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An Econometric Analysis of Support Scheme Effects on Renewable Energy Investments in Europe

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Abstract

Support schemes for renewable electricity generation (RES-E) have been extensively applied the last decades. European countries have implemented both feed-in tariffs (FITs), renewable portfolio standards (RPS) and tendering schemes for different RES-E technologies. This paper examines the impact of these policies in the five largest electricity consuming countries in Europe using detailed data spanning 1990-2012. Following recent policy impact studies we employ the investment decision model specified by [1] where the share of return on an investment in renewable generation capacity that can be attributed to feed-in tariffs is isolated. Renewable portfolio standards and tendering schemes are also included in the econometric specification. Due to high FIT levels and reduced costs we find that investments in PV and onshore wind power have generally had a high expected return the last years. We conclude that FIT has significantly affected the development of PV and onshore wind in the five countries analyzed in the period 1990-2012. The significance of FIT on onshore wind generation contradicts previous findings. Also, it is confirmed that RPS has significantly positive effect on the development of bioenergy for power generation and that the presence of tendering schemes has contributed to the increase of onshore wind power.

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Keywords: Renewable energy investments; support scheme effects; Europe

1. Introduction

Policies to increase the use of renewable energy are widely used internationally and in the recent decade feed-in tariffs (FIT) are among the most commonly used in European countries. Due to high cost, and in many cases

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negative economic impacts for energy utilities using conventional generation technologies, the policies supporting electricity from renewable energy sources (RES-E) are much debated. A large literature exists on the role and effects of policies on the development of RES-E, but the main share of the literature is qualitative and descriptive. The number of studies analyzing *ex post* the impacts of different polices is more limited, but as summarized by [1] there are a few exceptions including [2]-[6]. With the exceptions of [6], these studies are not technology specific, and generally they ignore how specific market characteristics like prices and costs, as well as differences in policy design, affect the policy strength. Recently, [7] and [1] has developed new indicators for the strength of FITs including tariff size and duration, degression rates (a gradual decrease in the FiT rates applied in some countries) as well as electricity prices and technology specific production costs. These models are applied to analyze the effect of FIT on RES-E generation in Europe by estimating technology specific fixed-effects regression models on a panel dataset of 26 EU countries spanning 1992-2008. Both [1] and [7] conclude that FITs has affected solar PV capacity in EU significantly. Quite surprisingly, however, no significant effect of FIT is found for onshore wind in the same region and time window.

EU countries have spent large amounts on RES-E support through FIT schemes the last two decades and [1] and [7] represent the first rigorous econometric analyses of FIT in policy effectiveness in Europe. These studies do, however, not include data for the latest years and there are also indications of limitations in the data quality in their econometric estimations. As such, it is interesting to test the robustness of previous results using more detailed and more recent data. In particular, it is interesting to test the finding of no significant effect of FIT on onshore wind.

The objective of the present paper is to analyze the effects of support schemes on the production of onshore wind, solar PV and bioenergy in the five largest EU countries. We do this by estimating econometric models based on a behavior model similar to [1] and comprehensive, technology specific data spanning from 1990 to 2012.

The rest of the paper is organized as follows: Chapter 2 presents our methodology and data collection. In chapter 3 we present our regression results and sensitivity analysis, which is discussed further in chapter 4. The overall conclusions are summarized in chapter 5.

2. Methodology and data

The effects of RES-E support on RES-E deployment are tested by estimating an econometric panel data model inspired by [1] and [7]. The behavior model and econometric specification is presented in the following

2.1 Behavior model

As dependent variable we use the natural logarithm of cumulative RE capacity for each country, technology and year. Cumulative capacity is preferred to added capacity in order to avoid problems with negative values in the logarithmic transformation in years when there has been a net reduction of capacity. Three different independent variables are employed to explain the dependent variable:

- Share of return on an investment in RES-E, *SFIT*
- Incremental percentage requirement, *IPR*
- Binary tender, *BT*

In addition we include a range of control variables. These are the *nuclear share*, *coal share*, *gas share*, *petroleum share* and *renewable share* in the electricity mix in addition to *energy use per capita* and *real GDP per capita.* The latter two are expressed as growth rates. The independent variables are chosen on terms of what support schemes are present in the countries analyzed, as well as for comparative basis with previous studies.

Share of return on an investment in RES-E, *SFIT*: To measure the strength of a FIT we apply an investment decision model which calculates the share of return on an investment in RES-E that can be attributed to the existence of a FIT scheme, SFIT. The *SFIT,* which is specific for each technology, year and country is derived from calculation of the expected rate of return on an investment (ROI) in three different scenarios: electricity production without FIT present ($\mathrm{ROI}^{\mathrm{noFIT}}$), electricity production with FIT present ($\mathrm{ROI}^{\mathrm{FIT}}$) and an alternative investment exemplified by savings at year and country specific interest rates ($\mathrm{ROI}^{\mathrm{SAVINGS}}$) [1].

In general terms, return on investment can be expressed as:

$$ROI = \frac{discounted\ income - discounted\ costs}{discounted\ costs} \tag{1}$$

Mathematically ROI in the different scenarios are given as:

$$ROI_{hit}^{noFIT} = \frac{\sum_{l=1}^{LT_h} \frac{(P_{it})_l}{(1+\sigma_p+DR)^l} - \sum_{l=1}^{LT_h} \frac{(COE_{hit})_l}{(1+DR)^l}}{\sum_{l=1}^{LT_h} \frac{(COE_{hit})_l}{(1+DR)^l}} \tag{2}$$

$$ROI_{hit}^{FIT} = \frac{\sum_{l=1}^{CL_{hit}} \frac{FIT_{hit}}{(1+DR)^l} + \sum_{l=CL_{hit}+1}^{LT_h} \frac{(P_{it})_l}{(1+\sigma_p+DR)^l} - \frac{(COE_{hit})_l}{(1+DR)^l}}{\sum_{l=1}^{LT_h} \frac{(COE_{hit})_l}{(1+DR)^l}} \tag{3}$$

i.e. the summarized discounted income under FIT scheme + summarized discounted income after contract duration – sum discounted costs over lifetime.

$$ROI_{hit}^{SAVINGS} = \frac{(1+\rho_{it})^T}{(1+DR)^T} - 1 \tag{4}$$

where h, i, and t specifies technology, country and year respectively. LT_h is technology lifetime, P_{it} is electricity price, σ_p is a price uncertainty discount rate[†], DR is the discount rate, COE_{hit} is cost of energy in eurocent/kWh, FIT_{hit} is FIT amount in eurocent/kWh, CL_{hit} is the contract duration of the FITs, ρ_{it} is the interest rate and T is the investment duration, set equal to the lifetime of the technology we compare it to. The *SFIT* is then derived by subtraction of $ROI^{SAVINGS}$ and ROI^{noFIT} from ROI^{FIT}. Whichever of the subtractions yields the smallest value equals the *SFIT*, thus representing the additional ROI directly attributable to the presence of FIT in the market. This approach allows taking market characteristics into account when estimating the effects of FIT. We use cost of energy in place of separate terms for investment costs and maintenance costs. This is done from a data accessibility standpoint. We expect investments in the selected renewable technologies if SFIT>0.

Incremental percentage requirement, *IPR*: Renewable portfolio standard (RPS), which is a widely used regulation by European governments, requires that production from renewable energy sources should increase to a certain level within a specific time frame. One such example is the "Renewable Obligation" implemented in the UK. To account for, and analyze, the impacts of renewable portfolio standards (RPS) we use the variable "incremental percentage requirement" (*IPR*) introduced by [5]. *IPR*, as specified by [5] measures the strength of an RPS by taking heterogeneity of the RPS design into account, correcting for exceptions from the scheme and the amount of existing renewable capacity eligible for certificates. We have found the exceptions hard to measure exactly. They do however seem rather negligible in our selected countries, which in this study imply that the *IPR* is set equal to the RPS percentage.

Binary tender: The presence of tendering schemes for RE investments is controlled for by introducing a binary variable taking the value 1 if there existed such a scheme in a specific country for a specific technology and otherwise 0.

2.2 Econometric model – specification and properties

Fixed effects panel data models are estimated with technology, country and time specific observations from 1990-2012 for PV and wind. For biomass, the study period is 1990-2011 because of lack of reliable capacity data

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[†] Since the investor is not able to predict the wholesale market price development over the lifetime of the system Jenner suggests that the investor expects P_{it} to remain stable as of year t at the additional uncertainty discount σ_p. σ_p captures the investor's uncertainty about future price fluctuations and thus about future revenues.

for 2012. For Italy, we have limited the period to 2005-2012 as reliable data on the feed-in tariff scheme before 2005 has been unobtainable. This gives us the following econometric model:

$$\ln(cap)_{hit} = \beta_1 SFIT_{hit} + \beta_2 IPR_{it} + \beta_3 binary\ tender_{hit} + \beta_x K_{it} + a_i + u_{it} \quad (5)$$

Where $\ln(cap)_{hit}$ is the natural logarithm of cumulative capacity for technology h, country i and year t. $\beta_x K_{it}$ is a number of control variables, while a_i is time independent country specific unobserved characteristics. u_{it} is the error term. A Wald test for groupwise heteroscedastisity and a Wooldridge test for autocorrelation indicated heteroscedastisity and autocorrelation at 0.99 significance level in all models. To correct for this we employ Hoechles modified Driscoll-Kraay heteroscedasticity, autocorrelation and spatial autocorrelation robust standard errors for use on unbalanced datasets [8].

2.3 Data

We have gathered technology- and country specific data for renewable energy capacities from 1990 to 2010 from [9]. These data was supplemented with data from [10, 11] for 2011 and 2012 for onshore wind and [12] for PV. We did not find adequate capacity data for biomass used for electricity production in Spain, France and Italy for 2011 and 2012, as well as for Germany in 2012. The analysis for biomass is therefore conducted to and including 2010 for Spain, France and Italy, and 2011 for Germany. Energy use per capita and GDP per capita are from [13, 14]. Several sources were used to map country and technology specific FIT levels, FIT contract lengths as well data for the control variables specified in section 2.1. There is a scarcity of reliable cost data for European countries and to obtain the best possible cost data we used the sources [15-20] for mainland Europe and [21-23] for the UK. The long term marginal cost (LRMC) for PV has reduced from about 50-60 c€/kWh in the early 1990-ies to levels around 20 c€/kWh in 2012, according to our data (costs measured in fixed 2005 Euro. LRMC for onshore wind power has reduced from 15 c€/kWh to below 7-9 c€/kWh during the same period. A complete list of data sources is provided in [24].

3. Estimation results and discussion

The estimation results from the regressions in equation 5 are presented in table 1.

Table 1. Fixed effects regression models for onshore wind, solar PV and biomass.

Variable	Onshore wind		Solar PV		Biomass	
	Coeff	St. error[1]	Coeff	St. error[1]	Coeff	St. error[1]
SFIT	1,458***	0,474	1,871***	0,227	0,507 ()	0,348
Incremental percentage requirement	-0,071	0,065	0,038	0,063	0,223***	0,045
Binary tender	3,848***	0,943	0,904	0,544	0,026	0,115
Nuclear share	-0,287***	0,074	-0,387***	0,122	-0,290	0,181
Coal share	-0,249***	0,079	-0,183	0,110	-0,379*	0,190
Gas share	-0,175**	0,071	-0,244**	0,112	-0,289	0,193
Petroleum share	-0,253**	0,110	-0,561***	0,112	-0,172	0,203
Renewable share	-0,155*	0,088	-0,004	0,142	-0,212	0,203
Energy use per capita	0,013	0,046	-0,111**	0,044	0,000	0,036
GDP per capita	-0,053	0,073	0,045	0,072	0,099**	0,038
N	88		88		74	
R-squared	0,640		0,853		0,810	

Significant at *p<0,10, **p<0,05, ***p<0,01

[1] Modified Driscoll-Kraay robust standard errors.

Based on the regression output we reject the null hypothesis that *SFIT* has no impact on cumulative installed capacity of PV and onshore wind at a 1% significance level. An increase in one percentage point of the variable *SFIT* is expected to increase cumulative capacity of PV by 1.87 % and by 1.46 % for onshore wind. We cannot reject the null hypothesis for biomass, implying no significant effect of FITs.

Further we reject the null hypothesis that incremental percentage requirement, *IPR,* has no impact on cumulative capacity of biomass at a 1% significance level. An increase in one percentage point of the variable *IPR* increases the cumulative capacity of biomass by 22.3 %, all other variables fixed. For this variable, we cannot reject this null hypothesis for PV and onshore wind. For the variable binary tender we reject the null hypothesis that the presence of tendering schemes has no impact on cumulative capacity of onshore wind at a 1% significance level but we cannot reject the null hypothesis of no such effect for PV or biomass in our analysis. It should be noted that the use of a continuous variable for the volumes within the tendering schemes could have given more precise insights, but a binary variable was the only possible option within this study. We do find significant values for several of the control variables and expect these to impact the cumulative capacity of PV, onshore wind and biomass.

3.1 Sensitivity analysis – sensitivity of FIT design

To assess the impacts on cumulative installed capacity of onshore wind and PV of change in FIT design, we conduct a sensitivity analysis for change in SFIT as a function of a marginal change in FIT amount. For the sensitivity analysis we use observed 2012 data for Germany, Italy, France and the UK and 2011 data for Spain, where FITs were discontinued in 2012**.** All other factors held constant, we have increased FIT amount by 1 eurocent/kWh. The sensitivity analyses results are shown in Table 2. From this analysis we can predict expected change in capacity for each technology in each country attributable to a 1 eurocent/kWh increase in FIT amount. Further, we can calculate predicted production based on expected added capacity and country and technology specific capacity factors from [25]. According to our results, an increase in FIT amount by 1 eurocent/kWh is expected to increase cumulative installed capacity by 270 MW for PV and 1245 MW for onshore wind power in France. This implies an increase in production by 284 GWh/year for PV and 2431 GWh/year for onshore wind power. By comparing all countries we see that the largest impact on *SFIT* by a marginal increase in FIT amount is found in Germany for onshore wind and Spain for PV.

Table 2 - Impacts of a 1 c€/MWh increase in the FIT level for PV and wind power in different countries

±1 eurocent change of FIT amount		**France**		**Germany**		**Italy**		**Spain**		**UK**	
Technology		*PV*	*Wind*	*PV*	*Wind*	*PV*	*Wind*	*PV*	*Wind*	*PV*	*Wind*
Δ SFIT		0.041	0.119	0.041	0.142	-	0.119	0.044	0.14	0.033	0.084
Δ Capacity	*MW*	270	1245	2492	6449	-	1409	351	4424	130	704
Capacity factor	*%*	12,0	22,3	11,0	17,5	17,0	19,1	17,0	24,8	8,0	26,1
Δ Production	*GWh*	284	2431	2401	9886	-	2357	522	9611	94	1611
Cost of 1 cent increase	*Mill. euro*	2,84	24,31	24,01	98,86	-	23,6	5,2	96,1	0,9	16,1

3.2 Discussion

The estimation results show a significant positive impact of FITs on investments in PV capacity. This finding fits well with the findings from [7] and we find the result both intuitive and unsurprising. The learning rate for PV has been high, causing substantial cost reductions the latest years. However, PV is still a comparatively young large scale technology and the costs are still higher than costs for onshore wind and biomass. Without FITs present we observe negative return on PV investments for all years in all countries. Under these circumstances, investments in PV should not be observed unless incentive schemes are present, there are large information assymetries in costs or actors behave irrationally. This considered, it is not surprising that investments in PV capacity are driven by FITs.

In addition, we find a significant positive impact of FITs on onshore wind. This result contrasts the findings of [1] and [7] where no such effect was found. It is noted by [1] that wind power may already be competitive in the market without support as a reason for lack of impacts of FITs on onshore wind capacity. Compared to the previous studies, the current analysis uses more detailed data on wind generation costs, and the main reason for our opposing conclusion is probably the higher cost of generating wind power electricity assumed in this analysis, reducing the competitiveness for wind power without policy support. We observe that the *SFIT* for onshore wind is very high in some countries compared to others. A very high *SFIT* for a given country and technology may cause very high investments and a rapid increase in capacity. This situation may cause unnecessarily high public costs through policy support. Another possibly influential factor causing different results from [1] and [7] may be our different selection of countries. While the two previous studies examine all EU countries except Malta, we have limited our study to the five biggest electricity consumers in Europe in order to ensure high data quality. It is also interesting that we, as opposed to [7], find no significant impact of FITs on investments in biomass capacity. This might again be due to differences in production cost approximations or different sample of countries. Another point is that an investor is likely to invest in the most profitable renewable technology. *SFIT* for biomass is lower than *SFIT* for wind and solar PV in all five countries (as shown by [13]).

In [1], a significant and negative relationship was found between *IPR* (measuring quota systems) and electricity generation from onshore wind and PV, while bioenergy was not affected. In our study, we do not find evidence that the presence of IPR (quota systems) affect onshore wind and PV, while providing positive impacts on installed biomass capacity.

We find a positive impact of the presence of tendering schemes on onshore wind, but not the other technologies. PV and biomass installations are not common objects for tendering, making the lack of effect on these quite intuitive. We also find that a high *renewable share* negatively impacts onshore wind. This seems immediately counterintuitive, but a possible explanation is that as the share of renewable energy in their electricity mix increases, countries become increasingly dependent on other more stable and predictable production to balance their energy supply. In addition to this, countries with high renewable shares have less incentive to further increase renewable installations. The need for balancing and security of supply may also explain why we find a negative correlation between *energy use per capita* and PV capacity.

4. Conclusions

Due to firm FIT levels and reduced costs we find that investments in PV and onshore wind power have generally had a high expected return of the investment the last five years. Furthermore, we conclude that FIT has significantly affected the development of PV and onshore wind in the five countries analysed in the period 1990-2012. The significance for the onshore wind generation contradicts previous findings. Also, it is confirmed that RPS has significantly positive effect on the development of bioenergy for power generation and that the presence of tendering schemes has contributed to the development of onshore wind. The penetration of the different RE technologies as well as the energy supply mix as a whole varies significantly in the different counties. Our results indicate that a marginal support increase of 1 €-cent/kWh would increase the annual RE generation by 94 to 9886 GWh and annual added capacity by 130-6449 MW dependent on technology and country. While an increase in FITs contract length by one year would increase the annual RE generation by 97-1644 GWh and annual added capacity by 92-1339 MW dependent on technology and country. The results from this paper are of interest for policy making in multiple ways. First, it is demonstrated that the expected return on RE investments, taking policy support into account, in many cases have developed from quite minor to relatively firm the last five years. Second, it is confirmed that the RE policies in general have contributed significantly to the RE capacity expansion. In addition, the results from the sensitivity analysis show the expected change in capacity and production from a change in FIT design. This knowledge is relevant and important to optimize the FIT schemes, e.g. to reach a compulsory goal like share of renewables in total energy supply. The results also show that it is a substantial difference in the effect of changes in policy design between the countries. Further, a comparatively high *SFIT* may be an indication of overly beneficial FIT contracts which cause investments levels beyond the intended scope of the support scheme.

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