On the incidence of renewable energy subsidies into land prices - Evidence from Germany*

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Abstract

In 2012, the subsidy for electricity produced by wind turbines - introduced with the Renewable Energy Act (REA) in Germany 2000 - amounts to almost 14 billion Euros or roughly 100% of the corporate income tax revenue. The central aim of this subsidy is to foster investment into renewable energy sources by providing long run financial security. In this analysis, we study the incidence of this subsidy on land prices. Our empirical design exploits variation over time in the return of wind turbines due to the introduction of the REA and relates it to changes in transaction prices for agricultural land for 250 non-urban counties between 1997 and 2012. We employ an instrumental variable estimator to ensure unbiased coefficients despite the endogeneity of the plants' location decision. We find that 11% of the subsidy paid to wind turbine investors is capitalized into land prices. Accounting for investor's costs, the share raises to 24% of investor's profits. The results are robust for a wide range of specifications.

JEL Classification: H22, H23, H25, Q28, Q42.
Keywords: Incidence, subsidy, renewable energy, wind turbines, land prices.

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1 Introduction

To foster the investment in renewable energy sources, most OECD countries have introduced specific subsidies, quotas or price guarantees. One typical example is the Renewable Energy Act (REA) which was introduced by the German government in the year 2000. The REA guarantees that electricity produced by renewable energies, for example wind power or solar, can be sold at a fixed priced for 20 years after the installation of the plant. Following the introduction of the REA the share of electricity produced by renewable energy sources of overall electricity generation in Germany increased from 6.8% in 2000 to 23.5% in 2012. The costs strongly increased as well to almost 14 billion Euros or 100% of the corporate income tax revenue in 2012.

Given this large share of tax revenue is spend for the promotion of green energy, it is of central importance to understand who benefits from the subsidy: is it the investor who receives the subsidy and therefore does the subsidy really promotes renewable energies or to which extend do other market participants reap a share of the subsidy as windfall gains? It is the aim of this paper to provide empirical evidence to this incidence question and to discuss in particular the distributional consequences and the efficiency effects of the specific subsidy.

In this paper we use quasi-experimental variation to study to which extent investors of wind power plants receive the subsidy or whether and if so, to which extend the subsidy is passed on to land owners. We exploit the large regional variation in wind strength in combination with the introduction and partial abolition of the REA and apply both a difference-in-differences and an instrumental variable estimation to account for the endogeneity of the location decision. In more detail, we analyze the effect on transaction prices for agricultural land[1] on a county level in Germany between 1997 and 2012 and empirically study the incidence of the provided subsidy. The variable of interest in the empirical analysis is the net present value of the future income streams generated by wind turbines in a particular county.

We focus on the subsidy for wind energy for three reasons. Firstly, wind energy accounts for almost half of the electricity produced by using renewable energy sources in the time period studied. Secondly, compared to biomass plants, there is no labor involved in the production of electricity using wind turbines. Thus, once wind turbines are build, their return does not differ depending on the investor. Finally,

[1]We focus on agricultural land as it is the main building ground for wind turbines due to required minimum distance to population areas. Further, transaction prices react instantaneously compared to lease payments.

there is only one tariff for all onshore wind turbines build in one year. The optimal decision to build a particular wind turbine is, therefore, not distorted due to different tariffs as, for example, in contrast to photovoltaic plants.

Our study relates to at least two streams of literature. Firstly, as the subsidy paid depends on the electricity produced, and thus equals a subsidy on income, the analysis has links to the recent work on the incidence of corporate taxation. Suárez Serrato and Zidar (2014) study the incidence of corporate income taxation in the US and find that on average house owners (respectively land owner) bear 25% to 30% of the tax burden, workers 30% to 35% and firm owners 40%. For Germany there is so far only evidence for the incidence of corporate taxation on employees. Fuest et al (2013) find that workers bear almost 80% of the tax burden. This share is, however, not directly comparable with the estimate by Suárez Serrato and Zidar (2014), as the latter estimate the net effect on workers, accounting for the change in rents and housing prices, respectively, as well.

Secondly, our work relates to the literature on the incidence of agricultural subsidies on land prices. Within the European Union, the average share of an agricultural subsidy reaped by land owners amounts to 19% (Ciaian and Kancs, 2012). In Germany, it seems almost twice as large according to the results by Breustedt and Habermann (2011). The authors find that in the state of Lower Saxony 38% of an agricultural subsidy goes to land owners. Kirwan (2009) analyses agricultural subsidies in the US and finds that land owners benefit to 25% from a subsidy. Moreover, he provides evidence that the share varies significantly with the concentration of demand for farms.

Our results suggest that on average 11% of the subsidy paid to wind turbine owners are reaped by land owners. This result is robust across various specification. Accounting for wind turbine investors' costs increases the share to almost 25%. Thus, from the pure rents of wind turbines in Germany 1/4 goes to land owners.

The outline of the paper is as follow. Section two describe the REA in detail and offers some descriptive statistics about the installed capacity and the technological development of wind power plants. Section three presents a small theoretical framework for our analysis. The methodological approach is introduced in section four. In section five descriptive statistics are presented, followed by the results in section six. Section seven concludes.

2 Institutional and Theoretical Background

2.1 Institutional Background

The EU member states agreed with the resolution of the Lisboa program to increase the share of renewable energies to 20% in 2020. The policy design to reach the aim was left to the member states including subsidies, specific quotas, or price guarantees. The German government decided for a feed-in-tariff system with the introduction of the Renewable Energy Act (REA) in 2000 to promote the building of renewable energy plants. The two main elements of the REA are the long time period for which the subsidy is paid, which is 20 years after plant installation, and the renumeration. In contrast to a subsidy that is a mark up on the market price as e.g. in Denmark, the German subsidy is a fixed price per produced kwh and thus fully independent of the market price. In more detail, the REA guarantees wind turbine operators a price per produced kwH and obliges the grid operator to which the plant is connected to buy the electricity produced. The grid operator, which is one of the four big electricity companies in Germany, sells the electricity at the electricity market and receives a refund of the difference between the price paid and the market price. The difference is paid out from a fund into which all electricity consumer in Germany, including private households and firms, pay into it a share of their electricity bill with large exemptions for energy intensive companies.[2] Since the renumeration significantly increased in recent years and the whole sale costs for electricity are decreasing, the average direct costs per citizen in Germany has increased in recent years to 80 EURO per citizen.[3]

Since its introduction the REA has undergone three reforms, in 2004, in 2009 and in 2012. Those reforms affected the generosity of the subsidy, e.g. the feed-in-tariff but the general design was not changed. These reform will provide additional variation over time which we will exploit for identification.

The tariff guaranteed in the REA depends on the renewable energy source used for the production. Further, it might vary even within one sources, e.g. with respect to the installed capacity of the plant. For photovoltaics for example, the tariff according to the REA 2000 was the highest with 48.1 cent per kwh, for water energy it amounted to 7.67 cent per kwh. Energy produced by wind power plants was in 2000 remunerated with 9.1 cent per kwh. There is however not a single rate

[2] The European Commission investigated the exemption for energy intensive companies as forbidden subsidy recently, and allowed for certain industry classes the exemption.

[3] See http://windkraftsatire.de/strompreis-story-die-faz-verirrt-sich-im-1000-euro-haushalt/

for the whole life span, but the life span is split into a period with a higher feed-in-tariff and a life span with a lower tariff. The second tariff amounted in 2000 to 6.19 cent per kwh. The first, higher feed in tariff is paid for a minimum of 5 years. This period is extended if the wind turbine has a lower productivity compared to a reference plant defined in the law. More precisely, the time period is extended by two months for each 0.75 percent of which the produced energy is below 150% of the return of a the hypothetical reference wind power plant. The hypothetical reference wind power plant is defined as the same plant at a location with 5.5 meter per second average wind strength at a height of 30 meters. This means, for a plant similar to the reference plant the higher feed in tariff is paid for 16.1 years (5 years + (1/0.75 * 2/12 * 150 - 100) years. Table 1 reports the evolution of the two feed-in-tariffs as well as the key parameter that determine the length of the first tariff. In 2000 and 2001 the renumeration amounts to 9.1 cent per kwh and decreased until 2009, where it jumped up again and sunk afterwards again. Most important, with the REA 2009 a minimum threshold was introduced. If it could not be proven that a wind turbine will produce at least 60% of the reference plant return, the REA did not apply and thus no subsidy was paid. This equals a partial abolition of the REA for certain areas.

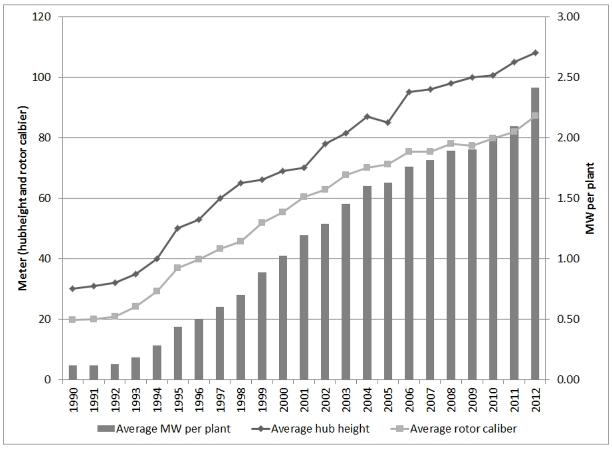
Table 1: Feed in tariff for wind energy

Year	Tariff 1	Factor for time period calculation for tariff 1	Tariff 2	Minimum return
2000	9.10	0.75	6.19	
2001	9.10	0.75	6.19	
2002	8.96	0.75	6.10	
2003	8.83	0.75	6.01	
2004	8.70	0.75	5.92	
2005	8.70	0.85	5.50	
2006	8.70	0.85	5.50	
2007	8.70	0.85	5.50	
2008	8.53	0.85	5.39	
2009	8.36	0.85	5.28	
2010	9.2	0.75	5.02	60%
2011	9.11	0.75	4.97	60%
2012	9.02	0.75	4.92	60%

Note: Tariff 1 is paid for at least five years. The time perios is extented if the return of the plant is lower than the return of a reference plant. See text for further details.
Source: REA 2000, 2004, 2009 and 2012

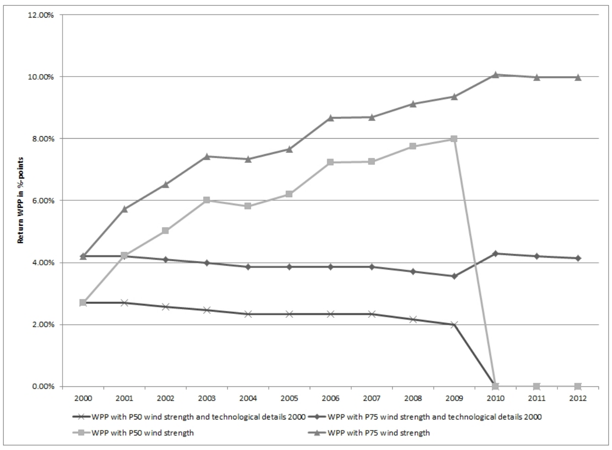
Based on the evolution of the feed-in-tariff, one might expect a decrease in the profitability of newly build wind power plants over time. This is, however, not the case, as the average installed capacity of a single wind turbine increased steadily between 1995 and today. In particular, it results from higher plants (as the wind strength is greater higher above the ground) and due to larger rotor calibers, which allow to extract more kinetic energy of the wind (see Figure 1). The decrease in the feed-in-tariff was thus overcompensated by the technological development of wind turbines as shown in Figure 2, in which the return of a wind turbine built in a

Figure 1: Technological development wind turbines



Notes: Averages are based on all wind power plants in Germany.
Source: Own calculation based on the data of the operator data base, 2000 to 2012.

Figure 2: Evolution wind turbines returns



Notes: WPP stands for wind power plants. P50 (P75) for the median (75th percentile).
Source: Own calculations based on the data of the operator data base, 2000 to 2012.

particular year is plotted.

2.2 Theoretical Background

We propose a stylized theoretical bargaining model with an investor and a land owner for studying the incidence of the subsidy for renewable energies. We first present the model and then discuss some extensions of the model which will provide a guideline for the empirical analysis and for the interpretation of our empirical results.

Suppose there a n fields of equal size that only differ in their wind strength. These fields are owned by n land owners. The share reaped by land owner k amounts to α_k. Land owners outside option is zero as a build wind turbine does not affect the agricultural return of the land. Further, there a j identical investors willing to build a wind turbine. The profits of the wind turbine on the k field is given by π_k. The outside option for the investors is given by out. The bargaining strength β of the land owners is exogenous given in the bargaining model and captures any macroeconomic impact on the relative bargaining strength of the partners, e.g. the available land in relation to the number of investors (which can for example be influenced by legal constraints). The outcome of the bargaining process is therefore given by

$$alpha_k = arg\, max\, \Omega_k \tag{1}$$

with

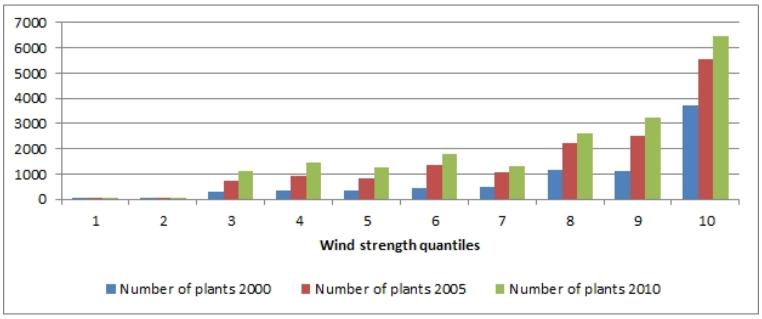
$$\Omega_k = \beta\, ln(\alpha_k) + (1 - \beta)\, ln(\pi_k - alpha_k - out) \tag{2}$$

The first order condition of the bargaining problem can be rearranged to yield

$$\alpha_k = \frac{\beta}{1-\beta}[\pi_{j,n} - out] \tag{3}$$

The fraction reaped by land owners equals thus a share of the profits of the investor after deducting the value of his outside option. In a full information framework, land owners and investors would know the wind strength for each field as well as the number of fields and the number of potential investors. In this case, investors outside option is the plant which is just not build, if there are less investors than fields. Or if there are more investors than fields, investor's outside option would be

Figure 3: Number of plants for different wind strength quantiles



Source: Own calculations.

to invest at the capital market.

If there would be more investors than fields, one would expect that now - more than 10 years after the introduction of the REA - on all fields on which turbines can be build have been build. However, the opposite result is suggested by a study by the German Umweltbundesamt (2013). According to their calculations, 7% of all available agricultural land can be used - legally and economically - to build wind turbines. This suggests that the number of investors is smaller than the number of fields. Thus, the outside option would not be the return of the private capital market but rather the plant, that is just not build.

From an economic perspective it is however not convincing that with full information there are not enough interested investors to build wind turbines. The assumption is further challenged by the fact that wind turbines have not only been build in areas with the highest wind strength in Germany but also in areas with an average wind strength (see Figure 3). This suggest that investors do not know the wind strength on each field but face costs to find out about the wind strength.

This suggest a bargaining framework with limited information. Since there are several ways to model limited information but our data does not allow us to explore the topic in great detail, we only highlight two simple cases in the following but abstract from providing a formal solution to the problem. Given that there are costs to uncover the wind strength, one could start with the case where each investors chooses randomly one field, pays the fee and discovers the wind strength. In the bargaining process, the outside option of the investor would then investing the capital in the private capital market. In case, the investor is able to pay the fee for several fields, the outside option in the bargaining process with the owner of one field is the return of the wind turbine on the next best field. Since the land owner does not observe investors outside option, he forms a belief about it. Reasonable, he expects that the outside option of the investor is the return of average wind turbine. In this case, the land owner receives a share of the wind turbine owner's profits minus the profits of the average wind turbine. Thus, the incidence share is smaller for less profitable plant (as long as they are more profitable than the average plant) respectively larger for highly profitable plans. To assess whether the incidence share varies with wind turbine profitability, we estimate in a robustness test a squared specification as well.

3 Methodology

In the following we discuss our the empirical strategy for the analysis of the incidence effects of the REA. In particular with the empirical model we want to identify the effect of the expected net present value of the subsidy paid for electricity produced by a wind turbine WR of type j on land m_i in county i on the value LP of the land in county i m_i at time t. In addition the value of the land depends on its expected agricultural value (AR). Importantly by installing a wind turbine, agricultural production is not affected as only limited space is needed to erect the turbine.

$$LP_{m_i,t} = c_k + \sum_{k=t} E_t[AR_{m_i,k}] + \beta \sum_{k=t} E_t[WR_{m_i,j,k}] + \epsilon_{m_i,t} \tag{4}$$

As discussed in more detail below in the data there is no direct information on transaction for land (m). Instead we observe transaction prices on the county level. Therefore, we aggregate equation (1) for all pieces of land in county i. Hence in the empirical application we will estimate the conditional effect of the net present value of the subsidy paid for electricity produced by wind turbines in county i on the average value of land in that county. Equation (2) accounts for different types of wind turbines j. Further, it accounts that different wind turbines need more space than others, not with respect to the building ground but with respect to the legally required minimum distance to the next wind turbine. It is given by $\delta_{i,j,k}$,

$$LP_{i,t} = c_i + \sum_{k=t} E_t[AR_{i,k}] + \beta \sum_{k=t} \sum_{j=1..n} E_t[(1 - \delta_{i,j,k}) WR_{i,j,k}] + \epsilon_{i,t} \tag{5}$$

Note, in the model we estimate the effect of the expectations on the building of wind turbine(s) on the land price. Since we can not observe the investor's and land owner's expectation in the data, we need to approximate the expectations with current and past information. In more detail, in our main specification we use the actual build turbines in the particular year t to approximate expectations. In robustness checks we assess the sensitivity with respect to this assumption by accounting in addition for the number of plants build in t and t+1, and t+2, for the expected discounted profits of wind turbines. Noteworthy, since a replacement of wind turbines with better ones is only reasonable after 10 years of the installation, we do not account for a change in the net present value due to a replacement of the wind turbine.

We propose to estimate the empirical model with an instrumental variable estimator and for identification we can exploit quasi random variation generated by the introduction of the REA. The IV estimator deals with two main problems that would lead to a bias using OLS. First, this strategy accounts for the measurement error induced by the approximation of market participant's expectations, as well as for measurement error in the calculation of wind turbine profits. Second, it accounts for the obvious endogeneity of the location decision of wind turbine profits.

We exploit county specific variation in wind strength in combination with the introduction and further time variation of the REA to construct a suitable instrument. In particular, based on detailed wind data, see below, we construct an arguable exogenous treatment group consisting of counties with high wind strength and a control group with counties with low wind strength. Identification then relies on the assumption that treatment and control group were differently affected by the introduction and further reforms of the REA. This assumption seems to be very plausible because wind strength is the key factor for producing wind energy and the subsidy is related to the amount of energy produced. Further, the validity of our strategy using county average transaction prices depends on the assumption, that the average transaction price of a county is representative. In other words the estimates are only unbiased, if investors are indifferent between buying the agricultural land and leasing it only. If not, the composition of the transacted land changes over time and thus comperability over time is limited. A shift between buying and leasing might for example occur, if wind turbine investors are credit constraints and thus prefer to lease the land. A further reasons could be risk sharing, as practioners suggest that lease agreements are sometimes only concluded for 10 years and the lifespan of a plant is 20 years. We assess whether there is evidence for a shift in the composition of transacted land by studying the change in the average size of the sold land, the quality as well as the number of transactions.

In the main specification we focus only on the introduction of the REA, in this respect the first stage of the IV is identical to a difference in differences estimator.In further specification, we exploit as well further differential time variation, namely the partial abolition of the REA related to the introduction of a minimum return with the REA 2009. Finally, we construct as well a more complex instrument which exploits in addition technological variation.

4 Data and Descriptive Statistics

Our empirical analysis requires information about the net present value of the profits of wind turbines within a county and the average transaction price of agricultural land on the county level. As discussed above, we use agricultural land as this is the main building land for wind turbines due to a required minimum distance to population areas. Further, we use transaction prices instead of lease payments as the latter only adjust when the turbine is finally build but transaction prices react much faster and thus allow us to account for the role of expectations.

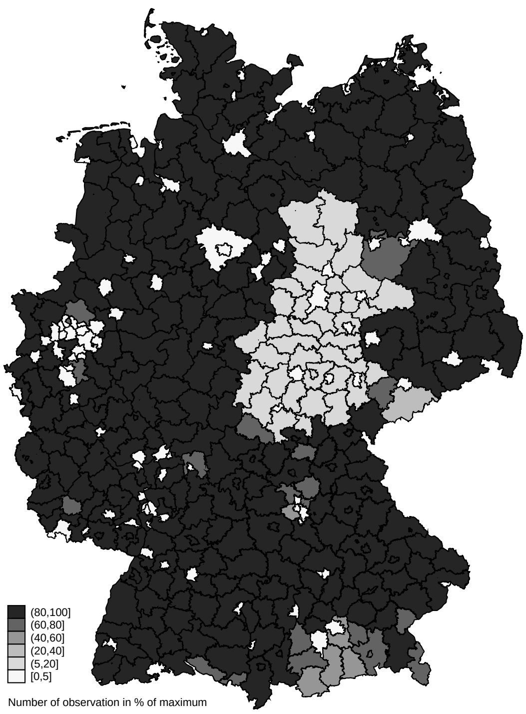
Information on average transaction prices on the county level for the period between 1997 and 2012 are obtained from the publications of the Federal Statistical Offices of the German states. Due to two changes in the administrative boundaries during the time period studied, counties in Sachsen-Anhalt are not in the sample. Counties in Thuringia are only included from 2004 onwards due to missing information before that time. For the same reasons, counties in Schleswig-Holstein, North Rhine Westphalia and Bavaria are not included for the year 1997. Further, we excluded urban counties (kreisfreie Staedte) as well as the three German city states, Berlin, Bremen and Hamburg, as they have only limited agricultural land. To ensure that the transaction price is not driven by extreme values, we exclude further counties in which less than 10 transaction occurred within a year or in which the absolute value of the growth rate of the transaction price was below the 1% or above the 99% percentile. This gives us an unbalanced panel for 1997 to 2012 with around 270 counties and 4,107 county-year observations. The counties covered account for approximately 90% of the installed capacity of wind turbines and plants (see Table 2). A graphical representation of the number of years per county included in the analysis is shown in Figure 3.

Table 2: Composition of the sample and representativity

Year	Whole of Germany		Sample	
	Produced wind energy (WE) in GWh	No of plants	Produced WE in % of total	No of plants in % of total
1997	2,490	4,387	90.6	87.9
1998	3,480	5,346	90.9	88.8
1999	5,229	6,954	89.0	86.9
2000	7,687	8,447	86.7	85.5
2001	11,093	10,482	86.0	84.3
2002	15,639	12,743	85.8	84
2003	20,255	14,458	84.9	83.8
2004	24,118	15,642	84.3	82.9
2005	27,187	16,705	87.2	86.1
2006	30,359	17,902	86.5	85.5
2007	33,572	18,774	85.8	84.8
2008	36,317	19,581	86.2	85.2
2009	39,175	20,503	85.7	84.8
2010	41,996	21,212	86.1	85.3
2011	45,083	22,077	80.1	79.2
2012	49,000	23,001	80.3	79.1

Source: Operator data base, own calculations.

Figure 4: Sample composition: Number of observations per county in % of maximum number



Source: Own calculations.

The main variable of interest is the net present value of the profits of wind turbines in one county. We construct this variable in several steps using the following data sources: Information on the location and the technological details of all wind turbines in Germany from the operator database[4], Information on the (1981 to 2000) average wind strength on a square kilometer raster 10 and 80 meter above the ground provided by the German Weather Service[5], and information from the financial statements DAFNE about the financing of wind turbines and the calculation of the depreciation allowances for the turbines.

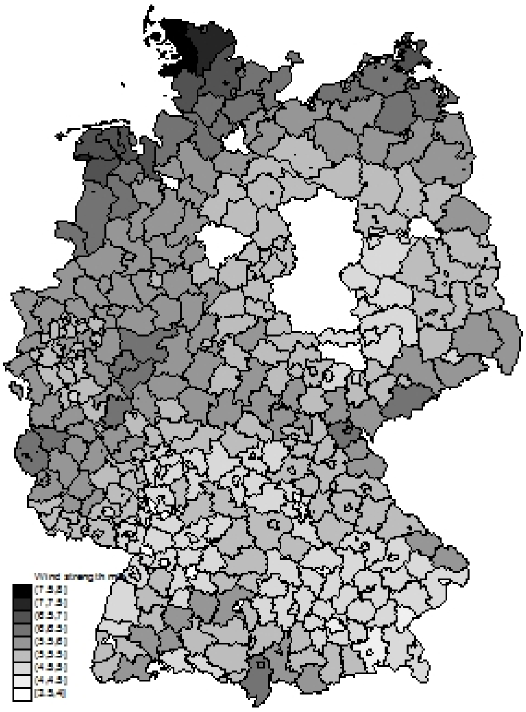
In more detail, in a first step, we calculated the produced energy for each wind turbine using information on the average wind strength in the county of the wind turbine. By using an efficiency parameter of all wind turbines, we ensured that the sum of the produced energy of all wind turbines equals the reported produced energy. Secondly, we calculated the subsidy paid for each wind turbines using the electricity produced and the guaranteed price given by the REA. The investment costs of each wind turbine are approximated by using a ratio of investment costs to installed capacity from Gasch and Twele (2011). Based on descriptive statistics of financial statements of companies having only wind turbines, we assumed a share of debt financing of 80% and a interest rate of 4.5%. Further, for tax purposes a geometric depreciation allowances with a rate of 16% is used. Further details on the calculation of the wind turbine revenue can be found in Appendix A and on the derivation of the costs in Appendix B, which includes also the descriptive statistics for the financial statements of wind turbine firms.

Since the dependent variable is measured as average price per hectare, we scaled the discounted revenue and discounted profits by the share of land used for wind turbines in the county. Since it is legally required that between two wind turbine there needs to be a minimum distance which depends on the installed capacity of the wind turbines, we divided the discounted profits of the wind turbines by the building ground and the minimum distance required to the next plant. We calculated the required minimum distance around the turbine using the ratio of installed capacity to required minimum distance published by the German environmental agency, Umweltbundesamt (2013). The resulting discounted revenue per hectare in

[4]Despite that the database is private it covers all wind turbines in Germany. We checked this by comparing the number of plants and installed capacity from the database of the network operator, which is a official database

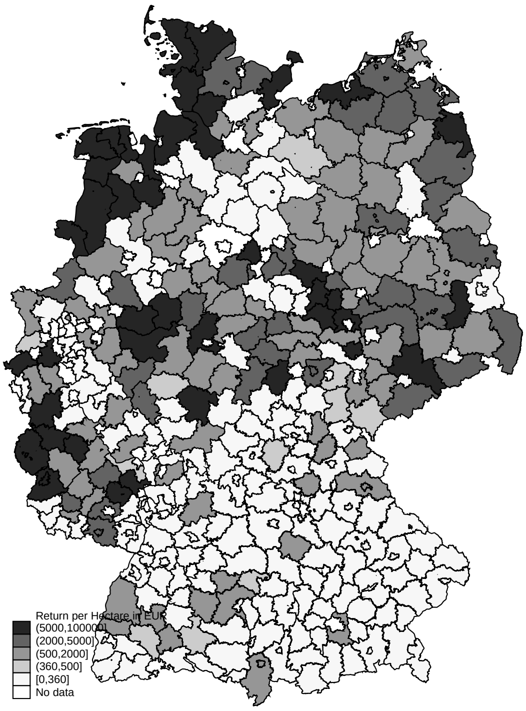
[5]We mapped the data to German county level, by first mapping it to the municipality level and then constructing a weighted average on the county level using the agricultural land within the municipalities as weighting factor.

Figure 5: Average wind strength in German counties



Source: Own calculations based on data of the German Weather Service.

Figure 6: Revenue per hectare of wind turbines in German counties



Source: Own calculations based on data of the German Weather Service and the operator database.

each county in Germany is shown in Figure 6.

In the following we provide more information about the instruments used in the empirical analysis.

The first sets of excluded instruments for the IV approach rely on variation in wind strength between counties in combination with the introduction and further reforms of the REA. The average wind strength varies substantially between German counties as shown in Figure 5. Although it is clear that the wind strength is in particular high at the coast, it is also much higher in the middle of Germany and higher in the western part of the north compared to the eastern part. Beside the introduction of the REA, we exploit as well the partial abolition in 2009 as with the REA 2009 a minimum return for each wind turbine was required to benefit from the subsidy. If the expected return of a turbine was below 60% of the return of a reference plan, the REA did not apply. As shown in Figure 2, this affects in particular plants in areas with wind strength between the 25th and 50th percentile. Moreover, we use change in the wind turbine return due to technological progress to instrument the discounted profits. Evidence on the increase in the return is again shown in Figure 3.

Table 3: Descriptive statistics

Variable	N	Mean	P25	P50	P75	SD
Average land price in EUR	4107	17090	8567	14627	23660	11393
Land quality (1 to 100)	4107	70	37	44	52	310
Number of transaction	4107	132	62	110	175	95
Average size sold land in hectare	4107	2.2	0.9	1.6	2.7	2.1
Total sold land in hectare	4107	311	78	153	304	507
Share total sold land in %	4107	0.48	0.23	0.37	0.59	0.42
Wind strenght in 80m above ground	4107	5.4	5.1	5.4	5.8	0.5
Discounted profits wind power plant per hectare	4107	6334	0	1288	8230	11514
Discounted revenue wind power plant per hectare	4107	7682	0	1590	10132	13776
Produced energy by wind power plants in MW	4107	79641	780	13875	74154	179414
Number of wind power plants	4107	47.65	2	13	56.5	88.43
Used land by wind power plants in hectare	4107	301.91	4.68	72	332.05	581.21
Used land by wind power plants in %	4107	0.45	0.01	0.16	0.64	0.66
Distance weighted average land price neighboring counties	4107	71.53	53.9	75.47	92.06	27.75
Share grassland in %	4107	32.93	17.3	27.33	44.8	21.02
Share farmland in %	4107	63.9	47.94	68.88	80.44	20.98
Share land wheat %	4107	38.47	28.78	40.3	48.99	14.22
Share land potatos %	4107	4.19	0.53	1.77	4.65	6.24
Share land corn in %	4107	8.47	4.33	7.26	11.48	5.53
Harvest each hectare wheat	4107	69.14	62.4	69.4	77.25	12.16
Harvest each hectare potatos	4107	341.83	295.4	343.35	391.3	80.18
Harvest each hectare corn	4107	430.85	396.6	445.55	480.55	77.41
Harvest each hectare wheat * Share land wheat	4107	2717.52	1849.03	2735.86	3567.91	1217.86
Harvest each hectare potatos * Share land potatos	4107	1642.49	168.48	548.56	1728.71	2751.06
Harvest each hectare corn * Share land corn	4107	3655.75	1791.54	2898.26	4942.22	2608.58
Share farms with cattle rearing in %	4107	0.72	0.63	0.77	0.84	0.17
log(Population + Distance weighted Population Neighbors)	4107	12.04	11.68	11.96	12.41	0.51
Average farmsize in hectare	4107	24	13.5	17.4	25.4	20.9
Herfindahl Index Farmsize * 100	4107	0.04	0.02	0.02	0.04	0.07

Source: Operator database, Statistik Lokal, Federal Statistic Offices of the States, own calculations.

To provide some evidence on potential differences between counties with a higher wind strength and lower wind strength, Table 4 shows descriptive statistics for the dependent variable and the agricultural variables in 1999 for treatment and control group based on the median wind strength. High wind strength counties differ in several dimension with respect to low wind strength counties. The land quality is lower in high wind strength counties, as shown by the quality indicator but also by the usage of land (the share of grassland is higher). The average price of low wind strength land is thus 50% higher.

Due to the imbalance of the control variables, a change in price for example for wheat that coincides with the introduction of the REA is more likely to affect the control group and thus might bias the results of the results. To control for potential different prices after 2000, we include thus further interaction terms with a reform dummy that is one for years after 1999 and all agricultural and the population variables.

Using again the treatment and control classification, Figure 7 shows the evolution of the land price in the treatment and control group counties between 1998 and 2010.[6] At least for the two observed years before the introduction of the REA,

[6] We do not include 1997 and 2011 and 2012, as for these years land price information for several states are not available and thus sample selection affects the average land price of treatment and control group.

Table 4: Descriptive statistics Treatment and Control Group 1999

Variable	All Firms MEAN	SD	Treatment Group MEAN	SD	Control Group MEAN	SD	p-value t-test
Land price in EUR per hectare	17625	12090.1	14154.6	9725.9	21801.3	13317.9	0
Wind strength 10meter above ground in m/s	5.4	0.5	5.8	0.4	5	0.3	0
Land quality	45.5	10.5	43.1	10	48.4	10.5	0
Share grassland in %	33.9	21.9	38.4	23.7	28.4	18	0
Share farmland in %	62.9	21.6	59	23.6	67.6	18.1	0
Share land wheat %	35.8	13.6	33.8	14.9	38.3	11.3	0.01
Share land potatos %	5	7	4	6	6	7	0.02
Share land corn in %	9	6	9	6	10	6	0.08
Harvest each hectare wheat	69	13	73	14	65	10	0
Harvest each hectare potatos	327	77	331	89	321	59	0.32
Harvest each hectare corn	445	65	440	66	452	62	0.14
Harvest each hectare wheat * Share land wheat	2550	1208	2562	1358	2535	1003	0.86
Harvest each hectare potatos * Share land potatos	1785	2955	1523	2993	2100	2890	0.12
Harvest each hectare corn * Share land corn	4119	2803	3772	2598	4537	2988	0.03
Share farms with cattle rearing in %	0.7	0.2	0.8	0.1	0.7	0.2	0
log(Distance weighted population)	12	0.49	12.02	0.53	11.98	0.43	0.26

Source: Statistical offices of the Laender 1997-2012, Statistik Lokal 1997-2012, Operator database 1990-2012, own calculations.

there is no evidence that the land price followed a different trend. Further, with the introduction a gap between the land prices of the two groups is introduced that is in line with our hypothesis.

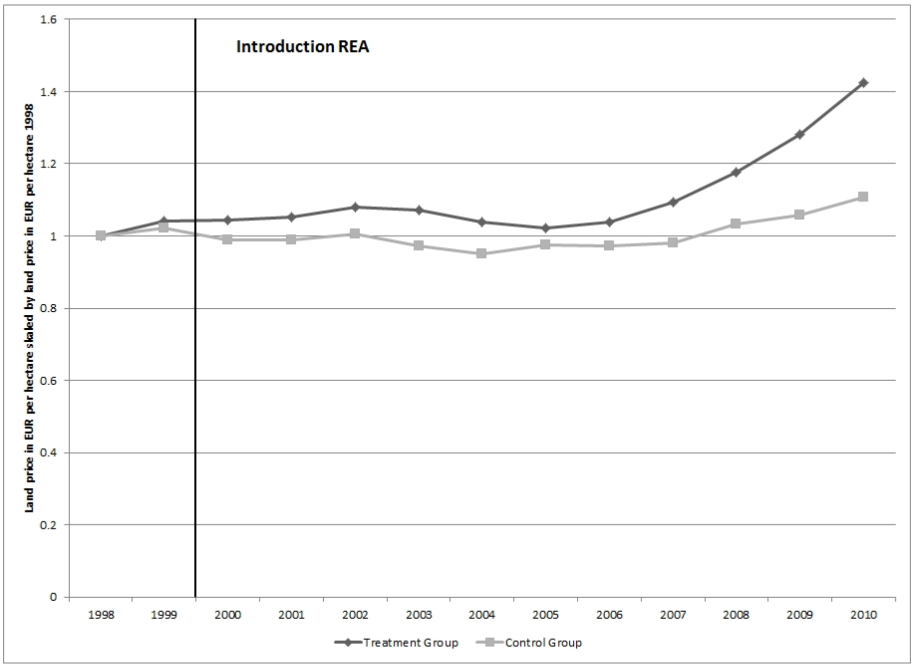
The second instrument we use in this study exploits more information and is the revenue per hectare of a county-representative wind turbine which has average technology. This instrument uses thus on top of the exogenous given average wind strength, the exogenous given feed-in-tariff as well as the non-choice influenced technological development of wind turbines.

To account for other determinants of land prices we include also the following sets of control variables. Firstly, we account for the average usage of land within the county. The data stems from *Statistik Local* and distinguishes between three forms of land usage: farmland, grassland and permanent crop.[7] The use of the farmland can be partitioned further in used for cereals, root crop, forage crop and trade plants. Further, the county average harvest for each hectare land is given for wheat, potatoes and silo corn. To account for the use and the return of agricultural land we include the share of farmland and the share of grassland. To account for the different forms of farmland, we include further the share of cereal, root crop and forage crop. Moreover, we interact the share of farmland with the respective fruits. To account for difference in the usage of grassland, we include further the share of farms with stock breeding.

Secondly, we account for the demand for agricultural products by including the natural logarithm of the population within the county as well as a (simple) distance weighted average of the (natural logarithm of the) population in neigh-

[7]Since the transaction prices are only available for counties in Saxony formed by the administration reform 2008, the data is imputed for these counties based on state-averages.

Figure 7: Evolution land price for treatment and control group



Source: Operator database, Statistik Lokal, Federal Statistical Offices of the States, own calculations, 1998-2010.

boring counties. The data is included in *Statistik Lokal*. Finally, in a robustness check, we account for a potential spatial dependence of agricultural land prices by including the distance squared weighted average transaction price in neighboring counties.Descriptive statistics for all variables are shown in Table 3.

5 Results

Before presenting the results of the IV approach, we report two other sets of results. Firstly, we provide intuitive and clear evidence on the relevance of the first set of instrument, by estimating a reduced form equation. The dependent variable as well as the control variables are defined as described above, but the main explanatory variable is the interaction term between wind strength and the REA reform dummy. For easier interpretation, we show the results using a treatment and control group design. The treatment group are counties with a wind strength above the median, the control group have a wind strength below. The results suggest that on average the price for land increased in the treatment group counties by 1,133 EUR after the REA. The exact number changes slightly when controlling for the agricultural and population variables, but is not significantly different. These results also do not change, when using the wind strength at a different height above ground.[8] A second difference in differences design can be constructed for the partial abolishment of the subsidy due to the introduction of a requirement minimum return introduced with the REA 2009. As shown in Figure 2, counties affected by the introduction of the minimum return have a wind strength below the median. We thus add the specification for the introduction of the REA further interaction between a dummy that captures counties with a wind strength between the 25th quantile and the median and interact this variable with the introduction dummy and a dummy indicating the introduction of the minimum return, which is one for years after 2007. The results are shown in column (2) and (3) of Table . They suggest firstly, the price increase after the introduction of the REA was similar for counties with a wind strength between the 25th quantile and the median and above the median, compared to counties with a wind strength below the 25th quantile. Further, from 2008 onwards, a significant decrease in land prices of around 1.800 EUR is observed for counties with wind strength between th 25th quantile and the median, for the counties with a wind strength above the median, the decrease is less strong with 425 EUR (= 1817 - 1392) on average. This provides support again that the REA did strongly affected land prices. The last specification in Table 5 distinguishes the increase in land prices between counties with a wind strength between the median and the 75th quantile and above to capture the potential different impact of technological development on the incidence share. Technological development changes two things, firstly the return of each plants increases and secondly the number of plants changes as more profitable wind turbines can be build. The interaction terms with the time dummies (2005, 2010) are to some extend randomly chosen as technological development takes place in each year. These specification are not designed to captures the whole technological development but to present evidence that a simple DiD is not able to exploit the whole variation of the impact due to the REA on land prices. The results in column (5) and (6) suggest that counties wind strength above the 75th percentile increased much stronger over time compared to the counties in the other wind quantiles.

The second set of results presented before turning to the main results concern the composition of the observed average transaction prices. To assess whether the introduction of the REA lead to a change in the composition, we study the change in quality of the sold land, the average size as well as the number of transaction. Table 6 reports the results. Since the estimated coefficients are for the log specification close

[8] Results are not reported but available upon request.

Table 5: Results DiD Specification exploiting introduction and partial abolishment REA as well as technological development

Dep. Var.	Land price in EUR per hectare					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment (Wind 80m> P25)*D(>1999)			1167*	1488**	1268**	1360**
			(634)	(605)	(614)	(613)
Treatment (Wind 80m> P50)*D(>1999)	1133***	1221***	579			
	(363)	(402)	(393)			
Treatment (Wind 80m> P75)*D(>1999)					1072***	518
					(387)	(367)
Treatment (Wind 80m> P25)*D(>2007)			-1743***	-1817***	-1756***	-1770***
			(617)	(615)	(615)	(616)
Treatment (Wind 80m> P50)*D(>2007)			1279***	1392***	1321***	692**
			(378)	(376)	(375)	(341)
Treatment (Wind 80m> P75)*D(>2004)						622**
						(278)
Treatment (Wind 80m> P75)*D(>2009)						1907***
						(478)
R^2	0.169	0.186	0.184	0.185	0.189	0.188
Observations	4,107	4,107	4,107	4,107	4,107	4,107
Control Variables						
Agric., Pop.	x	x	x	x	x	x
Agric., Pop.*D(>1999)		x	x	x	x	x

Note: Sample as described in the text. Robust standard errors with county clusters in parentheses. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Each regression includes a full set of county and time dummies (not reported).
Source: Statistical offices of the Länder 1997-2012, Statistik Lokal 1997-2012, Operator database 1990-2012, own calculations.

to zero, which could also indicate misspecification, we also use the absolute values of the variables. When controlling for the agricultural and population variables as well as the interaction terms with the reform dummy, a statistical impact is found on the number of transaction. One possible explanation could be the difference between East and West Germany since agricultural prices are still lower in East Germany. Thus, price changes in certain agricultural products could affect land prices in East and West Germany differently. When including further interaction terms with a West Germany dummy and the agricultural and population variables, the estimated coefficients for the number of transaction is reduced and not longer statistically significant. To ensure unbiased results in our main specification, we thus control in all following specifications also for differences between East and West Germany.

We turn now to the results of the IV approach. We start with analyzing the share of the net present value of the subsidy reaped by land owners. The results are presented in Table 7. In the first column the OLS estimate is reported. The estimated coefficient, which is close to zero, and statistically insignificant, is likely to be biased due to the measurement error in wind turbine profits and market participants expectations as well as the endogeneity of the location decision. Column (2) to (6) present the IV results, using different sets of instruments. In column (2) the excluded instrument is the interaction term between the wind strength in the county and a dummy that captures the introduction of the REA. The results suggest that around 11% of the net present value of the subsidy are reaped by land owners.

Table 6: Results w.r.t to the assumptions

Dep. Var.	# transactions			av. land size		land quality	
	log(#)	#		log(ha)	ha	log(EMZ)	EMZ
Excluded instrument	Revenue WPP: Wind Strength * D(>1999)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Discounted revenue WPP thd euro/per hectare	-0.006	-1.719**	-0.432	0.000	-0.010	-0.001	-0.030
	(0.006)	(0.859)	(0.531)	(0.003)	(0.007)	(0.001)	(0.028)
Adjusted R^2	0.172	0.094	0.221	0.031	0.012	0.021	0.027
Observations	4,107	4,107	4,107	4,036	4,036	4,107	4,107
Control Variables							
Agric., Pop.	x	x	x	x	x	x	x
Agric., Pop.*Dummy(>1999)	x	x	x	x	x	x	x
Agric., Pop.*D(West Germany)			x				
Agric., Pop.*D(>1999)*D(West Germany)			x				
Shea partial R^2 Revenue WPP	0.033	0.033	0.042	0.033	0.033	0.033	0.033
F-Statistics Revenue WPP	33	33	45	33	33	33	33

Note: Sample as described in the text. Robust standard errors with county clusters in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01. Each regression includes a full set of county and time dummies (not reported.)
Source: Statistical offices of the Länder 1997-2012, Statistik Lokal 1997-2012, Operator database 1990-2012, own calculations.

The point estimate is almost unaffected when using in addition the abolition of the REA in 2009 (column (3)) and dummies that capture the impact of the technological development, respectively (column (4)). However, the Hansen test has to be rejected when using the abolition variables in addition. In column (5), we use the simulated return of a representative wind power plant as excluded instrument. Although the point estimate is again 11%, it is not precisely estimated. When using the interaction term as well as simulated return of the representative wind power plants, the Hansen test of overidentifiying restrictions indicate that both instruments are valid.

Table 7: Main results

Dep. Var.	land price in EUR per hectare					
	(1)	(2)	(3)	(4)	(5)	(6)
Method	OLS			IV		
Excluded instrument Revenue WPP						
Wind Strength * D(>1999)		x	x	x		x
Wind Strength * D(<P50)* D(>2007)			x			
Wind Strength * D(>=P50)* D(>2007)			x			
Wind Strength * D(>=P75)* D(>2005)				x		
Wind Strength * D(>=P75)* D(>2010)				x		
Simulated Revenue WPP					x	x
Discounted revenue WPP	0.004	0.107**	0.104**	0.123***	0.112	0.108**
	(0.007)	(0.044)	(0.049)	(0.043)	(0.100)	(0.046)
Adjusted R^2	0.265	0.208	0.212	0.189	0.203	0.207
Observations	4107	4107	4107	4107	4107	4107
Shea partial R^2		0.042	0.056	0.045	0.015	0.045
F-Statistic R^2		44.896	16.477	17.229	10.893	25.199
Hansen p-value		.	0.004	0.315	.	0.961

Note: Sample as described in the text. Robust standard errors with county clusters in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01. Each regression includes a full set of county and time dummies (not reported). Each regression includes further agricultural and population variables and interaction terms with these variables and a reform dummy that is one for years after 1999 as well as interaction terms with a West Germany dummy(not reported).
Source: Statistical offices of the Länder 1997-2012, Statistik Lokal 1997-2012, Operator database 1990-2012, own calculations.

To assess the sensitivity of our results with respect to modeling investors and land owners expectation on how many plants will be build in a particular county, we run several robustness tests. In the baseline specification, we assumed that land owner and investor expect that as many plants will be build as observed in the current year. Since the used assumption might in particular be misleading in the first years after the introduction, we excluded the first two (2000,2001, column (2)), three (2000-2003, column (3)) and four years after the introduction (2000 - 2003, column (4)). The point estimate decreases but is in non of the specification significantly different from the baseline specification. In additional specifications, we assumed that market participants expected the number of plants, which have been build up to the year after (column (6)) or two years after (column 7). The point estimates are again not statistically from the baseline specification. The main reasons is probably that the IV approach is able to account for the potential measurement of the expectations.

Table 8: Results II - Sensitivity (Expectations)

Dep. Var.	land price in EUR per hectare						
Excluded instrument	Revenue WPP: Wind Strength * D(>1999)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Baseline		without				
		2000,2001	2000-2002	2000-2003	1997-2012	1997-2011	
Discounted revenue WPP	0.107**	0.087**	0.089**	0.080**			
	(0.044)	(0.040)	(0.040)	(0.040)			
Discounted Revenue WPP t+1					0.096**	0.102**	
					(0.041)	(0.042)	
Discounted Revenue WPP t+2							0.103**
							(0.048)
Adjusted R^2	0.208	0.242	0.256	0.275	0.179	0.066	-0.010
Observations	4107	3594	3338	3086	4107	3844	3844
Shea partial R^2	0.042	0.061	0.069	0.076	0.028	0.027	0.016
F-Statistic R^2	44.896	45.915	45.890	43.043	26.039	28.980	13.806

Note: Sample as described in the text. Robust standard errors with county clusters in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01. Each regression includes a full set of county and time dummies (not reported). Each regression includes further agricultural and population variables and interaction terms with these variables and a reform dummy that is one for years after 1999 as well as interaction terms with a West Germany dummy(not reported).
Source: Statistical offices of the Länder 1997-2012, Statistik Lokal 1997-2012, Operator database 1990-2012, own calculations.

Moreover, we assessed the sensitivity of our results further by including a variables that captures the subsidy paid to biomass plants within the county per hectare (see Table 9, column (1)).[9] The results do not change. Further, the results do not change when dropping the last two years of the analysis (column (2)). Column (3) accounts for a different time trend in West German counties. Column (4) uses only counties with at least 100 transaction to assess whether counties with small number of transactions are driving the results. Finally, in column (5) we control for the distanced weighted transaction price in neighbor counties. In none of the specification, the point estimate is significantly different from the baseline specification.

Since the incidence share based on the subsidy may by misleading if investors costs are 90% of the subsidy, we estimate the incidence share in relation to the after tax profits or pure rents of the wind turbine investors. Results are shown in Table

[9] The variable is calculated using information on the installed capacity of all biomass plants in Germany and using the aggregated payments for electricity produced by biomass plants.

Table 9: Results III - Sensitivity

Dep. Var.	land price in EUR per hectare				
Excluded instrument	Revenue WPP: Wind Strength * D(>1999)				
	(1)	(2)	(3)	(4)	(5)
	with discounted revenue biomass	1997-2010	West Germany* Year Dummies	transaction > 100	Neighbor price
Discounted revenue WPP	0.109**	0.121**	0.107**	0.097***	0.103**
	(0.043)	(0.047)	(0.043)	(0.035)	(0.043)
Discounted revenue biomass per hectare	0.120**				
	(0.049)				
Adjusted R^2	0.214	0.079	0.214	0.233	0.218
Observations	4107	3581	4107	2237	4107
Shea partial R^2 Revenue WPP	0.042	0.063	0.043	0.039	0.042
F-Statistic R^2 Profits WPP	45.150	52.259	44.314	27.663	44.425

Note: Sample as described in the text. Robust standard errors with county clusters in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01. Each regression includes a full set of county and time dummies (not reported). Each regression includes further agricultural and population variables and interaction terms with these variables and a reform dummy that is one for years after 1999 as well as interaction terms with a West Germany dummy (not reported).
Source: Statistical offices of the Länder 1997-2012, Statistik Lokal 1997-2012, Operator database 1990-2012, own calculations.

10. Based on the profits of the owner, the share reaped by land owner amounts to 24%. In the second column, we assessed whether the incidence share is larger for highly profitable wind turbines. We do not find evidence for that. It is however important to note that this could also be due to weak instruments.

Table 10: Results 2nd research question

Dep. Var.	land price in EUR per hectare	
	(1)	(2)
Excluded instrument Profit WPP		
Wind Strength * D(>1999)	x	x
Simulated revenue WPP		x
Discounted profits WPP	0.239**	0.250
	(0.097)	(0.359)
Discounted profits WPP, sqrd.		-0.000
		(0.000)
Discounted profits WPP * Herfindahl 1998		
Discounted profits WPP * Average farmsize 1998		
Adjusted R^2	0.212	0.220
Observations	4107	4107
Shea partial R^2 WPP	0.046	0.011
F-Statistics WPP	46.819	25.403
Shea partial R^2 WPP, sqrd.		0.001
F-Statistics WPP, sqrd.		6.501

Note: Sample as described in the text. Robust standard errors with county clusters in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01. Each regression includes a full set of county and time dummies (not reported.) *Source:* Statistical offices of the Länder 1997-2012, Statistik Lokal 1997-2012, Operator database 1990-2012, own calculations.

6 Conclusions

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7 References

Breustedt, G., and Habermann, H. (2010). Einfluss der Biogaserzeugung auf landwirtschaftliche Pachtpreise in Deutschland., German Journal of Agricultural Economics 60, 1-15.

Breustedt, G., and Habermann, H.(2011). The incidence of EU per hectare payments on farmland rental rates: A spatial econometric analysis of German farm-level data. Journal of Agricultural Economics 62(1), 225-243.

Ciaian, P., and Kancs, d'A. (2012). The capitalization of area payments into farmland rents: Micro evidence from the new EU member states. Canadian Journal of Agricultural Economics 60, 517-540.

Fuest, C., Peichl, S., and Siegloch, A. (2013). Do higher corporate taxes reduce wages? Micro evidence from Germany. IZA Discussion Paper 7390.

Gasch, R., and Twele, J. (2011). Windkraftanlagen: Grundlagen, Entwurf, Planung und Betrieb. Vieweg+Teubner Verlag.

Kirwan, B.E. (2009). The Incidence of U.S. Agricultural Subsidies on Farmland Rental Rates. Journal of Political Economy 117 (1), 138-164.

Requate, T. (2014) Green Tradable Certificates versus Feed-in Tariffs in the Promotion of Renewable Energy Shares. CESifo Working Paper 5149.

Suárez Serrato, J.C., and Zidar, O. (2014). Who benefits from state corporate tax cuts? A local labor market approach with heterogenous firms. NBER Working Paper 20289.

Umweltbundesamt (2013). Potenzial der Windenergie an Land - Studie zur Ermittlung des bundesweiten Flaechen- und Leistungspotenzials der Windenergienutzung an Land, Dessau-Roßlau.

References

A Appendix- Microsimulation of profit of wind power plants

The calculation of wind power plants profits is done in several steps. The data sources used are the information on average wind strength in 10m and 80m above ground, available in a 1 square kilometer raster for the whole of Germany, the technological details of each wind power plant in Germany and the feed in tariff.

Since we know the country in which each wind power plant is located, the wind strength data is firstly mapped to the county level. This is done in two steps, firstly, the wind data is mapped to German municipality level and in a second step weighted with the share of agricultural land in the municipalities to the county level.

To calculate the produced energy by each wind power plant, the wind strength at the hub height is needed. For a given roughness parameter (z_o), which accounts for the impact of the shape of the landscape and a given wind strength in one height, the wind strength in every other height can be calculated (see equation (1)). Since the average wind strength in 10m and 80m above ground is given, the roughness parameter is calculated first and afterwards the average wind strength at the hub height.

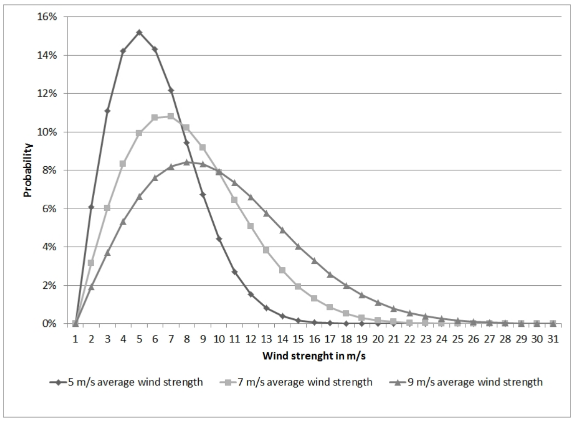
$$ws_i = ws_j * \frac{ln(\frac{height_i}{z_0})}{ln(\frac{height_j}{z_0})} \tag{1}$$

$$R_R = \eta * 0.5 * AD * \frac{\pi}{4} * RD_i^2 * \sum P_k WS^3_{k,R,h_i} \tag{2}$$

With the wind strength at the hub height and the technological information for each wind power plant, the amount of produced energy can be derived using equation (2). The efficiency of the power plant is given by η and set to 36% such that the overall produced energy fits the aggregated values.[10] AD is the air density at the hub height. It amounts roughly to 1.2 $\frac{kg}{m}$. RD is the rotor diameter and stems from the wind power plant information. Finally, WS stands for the wind strength. Since wind strength affects the return of the power plant to the power of three, the return cannot be calculated using only the mean wind strength but the distribution of the wind strength is needed. We approximated the wind strength distribution using the mean wind strength and a Rayleigh distribution. Thus, in a first step the

[10] In a robustness check we used also the 80% percentile wind strength, where we end up with an efficiency parameter of 0.33. This suggest that our microsimulation is quite accurate as the efficiency of wind power plants is between 0.2 and 0.4. The efficiency parameter includes the potential breakdown of the plant.

Figure A.1: Wind strength distribution for different means



Source: Own calculations using Rayleight distribution

probability to observe a wind strength of 1, 2, and so on up to 30 m/s is calculated. It is shown for an average wind strength of 5, 7 and 9 m/s in Figure A.1. Using the distribution of wind strength the produced amount of electricity for each wind power plant is calculated. We further multiplied the value per hour with 365 (days) and 24 (hours) to get the amount per year.

To derive the stream of revenue for each wind power plant, the feed-in-tariff which will apply has to be determined. The feed-in-tariff which apply is on the one side related to the year of the connection to the grid, which we will assume to be equal to the year of construction. It is further related to the return of the reference plant as the length of feed-in-tariff one depends on the ratio of the return of the plant to the reference plant return. The minimum length is 5 years and applies to all wind power plant that generate at least 150% of the reference plant return. The length increases by two months for every 0.75% (0.85% for the years 2005 to 2008) for which the return of the power plant falls below the return of the reference plant. Thus, if the return of the power plant is 8% below the reference return, the length is extended by one year.

To calculate the length of the higher feed in tariff, the return of the reference plant is calculated. According to the law the reference power plant features the same technological details as the wind power plant and is located at a place with a wind strength of 5.5 m/s 30 meter above ground and a roughness parameter of 0.1. Using the steps outlined above, we calculate the return for the reference plant, which allows us then to calculate the length of the higher feed in tariff. Finally,we calculate the discounted revenues of each wind turbine using a discount rate of 3% and a life span of 20 years. To account for the fact that in the year of construction, only part of the energy per year is produced, we assumed in the first year of grid connection that half the amount is feed in.

The costs of each wind power plant are assumed to be 650 EUR per installed kW capacity based on the survey by Gasch and Twele (2011). They suggest installation costs to be around 550 EUR per kW and around 15% other investment costs, e.g. connection to the grid or baseplate. The investment and related costs are considered by assuming geometric depreciation allowances with a life span of 16 years Further, we assume a ratio of debt financing of 80% with a interest rate of 4.5%. The bank loan is paid back in 8 years. All these variable base on descriptive statistics of financial statements of wind turbine firms in the data base DAFNE (see Appendix B). The equity rate of return is assumed to be 3%.

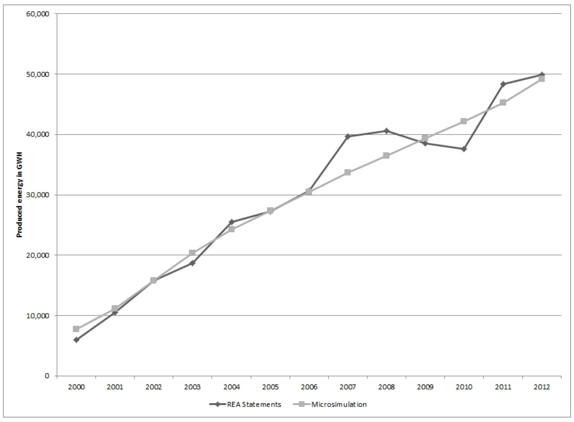
To calculate the revenue per hectare, we scaled the wind turbine profits by the land used. With regard to the land used, it is important to account not only for the floor space required to erect one wind power plant but also for their installed power, as the required distance between two plants depends on the installed power of the two plants. Firstly, federal law require a distance between two plants and secondly the distance is necessary to prevent that two plants interfere with each other. We follow the calculation by the Umweltbundesamt (2013), which reported that on average per 1 MW installed capacity 6 hectare of agricultural land are needed.

Accuracy of the model

The accuracy of the model is checked in two different ways. Firstly, the amount of produced energy from wind power plants is compared to the real ones according to the REA statements published by the network operators. The two series are shown in Figure A.2 and up to 2006 the two lines almost overlap, onwards there are temporary differences, which are two some extend related to the temporal optimization of wind power plants with regard to connecting the plant to the grid as there has been a jump in the tariff from 2008 to 2009. A further reasons might be differences in the wind strength between the years.

The second accuracy check of the model relates to the local business tax. The local business tax is a municipality tax and the profits of every wind power plant is subject to the tax in the municipality where the plant is located. This allows us to check whether the simulated profits show up in the aggregated local business tax revenue on a county level as they should. Since the tax depends on the tax rate that is set by the municipality, we use the tax base as dependent variable. The data stems from *Statistik Lokal* and is provided by the Federal Statistical Office. In case we would capture taxable profits perfectly, we expect a coefficient of 1. However, since

Figure A.2: Produced energy by wind power plants



Source: Own calculations and REA statements, 2000 to 2012.

we are not able to account for leasing payments, the coefficient should be smaller than 1. To derive the taxable income we account for depreciation allowances and wind turbines' financing behavior.

Descriptive statistics for the variables used in the regression are reported in Table A.1. The regression results are shown in Table A.2. The dependent variable is the aggregated local business tax on a county level in TEUR. The sample includes all non-urban counties in Germany for the years 1998 to 2010 with at tax base of at least 1 million EUR We exclude small municipalities as otherwise the standard errors would be to large. Each regression includes a full set of county and time dummies.

Table A.1: Descriptive statistics sample with local business tax

Variable	N	Mean	P25	P50	P75	SD
Total tax base local business tax in TEUR	3883	14856	5799	10182	18739	15053
Current revenue wind power plant * 0.05 in TEUR	3883	248	0	25	225	565
Tax base wind power plants in TEUR	3883	141	0	8	104	370
log(Population)	3883	11.96	11.6	11.86	12.32	0.53
Log(Population neighbor counties)	3883	13.48	11.44	13.87	15.37	2.91
Local business tax multiplier	3883	323	312	330	349	65
Local business tax multiplier neighbor counties	3883	1.98	1.64	2.03	2.28	0.51

Notes: Sample includes all non-urban counties in Germany from 1998 to 2006.
Source: Jahresrechnungsstatistik 1998-2006, own calculations.

Using the current revenue for the wind power plants suggests that on average 53% of the revenue are taxable income and thus 37% deductible costs. In column (4) and (6) the results for the simulated taxable profits are shown. The point estimate amounts to 0.92. It is however not significant when using clustered standard errors. One reason might be the volatility of the tax base and the small sample. Nevertheless, the simulation model is able to reproduce the generate amount of electricity and predicts a reasonable increase in local tax revenue.

Table A.2: Accuracy of the simulation: Local business tax base

Dep. Var.	Local Business Tax in TEUR					
Model	(1)	(2)	(3)	(4)	(5)	(6)
SE					county clusters	
Revenues wind power plants (WPP)	0.533*	0.577**	0.555*	0.555		
	(0.286)	(0.285)	(0.285)	(0.768)		
Taxaxable profits WPP					0.917**	0.917
					(0.415)	(1.144)
log(Population)*1,000,000	0.022***	0.030***	0.030***	0.030***	0.030***	0.030***
	(0.002)	(0.002)	(0.002)	(0.007)	(0.002)	(0.007)
Tax multiplier * 100		-0.256***	-0.275***	-0.275**	-0.277***	-0.277**
		(0.048)	(0.049)	(0.115)	(0.049)	(0.114)
Tax multiplier of Neighbors			13.029*	13.029	12.880*	12.880
			(6.750)	(14.982)	(6.750)	(14.993)
R^2	0.484	0.475	0.481	0.481	0.481	0.481
Observations	3883	3883	3883	3883	3883	3883

Note: Sample includes all non-urban counties in Germany between 1998 and 2010 with a tax base of at least 1 million euro. Standard erros in paranthesis. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01. Each regression includes a full set of county and time dummies (not reported.)
Source: Statistik Lokal 1998-2012, Operator database 1990-2012, own calculations.

B Appendix - Descriptive statistics based on DAFNE data base

The information on wind turbine firms' depreciation allowances and finance structure, which are crucial for the calculation of the profits, are derived from the DAFNE database. The DAFNE data base contains financial statements (mainly balance sheet but for a few firms also income statements) for German firms with a limited liability for the years 2004 to 2012. Since wind power plants at one location are often in single companies for simplicity, financial statements are for some wind power plant firms observed. We identify wind power firms are follows. In a first step all firms with WIND in their company name are identified. From these firm, firms with OPERATOR, REAL ESTATE, ADMINISTRATION or DEVELOPMENT in their company name are deleted. To derive an even finer sample, firms with less than 100k EUR fixed assets and firms with a standard deviation of the depreciation allowances above 0.1 are excluded. The first requirement is needed as already very small wind power plants with 133 KWH have assets of a value of 100k EUR. The second requirement ensures that only "one time build plants" are included and not wind power plant parks to which single plants are added in different years as this would not allow to identify the rate of depreciation allowance.

From roughly 30.000 firms with WIND in their company name 7.473 are left in the final sample. The number of firms for which the variables of interest are available differ due to data availability. The statistics are shown in Table B.1. They reveal that the rate of depreciation is between 10 and 14% for 90% of all firms in the sample. This is in line with a geometric depreciation with twice the rate of linear depreciation and a life span of 16 years, which was allowed in Germany for tax purposes.

Regarding firms financing behavior, the overall debt ratio that is available for all firms as well as the ratio of bank liabilities to total assets, available only for a subsample, is shown in the table as well. It should be noted that due to a different life span of fixed asset and the loans as well as payout policy the initial debt ratio can only be calculated in the first year. The descriptive statistics suggest a range from 77% to 100% for the overall debt ratio and from 63% to 89% for bank liabilities to total assets. The results for the life span of debt is similar using overall debt or only bank liabilities. The time span is around 8.5 years and has been calculated using the repayment rates of debt respectively bank liabilities. Finally, the interest rate calculated as interest payments divided by overall debt respectively bank liabilities is shown in the last four columns. Regardless of whether payments are scaled by current or lagged values, the rate is around 4.5%.

Table B.3: Descriptive statistics wind power plant firms

	N	p10	p25	p50	p75	p90
Depreciation allowances	5,825	-0.21	-0.14	-0.12	-0.10	-0.06
Debt ratio (DR)	7,473	0.48	0.74	0.91	0.99	1.00
DR year of incorporation	84	0.59	0.77	0.95	1.00	1.00
Bank liabilities to total assets (BL)	1,318	0.49	0.70	0.87	0.96	0.98
BL year of incorporation	18	0.32	0.63	0.81	0.89	0.92
Duration debt in years	5,849	1.54	5.14	8.41	12.19	19.96
Duration bank credit in years	703	3.37	5.98	8.78	11.49	15.98
Interest to debt in %	347	5.60	5.06	4.31	3.48	1.38
Interest to L.debt in %	244	5.02	4.56	3.86	3.15	1.46
Interest to BL in %	287	8.74	5.69	4.92	4.30	3.55
Interest to to L.BC in %	173	9.27	5.19	4.44	3.84	3.35

Source: DAFNE data base, 2004-2012, own calculations.