dependent variable in a first step and then is used as an independent variable in a second step when explaining wind power deployment outcomes. Such an approach could represent a potential avenue for future research. Nevertheless, it is also challenging, not least since it is difficult to capture land-use policy in one single measure.

probit model (PR) and the truncated regression model (TR) (see also Lin and Schmidt, 1984). We have:

$$\boldsymbol{\lambda} = -2[\ln L_{TO} - (\ln L_{PR} + \ln L_{TR})] \quad (5)$$

This thus permits us to test the more restrictive Tobit model against the Cragg (1971) specification in which one set of parameters is allowed to determine the probability of having any wind power investment (or not) while a second set of parameters determines the wind power capacity expansion in MW. The final econometric results have been obtained using the mhurdle-package in the software *R* (Carlevaro et al., 2012).

4 Empirical Results

Table 3 reports the results from the likelihood ratio test in equation (5). These suggest that for all three country data samples we can reject the Tobit model in favour of the double-hurdle Cragg specification. For this reason, we report the empirical results in two parts, i.e., first those from the probit model and then those arising from the truncated regression model.

Table 4 summarizes the corresponding parameter estimates for our three country samples. The first two columns display the probit and truncated model results for all (402) German districts, thus without including the role of priority areas. The following two columns show the corresponding results using the more limited German sample (with 209 districts), incorporating also priority areas. Finally, the last two columns present the double-hurdle model results for the Swedish sample of 290 municipalities. In the remainder of this section we briefly comment on these results, while Section 5 provides a broader discussion on how to interpret and comprehend the overall implications in the light of the different national and regional contexts.

Table 3: Likelihood Ratio Tests of the Tobit Specification

	Tobit	Probit	Truncated
Germany (full sample)			
Observations	402	402	402
Log Likelihood	-593.3145	-176.4054	-403.348
df	9	8	9
adjusted R²	0.5053		0.493
Germany (limited sample)			
Observations	209	209	209
Log Likelihood	-315.0523	-70.1543	-230.958
df	10	9	10
adjusted R²	0.5261		0.5079
Sweden (full sample)			
Observations	290	290	290
Log Likelihood	-396.4309	-158.4322	-196.8444
df	10	9	10
adjusted R²	0.1519		0.2695
Likelihood ratio tests			
λ	27.1222	27.8800	82.3086
Critical values $\chi^2_{0.01}$*	21.67 and 23.21	20.09 and 21.67	21.67 and 23.21
p-value	0.000673441	0.000998911	5.61449e-14

* The critical values with 8, 9, and 10 degrees of freedom (df) equal 20.09, 21.67 and 23.21, respectively, at the one (1) percent statistical significance level.

Table 4 shows that in the case of the priority area variables we find differential impacts across the two countries. In the German model (the limited sample) we find a positive and statistically significant relationship between the shares of designated priority areas and the probability of observing any wind power investment. However, for the Swedish sample no statistically significant impact of the share of so-called national interest areas on wind power deployment can be found. In the case of protected areas for wind power, the results are reversed. We find a negative and statistically significant effect in the Swedish truncated model, but for both of the German samples the double-hurdle models generate only statistically insignificant coefficients.

For both countries the empirical results show that higher installed capacities of onshore wind power (up until the year 2007) have overall implied more positive wind power outcomes during the period 2008-2012. In the Swedish case, the installed capacity variable is found to be positively related to both the likelihood of having any new wind power investment and to how much capacity (MW) has been newly installed. In the German case, though, previously installed capacity is reported to have a statistically significant and positive impact only in the truncated model. This holds for both data samples.

Table 4: Coefficient Estimates of the Double-Hurdle Regression Models (standard errors in parentheses)

Independent variables	Germany (full sample)		Germany (limited sample)		Sweden (full sample)	
	Probit	**Truncated**	**Probit**	**Truncated**	**Probit**	**Truncated**
Constant	-4.377 (2.06429) *	-6.12547 (2.93036) *	-8.70329 (3.62718) *	-3.51659 (3.25451)	-5.7998 (1.61172) ***	3.38955 (2.40146)
Priority areas in % per planning region area	---	---	0.93193 (0.32372) **	0.32715 (0.17448)	---	---
Priority areas in % per municipality	---	---	---	---	0.03738 (0.02354)	0.02863 (0.28482)
Protected area per district area in %	-0.02731 (0.02131)	0.03598 (0.05255)	-0.07936 (0.04458)	-0.03068 (0.07497)	---	---
Protected area per municipalities area in %	---	---	---	---	-0.00722 (0.00759)	-0.05808 (0.02034) **
Installed capacity within Federal States till 2007 (MW)	8e-05 (6e-05)	0.00026 (6e-05) **	2e-05 (7e-05)	0.00021 (6e-05) ***	---	---
Installed capacity within municipality till 2007 (MW)	---	---	---	---	0.18542 (0.04569) ***	0.04595 (0.01225) ***
Participation of the Green Party in German Federal Gov.	0.00375 (0.03473)	0.03722 (0.04237)	-0.16736 (0.06152) **	-0.00905 (0.06208)	---	---
Participation of the Green Party in Swedish Municipal Gov.	---	---	---	---	0.03622 (0.02719)	0.00373 (0.03614)
Unemployment rate in %	0.0955 (0.06073)	0.40283 (0.06493) ***	-0.03049 (0.08848)	0.31701 (0.07469) ***	0.01053 (0.06134)	-0.00986 (0.09411)
ln Population density in persons per m²	-0.12779 (0.14116)	-0.45772 (0.21032) *	0.08177 (0.25818)	-0.42753 (0.2591)	-0.0933 (0.08733)	-0.34626 (0.12934) **
ln Land area in km²	0.63026 (0.14686) ***	0.67387 (0.25724) **	0.73185 (0.26327) **	0.33656 (0.29041)	0.23179 (0.11116) *	0.13813 (0.16823)
Average wind speed in m/s²	0.24071 (0.20104)	0.74581 (0.24139) **	0.79743 (0.3147) *	0.75962 (0.2559) **	0.65138 (0.20084) **	-0.14188 (0.27989)
Sigma (σ)	---	1.4154 (0.08524) ***	---	1.27415 (0.08818) ***	---	1.1813 (0.09072) ***
Observations	402	402	209	209	290	290
Log Likelihood	-176.4054	-403.348	-70.1543	-230.958	-158.4322	-196.8444
adjusted R²		0.493		0.5079		0.2695

Statistical significance codes: '***' 0.001 '**' 0.01 '*' 0.05

The participation of the Green parties in the German Federal State governments and the Swedish municipally governments, respectively, is hypothesized to have a positive correlation with wind power outcomes at the regional level. However, the results suggest that overall we cannot reject the null hypothesis of no Green party impact.[7] We observe a negative (and statistically significant) parameter in the probit model estimates building on the more limited German data sample, but this result is not robust as the corresponding parameter is statistically insignificant in the full-sample German model.

Given that regional land-use policies often may be associated with regional benefits from deployment, we hypothesized a positive correlation between unemployment rates and wind power expansions. However, in the Swedish case we cannot reject the null hypothesis of no impact, and for the German sample the unemployment rate is statistically significant only in the truncated model. Thus, in the latter case districts with high unemployment rates are not more likely to host wind power investments, but in the presence of such investments they tend to experience higher capacity additions (in MW).

The inclusion of a number of control variables also implies some interesting results. The correlation between wind power deployment and population density rates has the expected negative sign in both countries. Nevertheless, this particular variable primarily affects the magnitudes of the wind power capacity additions in the truncated model, and thus not the probability for investment in the first instance. Regarding the size of regions, we find for the German sample that districts with a larger land area are more likely to have hosted wind power investment, and overall the capacity additions are (ceteris paribus) higher as well. This effect is less evident for the Swedish model estimates, although also here the probability of having wind power in the first place tends to be higher in municipalities with large land areas.

Finally, as expected, we find a positive and statistically significant correlation between wind power deployment and average wind speeds. However, these results also display differences across the two countries. Specifically, for the Swedish sample higher average wind speeds increase the probability of wind power investment, while they have no statistically significant impact on the level of capacity additions. In the German case we find the reverse results, i.e., the coefficient for wind speed is only statistically significant (and positive) in the truncated model.

5 Discussion

We have hypothesized that regional heterogeneity in wind power deployment may be driven by differences in both land availability and profitability. Our main interest is to understand the impact of one important driver underlying land availability: regional land-use policies, which we have measured

[7] One should however note that this impact appears to be sensitive to the ways in which the Green party variable is defined. For instance, if Green party participation is instead measured in terms of a dummy variable, which takes the value of one (1) if this party has been part of the local government location (and zero otherwise), we obtain a positive and statistically significant impact for the Swedish truncated model.

both directly (size of priority and exclusion areas) as well as indirectly (political willingness and institutional capacity). We have also controlled for other variables underlying land availability (size of a region, population density) and profitability of wind power generation (wind conditions) in a region. All in all, the empirical results based on the double-hurdle models indicate that a multitude of factors, not least land-use policies, have had important impacts on the regional allocation of wind power investment in both Germany and Sweden. Nevertheless, we also find important heterogeneity across the two countries in terms of these impacts. In this section we attempt to disentangle and discuss how the reported differences can be understood given the different national contexts, and what the implications of these differences could be.

5.1 Regional Land-use Policy: Size of Priority and Exclusion Areas

Our analysis suggests that acknowledging the role of regional land-use policy and its impact on the availability of sites is important to fully comprehend the spatial patterns of wind power deployment. Yet this role will depend on the stringency of land-use policy in the respective regulatory contexts.

First, in the case of designated priority areas we find a positive and statistically significant impact only in Germany (limited sample). In other words, the share of priority areas is positively correlated with the probability of observing wind power installations. The German data reveal a fairly strong preference for strong area categories, which can exclude wind power plants outside of designated areas. Our results are consistent with the notion that this transparent land-use policy has increased the possibility for new wind power installations in Germany. Essentially it ensures that at least some regional consensus has been reached on where to allocate new wind power plants before any potential wind power plant investors start to get involved.

In the Swedish case, however, the results indicate no statistically significant impact of priority areas on wind power deployment. This is consistent with the observation that the designation of areas as being of "national interest" for wind power represents a rather weak policy tool in the country. Such a designation implies that the area shall be protected against other activities that constrain the area's use for wind power. Still, if the same area is of national interest for other purposes as well (e.g., nature conservation, national defence etc.), the legal rules provide little guidance on how to weigh the various interests against each other. Previous analyses of Swedish case law confirm that these rules have been unpredictable both regarding the possibilities to avert obstructive activities as well as to explicitly promote wind power (Petterson, 2008; Söderholm et al., 2007). For instance, in Sweden there have been several examples of land-use decisions in which the national defence interest has been given priority over the wind power interest. In addition, since 2008 the Swedish veto right also makes it possible for the municipalities to block wind power investments regardless of how widespread the national interest areas are. The above suggests therefore that priority areas can spur wind power deployment – but only if they are binding (which appears to have been the case in Germany but not in Sweden)

Second, the empirical results show that the assignment of protected areas has posed a constraint to regional wind power development in Sweden, while no statistically significant impact could be identified in the German case. This difference can partly be explained by the generally higher average protection area shares in Sweden, which even reach 100 % in a few municipalities (see Tables 1-2). This should therefore pose a greater constraint to wind power expansion in Sweden, not the least in the mountain regions. An additional explanation may be related to the fact that in the German case, only protected areas that lie in the realm of federal state policy-making were considered. These so-called landscape protection areas constitute a relatively weak form of protection. In fact, they do allow for wind power development if certain conditions are fulfilled. This highlights again that the actual effect of land-use policies on wind power deployment is dependent on their stringency.

5.2 Regional Land Use Policy: Political Willingness and Institutional Capacity to Facilitate Wind Power

Typically, regional land-use policy does not only materialize as priority or exclusion areas. It also encompasses "softer" policy forms influencing the availability of sites, such as guidelines determining the ease of permitting procedures, resources allocated to permitting agencies or more generally the creation of a positive investment climate within a region. These forms of policy-making are hard to capture quantitatively. We consequently included some proxy variables for overall political willingness and institutional capacity to facilitate wind power. Overall, we do find significantly positive impacts for some of the proxy variables – while simultaneously controlling for the direct impact of priority and exclusion areas. This indicates that "softer" forms of regional land-use policy may also be an important trigger for wind power development by driving the availability of sites.

First, we noted that previous wind power installations in a given region may be correlated with a high political willingness and institutional capacity to facilitate further development, but it may also reflect a saturation effect that makes additional expansions difficult. Our results indicate that for both countries there is a positive and statistically significant impact of previously installed capacity on additions during the period 2008-2012. In other words, previous wind power expansions have overall primarily led to a self-reinforcing – rather than a constraining – effect on further development (see however below).

This finding is consistent with the notion that regions that have embraced wind power investments in the past are more likely to do so also in the future. This could reflect, for instance, a positive attitude towards wind power in general and in turn deliberate actions taken to encourage new investment projects (e.g., engaging in close interaction with prospective developers). Regions with a lot of experience in handling wind power in the planning process may also have accumulated a nonnegligible stock of knowledge in the field as well as developed efficient administrative practices (Ek et al., 2013). Investors will be attracted by such favourable institutional conditions, but potentially also by the presence of skilled wind power technicians, which often tend to be clustered in wind power dense regions.

Germany and Sweden differ a lot in terms of wind power installations prior to 2008, and an important finding was also that both the strength and the nature of this relationship differ between the two countries. Specifically, there is a statistically insignificant impact of previous wind power experience in the German probit model while for the Swedish sample the corresponding coefficient is statistically significant. The result for Sweden is in line with previous work (see Ek et al., 2013), while the German results in part contradict the recent findings of Goetzke and Rave (2016). In the German case there is a statistically significant impact in the truncated model.

This difference across countries, we argue, can plausibly be traced back to the way in which political power is allocated in the two countries. In Sweden the municipalities have a lot of discretionary power to say yes or no to wind power (see Section 2). This implies, for instance, that some of the Swedish municipalities that had no capacity installed by the end of 2007 were in this situation because they had decided to opt out of wind power and there has not existed any higher-level government being able to change this. Consequently, these local governments' willingness to attract investments in the latter period, e.g., by the adoption of new detail plans, will likely be weak as well. In Germany, though, the situation has been different as decision-makers at the district level have less power over the planning process, e.g., the priority areas are determined in a regional plan typically consisting of several districts. The priorities made in these regional plans are therefore more likely to reflect, at least in part, the preferences of higher-level governments.[8]

The results addressing the political power of the two countries' Green parties at the regional level indicate that overall this variable has not proved to be an important factor behind regional wind power development. In part this may reflect that other variables, e.g., previously installed capacity, may better reflect the overall political preferences for new wind power. Moreover, in some cases both Green parties have been split between wind power supporters and sceptics, the latter emphasizing the negative landscape impacts of wind mills. There has also been broad support for wind power among the other political parties. For instance, in Sweden coalitions consisting of the Green party and the Social Democrats will not necessarily be more likely to support wind power than a coalition in which the Social Democrats collaborate with the more liberal Centre party. Similarly, Goetzke and Rave

[8] The German (insignificant) results could also be attributed to positive agglomeration effects, favorable political preferences etc. being neutralized by the presence of congestion effects in some districts. In other words, previous wind power expansions may have led to increased difficulties in identifying favorable locations, while such situations are less prevalent in Sweden. Still, for those German districts that have had wind power installed even during 2008-2012, there is little indication of such congestion as the capacity variable becomes statistically significant in the truncated model.

(2016) find that left-of-centre governments (at the state level) – involving the German Green party – are not more likely to endorse wind power than are other political coalitions. Another explanation for the absent relationship may be related to the fact that in Germany, responsibilities for regional land-use policy do not exclusively reside with the States but at least partially also with other political levels. Finally, political decisions on land-use policies usually take vary long to materialized in law (sometimes more than 10 years in Germany). Our attempt to account for this time lag by referring to the time span from 2000 up to 2012 thus may still be insufficient to capture the full effect.

Finally, in Section 2 we noted that in both Germany and Sweden the promotion of wind power is often linked to its potential role as a vehicle for regional development and local job creation. The results for Germany indicate empirical support for the hypothesis that districts with high unemployment rates have had higher wind power capacity additions during the 2008-2012-period. German districts thus appear to face incentives to attract wind power investments, which increase the demand for local work forces (e.g., construction workers). Such incentives may in fact go beyond job creation. For instance, since 2009, municipalities that host wind power plants receive 70 % of the business tax revenues (BWE, 2015).[9] The corresponding tax incentives do not exist in Sweden, and in this case our results do not show a positive correlation between unemployment rates and wind power deployment. This finding is somewhat surprising given that many substantial wind power investments have been made in municipalities with historically negative population trends. A partial explanation could be that the time period 2008-2012 was characterized by a boom in the global mineral commodity markets. Since the northern parts of Sweden host substantial mineral resources (e.g., iron ore deposits), these regions experienced regional growth and employment increases during the period.

5.3 Additional Regional Drivers of the Availability of Sites: Size of Region and Population Density

The availability of sites for wind power deployment is also influenced by geographic conditions, and our results display the roles of total land area and population density, respectively. The results confirm that districts/municipalities with larger land areas have experienced a higher probability of wind power investments and hosted more wind power capacity additions during the studied period. These impacts were particularly evident in Germany, in part reflecting the lower general area availability in Germany compared to Sweden. The average land area for German districts is less than half of that of Swedish municipalities (see Tables 1-2). This should make it easier to identify potentially favourable locations for wind power in Sweden, and significant investment activities have occurred in sparsely populated and forest-rich regions with decent wind conditions (Energimyndigheten, 2013).

In the light of this, however, it is somewhat surprising that high population densities appear to impose a more profound constraint on wind power in Sweden compared to Germany. At least a partial

[9] 30 % of the tax revenues accrue to the municipality that hosts the *company* owning the wind power plant.

explanation for this paradox may be attributed to Swedes' access to holiday cottages. Surveys show that over half of the Swedish population spends time in a holiday cottage (for at least a week or more) every year, and 20 % out of these owned the house (SCB, 2004). People are likely to be particularly sensitive to nuisance caused by energy production facilities when on holiday in scenic landscapes (see Lundgren (1994) for evidence of this in the case of nuclear power plants in Sweden). In addition, since a majority of the households travelled less than 100 kilometres to the holiday cottage, this implies that in relatively densely populated Swedish municipalities the risks for negative wind power attitudes could be strong. In other words, the access to holiday cottages increases the footprint of the population in areas where wind power investments may be frequent.

5.4 Regional Drivers of the Profitability of Wind Power Generation: Windiness

Obviously, the regional patterns of wind power deployment are not only determined by the availability of sites but also the profitability of wind power generation. Our empirical results confirm the important role played by favourable wind conditions for wind power investment, and this even in Germany where feed-in tariff levels are negatively linked to average wind speeds. In the latter case higher wind speeds do not affect the probability of having any wind power at the district level, but they are positively correlated with higher installed capacities (in MW). These results suggest therefore that lower feed-in tariff levels do not entirely neutralize the isolated effect of higher wind speeds. One reason for this is that by design the total revenues of a wind power plant will first increase linearly with output, but locations with medium and high wind speeds will typically tend to receive the same revenues (e.g., Hitaj et al., 2014). Still, it is probably fair to conclude that small-scale wind power investments at less favourable (less windy) locations are more likely in the German policy setting (compared to the Swedish one)

For the Swedish municipalities we find a positive and a statistically significant relationship between average wind speeds and the likelihood of having any capacity additions during the studied period. This suggests that investors tend to target municipalities with overall favourable wind speeds, while the resulting level of capacity additions rather will be determined by the specific conditions at each particular site. In Sweden average wind speeds are not in any way linked to the remuneration level in the certificate scheme; there exists however a link to the designation of areas of national interest. One of the most important criteria for assigning such areas has been average wind speeds. This has thus assisted in spreading the knowledge about the distribution of wind resources in the country, and also for providing support for the local authorities when deciding if – and where – it could be appropriate to plan for wind power (see Ek et al., 2013). Our results suggest therefore that this type of information dissemination may have been the most important function of this planning policy tool, rather than the fact that it defines clear guidelines for how to weigh different land use interests against each other.

6 Concluding Remarks

The overall purpose of this paper was to investigate the impacts of land-use policies on wind power deployment at the regional level in Germany and Sweden. The results confirm that the regional allocation of wind power has not only been driven by environmental and geographic endowments and RES support schemes. A significant component of the regional variation in the level and speed of wind power deployment can be attributed to land-use policies. These determine the availability of sites for wind power deployment, not least in the form of priority areas and the designation of restricted areas. An important finding is also that the political willingness to promote wind power – which we include as an additional proxy measure for regional land-use policy – appears to have influenced wind deployment outcomes in both Germany and Sweden. This is in part reflected in the positive correlation between the unemployment rate and wind power capacity development. Furthermore, previous wind power expansions appear to have had a self-reinforcing – rather than a constraining – effect on further development; regions that have embraced and attracted wind power investments in the past seem to possess the capacity and the willingness to do so also in the future. Overall, these findings may underpin the potential importance of other, "softer" means of regional land-use policy, such as guidelines, institutional resources and investment climate.

An important contribution of this paper compared to related previous research was the opportunity to contrast results across two countries that both have experienced significant wind power expansions during the chosen time period but within different regulatory and institutional contexts. Our results display a few interesting differences across the two countries. In particular, the role of priority areas is much more profound in the German case compared to the Swedish one. This can be attributed to the fact that the German designated priority area has been a more stringent land-use policy compared to the designation of areas being of national interest for Swedish wind power. The de facto planning monopoly on the part of Swedish municipalities also implies that local decision-makers can block additional wind power investment in the own region irrespective of the national designation of areas. In contrast, the assignment of protected areas appears to have been a more stringent policy in Sweden compared to Germany.

Furthermore, our empirical specification, i.e., the Cragg model, permitted us to distinguish between the probability of having wind power additions on the one hand and the level of wind power capacity additions (in MW) on the other. This approach also revealed differences across the two countries. For instance, while the results for both countries indicated a positive correlation between previous wind power investments and new investments, in the Swedish case these results were reflected in the probit model while the corresponding results for Germany appeared in the truncated model. This can also in part be traced back to the more decentralized planning system in the former country. A similar result is found in the case of average wind speeds.

Finally, our results that display the importance of land-use policies and the availability of sites for wind power deployment and that highlight important differences across national contexts, should also pave for additional research. Overall, one could expect the importance of land-use policies to increase in the future. The available land is going to be scarcer with additional development, and other policies, particularly RES support schemes, tend to become less important as wind power generation reaches grid parity. While there certainly is a need for both qualitative and quantitative research, the latter should increasingly address also changes over time in the adoption and implementation of land-use policies in various national contexts. Moreover, there should also be room for more elaborate model specifications of the specific decision-making processes in the countries under study, e.g., by employing nested regression models. This paper has also illustrated the importance of acknowledging the significance of institutional and regulatory contexts for fully comprehending wind power deployment outcomes. This should open up the field for additional inter-country comparisons covering also other RES technologies such as solar PV; bioenergy etc.

Appendix: Correlation Coefficient Matrices

Table A1: Correlation Coefficient Matrix: German Sample

	Cap 08-12	Priority area	Protect area	Cap 2007	Green party	Unem-ploy	Pop dens	Land area	Wind speed
Cap 08-12	1								
Priority area	0.32	1							
Protect area	-0.19	-0.06	1						
Cap 2007	0.19	0.12	-0.16	1					
Green party	0.20	0.58	-0.05	0.05	1				
Unemploy	0.21	0.14	0.11	0.13	-0.08	1			
Pop dens	-0.23	0.05	0.48	-0.10	0.09	0.13	1		
Land area	0.43	0.16	-0.45	0.14	0.00	0.26	-0.53	1	
Wind speed	0.36	0.23	-0.20	0.13	0.44	0.02	-0.27	0.25	1

Table A2: Correlation Coefficient Matrix: Swedish Sample

	Cap 08-12	Priority area	Protect area	Cap 2007	Green party	Unem-ploy	Pop dens	Land area	Wind speed
Cap 08-12	1								
Priority area	0.06	1							
Protect area	-0.05	0.04	1						
Cap 2007	0.39	0.06	-0.05	1					
Green party	-0.03	-0.01	0.16	0.10	1				
Unemploy	0.15	0.02	-0.02	0.07	0.01	1			
Pop dens	-0.10	-0.07	0.10	0.05	0.10	-0.17	1		
Land area	0.26	-0.03	0.22	0.22	0.04	0.39	-0.15	1	
Wind speed	0.02	0.06	-0.02	0.24	0.04	-0.52	0.15	-0.36	1

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