Explaining regional differences in investments: The example of PV expansion in Germany

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Explaining regional differences in investments. The example of PV expansion in Germany

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Abstract

The German electricity market has been subject to a fast and dynamic increase of photovoltaics (PV) in the last years. This increase is to a great extent driven by small scale PV rooftop plants that represent the majority of installed PV plants in Germany and are mainly investments of private households. Even though investments are in general driven by a risk and return logic that is very similar across regions in Germany, we observe regional differences regarding the number of rooftop PV plants across Germany. Thus, a simple risk and return logic cannot explain the regional heterogeneity in the coverage of PV rooftop plants. Therefore, we investigate whether additional, non-monetary factors influence investments in PV rooftop plants. In particular, we empirically analyze whether the political orientation of the population has an impact on PV coverage. We use panel data containing all German counties in the period from 2000 to 2012 and find a strong and robust impact of the political orientation of counties on PV penetration. While a high share of conservative voters in the population is associated with a low PV penetration, a high share of green voters is associated with a high PV penetration. The political orientation effects on PV penetration are often much more pronounced in rural regions than in urban regions.

1. Introduction

The German electricity market has been subject to a fast and dynamic increase of photovoltaics (PV) in the last years. Until 2014, 38.2 GWp of PV have been installed in Germany. The electricity generation of PV plants contributes with around 33 TWh to almost 6% of the German gross electricity production. In total, there are 1.5 million PV plants installed in Germany (BMWi, 2015). This dynamic increase is to a great extent driven by small PV rooftop plants with a

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capacity below 10 kWp representing more than 50% of installed PV plants in Germany and mainly investments of private households. One important driver of the strong expansion of PV plants during the last decade is the German subsidy scheme under the German Renewable Energy Act (EEG) that legally specifies a remuneration for every self-generated kilowatt hour that is fed into the grid. This bonus made investments in PV plants economically attractive.

Traditional economic theory postulates that investment decisions are based solely on risk and return aspects i.e. investors only consider the expected payoff and risk of a potential investment. In the case of PV, the feed-in-tariff pays the same amount of money for each unit of PV electricity fed into the grid and the electricity production per invested Euro is very similar across Germany (Huld and Pinedo-Pascua (2012)). Hence, the expected return on equity of PV investments is not only positive, but very similar across Germany. On the other hand, the expected variance of returns, i.e., the risk, is relatively small and also very similar across different German locations. In summary, following this simple risk and return logic, one would expect an evenly distributed growth and coverage of PV rooftop plants across Germany - at least across all locations in Germany that are in principle technically suitable for PV rooftop installations.

However, we observe a very heterogeneously distributed growth and coverage of PV rooftop installations across Germany. Figure 1 depicts the PV penetration[2] in German counties in the years 2005 and 2012 (counties refer to municipal associations with municipal self-government rights). The intensity of the color indicates the penetration of PV rooftop plants per county. One interesting case is the state of Baden-Württemberg (in the southwest) where the PV penetration increases drastically between 2005 and 2012. During the same period, the PV penetration in Mecklenburg-Western Pomerania (in the north of Germany) only increases slightly. This suggests that there are additional, non-monetary factors that influence the investments in PV rooftop plants and thus explain the heterogeneous regional PV penetration across German counties.

[2]PV penetration is defined as the share of PV installations per county and the number of one- and two-family houses per county.

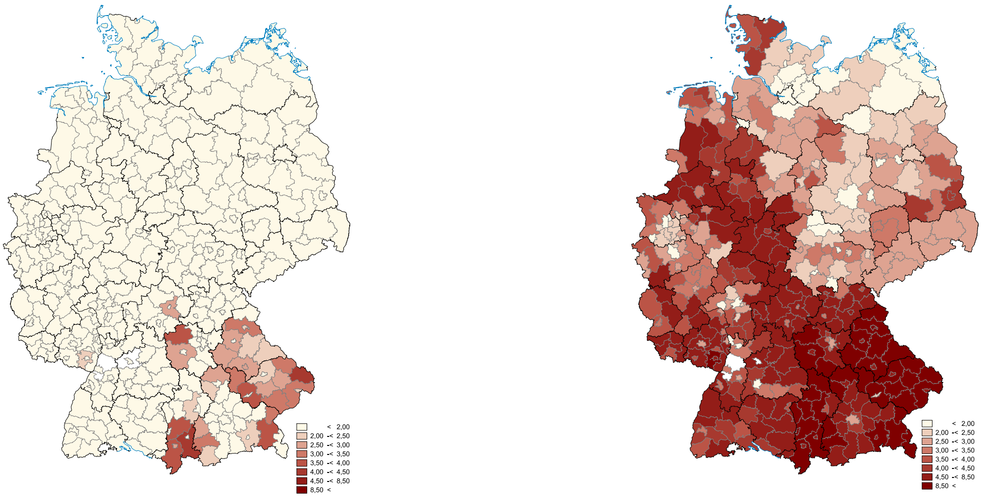

Figure 1: PV penetration in Germany in 2005 (left) and 2012 (right)

This paper aims at identifying non-monetary drivers that might explain the heterogeneous distribution of PV rooftop installations across German counties. Investments in renewable energies are often considered as "green investments".It might be argued that these "‘green investments"’ correspond to a "‘green"’ political orientation. Hence, we aim at exploring whether there is a link between green investments (in our case the investment in PV rooftop plants) and the political orientation of counties in Germany that might explain the different regional distribution of investments. This serves to be an interesting case as the political orientation of a county might reflect other underlying, unobservable values and views of the inhabitants that influence the investment in PV rooftop systems (i.e. environmentalism, altruism or conservatism). The correlation between personal values and the political orientation has been investigated for many years. For example, Tognacci et al. (1972) find that Democrats and Liberals are more concerned about the environment than Republicans and Conservatives. Neumayer (2004) shows that "left-wing political orientation goes hand in hand with [..] more pro-environmental beliefs". In contrast to personal attitudes and values, the political orientation can be observed by means of the election results and therefore offers a way to evaluate the effect of personal values and beliefs on the differing allocations of capital into renewable energies across counties.

By analyzing the influence of political orientation on green investments, our paper is located in two strands of literature: on the one hand, literature analyzing the influence of non-monetary factors on green investments and on the other hand, literature dealing with the influence of political preferences on investments. Among the papers analyzing the influence of non-monetary factors on green investments, Getzner and Grabner-Kruter (2004) explore the willingness to invest in green shares and show that education, income and environmental awareness are the main explanatory variables. Amelia and Brandt (2015) study factors behind consumer choices regarding investments in energy efficiency and renewable energy technologies using the OECD Survey on Household Environmental Behaviour and Attitudes. Their empirical results suggest that the driving factors of households' propensity to invest are home ownership, income and social context. Kotchen and Moore (2008) analyze the impact of environmental concerns on the voluntary restriction of consumption and on the willingness to pay a (voluntary) price premium. Their empirical results of households' electricity demand in Traverse City in Michigan confirm their theoretical model and show that environmentalism positively influences the voluntary conservation. Masini and Menichetti (2013) identify non-financial factors that affect the decision to invest in renewable resources and that might lead to different allocations of resources. They find that a priori beliefs on the technological reliability and preferences over policy instruments are important determinants of investments in renewables. Zarnikau (2003) examines reported willingness to pay for green power and energy efficiency and finds that age, education, and salary affect the reported willingness to pay for electric utility investments in these resources. Next to these papers dealing with the influence of non-monetary preferences on green investments, the other relevant stream of literature deals with the influence of political preferences on investments. For example, Kaustia and Torstila (2011) analyze the influence of political preferences when participating in the stock market and find that left-wing voters and politicians are less likely to invest in stocks. Gtzke and Rave (2015) explore the heterogeneity of wind energy expansion across German regions. They find that the preference for civil society support for renewable energies has an impact on the investment into wind capacity. Kahn (2007) finds that the share of Green Party registered voters impacts the choice of transportation in California. Green voters are more likely to use public transit, purchase hybrid vehicles and use less gasoline than non-green voters.

In order to analyze our research question we develop a model explaining the regional expansion of PV rooftop plants in Germany. Therefore, we construct a panel data set containing the PV penetration on the county level from 2000 to 2012. With the aim of clearly identifying the impact of political orientation on the PV penetration in German counties, we include further explanatory variables that might have an impact on PV installations and that are potentially correlated with the political orientation. Therefore, we include variables that can be divided into variables reflecting the investment capability variables reflecting the propensity to invest of each German county.
The paper is structured as follows. Chapter 2 sets up the econometric model and describes the data set used for the empirical analysis. Chapter 3 presents the estimation results, while chapter 4 concludes.

2. Empirical Model and Data

In order to analyze the influence of the political orientation on the penetration of PV rooftop installations in German counties, we model PV penetration y_{it} as a linear function of a set of explanatory variables where X_{it} represents the political orientation per county and C_{it} other control variables. u_i controls for unobserved heterogeneity that varies between counties but not over time and ϵ_{it} controls for all unobserved heterogeneity that may vary between counties and over time.

$$y_{it} = \beta X_{it} + \gamma C_{it} + u_i + \epsilon_{it} \tag{1}$$

For each year t and county i PV penetration is measured as the share of suitable houses on which a PV rooftop system is installed. As we are explicitly looking at investments of private households, we only consider PV rooftop systems with a capacity below 10 kWp. The number of suitable houses is defined as the number of houses with one or two accommodation units - the type of building where the overwhelming share of PV rooftop systems below 10 kWp is installed. By choosing PV penetration as the dependent variable (instead of the mere number of PV rooftop installations), we implicitly control for the technical capacity of a county to install PV rooftop systems. Naturally, not all houses with one or two accommodation units are suitable for a PV rooftop system due to for example roof tilt or roof orientation. It is, however, assumed that the share of houses with one or two accommodation units that is suitable for a PV rooftop system does not vary systematically between counties. The number of PV installations per year is obtained from the installation register of EEG generators published by the four German transmission system operators (50 Hertz and Amprion and Tennet and Transnet BW (2015)). The data contain all PV plants subsidized by the EEG with information on the installed capacity, the installation date, the exact location indicated by the respective municipality, zip code, street and house number. To obtain the regional distribution of PV plants, we allocate each PV plant to the respective county by means of the zip code. The classification of counties as well as the assignment of zip codes to counties was taken from the Federal Statistical Office. The classification results in 402 counties for Germany. As there have been several reorganizations of counties in the past, historical data have been adjusted to reflect the current structure of counties. The number of one- and two-family-houses per county is obtained from the Regional Database Germany (Federal Statistical Office and the Statistical Offices of the States (2016)).

Political orientation, X_{it}, contains a group of variables each measuring the share of voters (of the total population) who voted for a certain political party in a certain county in the respective year.[3] The parties include the Social Democratic Party (SPD), the Green Party (Grüne), the Conservative Party (CDU\CSU), the Liberal Party (FDP) and the Socialist Party (Linke).[4] The voters of marginal parties are left out as they never had a significant effect on PV penetration and their inclusion had practically no influence on other estimated parameters. Accordingly, X_{it}

[3] More specifically, we use the number of so called "second votes" for the German federal elections for each county and divide it by the number of inhabitants.

[4] To be precise, CDU\CSU, the so called Union Parties, represent a conservative, liberal and democratic orientation. However, the conservative element is arguably the most outstanding value compared to the orientation of the other important parties.

contains five variables reflecting the voting share of the respective political parties. The election results are again derived from the Regional Database Germany (Federal Statistical Office and the State Statistical Offices (2016a) and Federal Statistical Office and the State Statistical Offices (2016b)). In order to maintain a balanced panel, election results are linearly interpolated between the years of an election. The included variables represent the share of valid second votes for the respective political party.

In order to clearly identify the effect of the political orientation on PV penetration, we also include a set of control variables, C_{it}, that might be correlated with the political orientation as well as with the PV penetration.[5] We classify the controls into variables reflecting the investment capability as well as the propensity to invest. First, in order to account for the investment capability, we include the average real income per capita (adjusted for inflation) defined as the total available household income at time t divided by the total population of a county at time t. We argue that the inclusion of the average income per capita can be used as a proxy for the average solvency of the households in a county and hence the capability to invest in PV. Data about the average household income are obtained from the German Federal Office for Building and Regional Planning (German Federal Office for Building and Regional Planning (2015a)).

Second, in order to control for the propensity to invest, we include the educational level as well as the age structure in each county. The educational level is included to account for the fact that the profitability of investing into a PV rooftop plant might not have been known to every "'suitable"' household, i.e., households that have the technical and financial possibility to invest. Thus, the educational level serves as a proxy for the knowledge about the investment profitability and, hence, the propensity to invest. The educational level is represented by the share of citizens with higher education of the total population.[6] These data come from the Federal Labour Office (Federal Labour Office (2012)). The propensity to invest might furthermore differ between households of different ages. We argue that especially older and younger people might have a lower motivation to invest in PV plants (even if they have the technical and financial possibility to do so). For this segment of the population the opportunity costs of this investment might be too high compared to other short-term investments or consumption today. In order to account for this possible effect, we include the share of inhabitants per county who are older than 30 and younger than 60 years. Data on the age structure of counties is obtained from the Federal Office for Building and Regional Planning (German Federal Office for Building and Regional Planning (2015b)). Finally, we assume that PV penetration is also dependent on unobserved, county specific effects u_i that do not vary over time such as solar radiation or the overall suitability of the county for PV installations e.g.

[5] Monetary variables that reflect the profitability of the investment such as the feed in tariff, the interest rate, the electricity price and investment costs for PV systems are therefore not included in the analysis as these are not correlated with political orientation of a county.

[6] More specifically, citizens with higher education include all people who contribute to social insurance and hold a university degree or a degree of a university of applied sciences.

densely populated urban areas might not be as suitable for rooftop PV installations due to a different building density and structure. Some of the county fixed effects might be correlated with the explanatory variables. Therefore, we employ the fixed effects estimator to account for u_i. Furthermore, as PV penetration might be dependent over time within a certain county, we use robust standard errors that account for serial error correlation within a county. Due to data availability, we consider the time period from 2000 to 2012. Summary statistics of the variables included in the regression are shown in Table 1.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
PV penetration	1.53	1.92	0	14.87	5226
Conservative	18.77	5.5	6.04	76.2	5123
Soc. Dem.	13.08	5.82	3.3	97.07	5123
Green	3.58	2.41	0.46	46.29	5123
Liberal	2.96	1.37	0.29	13.69	5123
Socialist	2.97	4.44	0	36.95	5123
Income p.c.	18.89	2.33	14.38	38.61	5226
Education	10.01	4.97	3.13	41.36	5219
Dependent Population	50.99	1.65	45.5	57	5226

For better readability, the share variables show percentage numbers.
Income p.c. is measured in 1000s of euros.

With a mean of 1.53 percent, PV penetration is small in most counties and years. However, the dependent variable varies considerably in our sample. While there are several county-years with no or little PV penetration, there are also county-years with PV penetration as high as 14.9 percent, especially in the later years in the sample. The political preference variables also vary strongly across the sample. For example, while the average conservative voter share in the population is 18.7 percent, the maximum share is 76.2 percent. Disposable income per capita occurs in the range of 14380 to 38610 Euro with an average of 18890 Euro. Education i.e. the share of citizens with a university entry certificate varies greatly with a minimum of 3.13 percent and a maximum of 41.36 percent. In contrast, the share of the dependent population variable lies within a much smaller interval from 45.5 to 57 percent.

In conclusion, the explanatory variables have a large variation that can help to explain the similarly large variation in the dependent variable PV-penetration.

3. Results

3.1. Influence of political orientation on PV penetration

In our most basic model specification in column (1) we only include the share of valid second votes of the German political parties: CDU\CSU *(Conservative Party)*, SPD *(Social Democratic Party)*, GRÜNE *(Green Party)*, FDP *(Liberal Party)* and LINKE *(Socialist Party)*. We gradually extend the set of explanatory variables by including the average income per capita *(Income p.c.)* to account for the investment capability in column (2) as well as the share of citizens with a higher education *(Education)* degree in column (3). In order to account for the investment propensity we include the share of people between age 30 and 60 *(Population 30-60)* in column (4). In column 5 to 7 we include the previously individually added control variables in groups.

The estimation results are shown in Table 2.

Table 2: Regression table

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Conservative	-0.29**	-0.23**	-0.21**	-0.30**	-0.14**	-0.24**	-0.13**
	(-18.96)	(-14.57)	(-13.57)	(-18.29)	(-9.36)	(-14.52)	(-8.51)
Soc. Dem.	-0.0098	-0.0032	0.018	-0.048**	0.025	-0.030	-0.026
	(-0.67)	(-0.25)	(1.21)	(-2.67)	(1.64)	(-1.88)	(-1.88)
Green	0.33**	0.27**	0.15**	0.39**	0.087**	0.31**	0.12**
	(9.00)	(8.01)	(4.18)	(10.63)	(2.71)	(8.94)	(4.13)
Liberal	-0.17**	-0.099**	-0.13**	-0.099**	-0.053	-0.053	0.069*
	(-5.25)	(-3.02)	(-3.78)	(-2.71)	(-1.56)	(-1.54)	(2.13)
Socialist	0.26**	0.15**	0.17**	0.30**	0.057*	0.19**	0.11**
	(10.31)	(6.44)	(6.03)	(9.31)	(2.07)	(6.77)	(4.24)
Income p.c.		0.82**			0.82**	0.77**	0.72**
		(6.55)			(7.15)	(6.56)	(7.80)
Education			0.43**		0.44**		0.59**
			(7.74)		(8.53)		(9.36)
Population 30-60				0.35**		0.24**	0.54**
				(5.91)		(4.20)	(8.99)
N	5061	5061	5054	5061	5054	5061	5054
adj. R^2	0.389	0.491	0.457	0.414	0.560	0.502	0.611

Note: t statistics in parentheses. * represents $p - value < 0.05$, and ** $p - value < 0.01$.

The estimation results in column (1) of Table 2 show a statistically and economically significant effect of most of the political orientation variables on PV penetration. Only the share of the social democratic party voters has no significant influence on PV penetration. While conservative and liberal voter shares show a negative impact on PV penetration, green and socialist voters positively influence PV penetration: an increase of the share of the Conservative and the Liberal Party by one percent decreases PV penetration by 0.29 and 0.17 percent, respectively, whereas a one percent increase in green and socialist voters increases PV penetration by 0.33 and 0.26 percent, respectively. Hence, green voters show the strongest positive and conservative voters the strongest negative impact on PV penetration.

In order to improve the identification of the effect of the political orientation on PV penetration, we gradually add control variables, first individually - models (2) to (4) - and then in groups - models (5) to (7). Model (7) represents the most comprehensive and, hence, most reliable specification as it includes all three controls for investment capability and investment propensity. When controls are added, the overall model fit improves as the adjusted within R^2 increases up to 0.61 in model (7). Further, we notice that the impact of the political orientation variables decreases quantitatively. However this does rarely lead to drops in statistical significance under conventional levels - the liberal voter share in (5) and (6) being the exception. Overall, the share of social democrat voters does not appear to have a robust significant influence on PV penetration. Notably, once all control variables are added, socialist voters have an equally high positive impact on PV penetration as green voters. According to model (7), an additional percent of socialist voters increases PV penetration by 0.11 percent whereas an additional percent of Green voters increases PV penetration by 0.12 percent. The effect of income per capita representing the investment capability is significantly positive and the size of its coefficient remains quite stable in all specifications. Accordingly, one thousand Euros of additional disposable income per capita leads to a 0.72 to 0.82 percent increase in PV penetration. The variables education and independent population accounting for investment propensity both have the expected positive sign and are highly statistically significant in all model specifications.

Overall, the results in Table 2 reveal a decisive role of counties' political orientation for the penetration of PV rooftop plants in German counties. Taking a look at the coefficients of model (7) shows that one thousand Euros of additional disposable income per capita have the same impact on PV penetration as 6 percent more green voters or will compensate an additional 5.53 percent conservative voters. Similarly, an increase of one percent of the share of the population with higher education will increase PV penetration by the same amount as 5.36 percent more socialist voters.

3.2. Influence of political orientation on PV penetration in rural and urban counties

The influence of political orientation on PV penetration might differ with respect to whether a county is in a rural or in an urban region. This could be motivated by a different house ownership structure in urban and rural areas. Rural voters are more often the owners of their house, while in urban areas it is more common to rent the house. Hence, rural voters can more easily let their political believes guide the decision on whether or not to invest into a PV installation on their roof. In contrast, in urban areas voters cannot always influence the investment decision regarding rooftop PV plants.

Thus, we would expect a stronger effect of political orientation in rural than in urban counties. In order to test this hypothesis, we re-estimate model 1 and 7 from Table 2 by differentiating between the effect of political orientation in urban and in rural areas. Therefore, we use two specifications to estimate whether the difference in the effect of political orientation on PV penetration is statistically significant (Model 1a and 7a (difference)) in order to obtain estimates and significances of the effect of political orientation in both rural and urban counties (Model 1a and Model

7a (rural and urban)). The results of the different specifications are shown in Table 3.

In order to estimate whether the difference in the effect of political orientation on PV penetration is statistically significant, we simply interact a dummy for rural counties with the political orientation variables and add this interaction term to the specifications used in Table 2. With this we obtain the coefficient estimates and significance levels for the difference in the effect of political orientation between rural and urban counties (Model 1a and 7a (difference)). The standard errors and p-values of the interaction term tell us whether the difference in the political orientation effect is statistically significant. The estimates for the coefficient of the interaction terms and the significance level are shown in Table 3 in the third column of the respective model.

To obtain coefficients that enable a direct comparison between the effect in rural and urban counties, we define two distinct variables for each political orientation variable. We use these two new variables instead of the simple political orientation variables (Model 1a and Model 7a (rural and urban)). The first variable is the interaction term of a respective political orientation variable used in Model 1a and 7a (difference). The coefficient of this variable can be interpreted as the effect of the respective political orientation in a rural county. The second variable is the respective political orientation variable multiplied by one minus the interaction term. The coefficient of the second variable can be interpreted as the effect of the respective political orientation in an urban county. The advantage of the approach of Model 1a and Model 7a (rural and urban) is that we obtain significance levels for the effect of political orientation for both rural and urban counties. The coefficients and significance levels of the political orientation variables separated for rural and urban counties are shown in Table 3 in the first and second column of the respective model.

Model 1a exclusively contains the political orientation variables. Model 7a includes all control variables. Similar to the results shown in Table 2, the coefficients of the political orientation variables in Table 3 often decrease in absolute value when control variables are added. In both models, the effect of conservative voters is significantly negative in both rural and urban counties. The difference in the effect of conservative voters is never statistically significant between rural and urban counties in both models. The effect of social democrat voters on PV penetration is positively significant in rural counties. In contrast, the effect is insignificant in urban counties. The difference between the rural and urban effect of social democrat voters is significant in both models. The difference in the effect of rural and urban green voters on PV penetration is quantitatively very pronounced and significant. According to the results of model 7a, green voters in rural counties increase PV penetration by about 0.29 percent per additional percent voter share. In comparison, the increase is only 0.085 in urban counties. Furthermore, liberal voters have a significantly different effect in urban and in rural counties. Interestingly, the effect of the share of rural liberal voters differs in model 1a and 7a in the sign and significance level. Whereas in model 1a the share of liberal voters has an insignificant, negative effect on PV penetration, it has a significantly positive effect in the more comprehensive model 7a. The effect of liberal voters in urban counties also differs across models. Whereas urban, liberal voters seem to have a significantly negative effect on

PV penetration in model 1a, they have no significant effect once control variables are accounted for in model 7a. The effect of the share of socialist voters on PV penetration does not vary significantly between rural and urban counties. In both types of counties the share of socialist voters has a significant positive impact on PV penetration. The effect of variables measuring investment capability (income p.c.) and investment propensity (education and population 30-60) are quantitatively very similar to the results shown in Table 2.

Comparing the coefficients of rural political orientation and the control variables in model 7a of Table 3 illustrates the magnitudes of the effects: for example, an increase of one thousand Euros disposable income per capita will increase PV penetration by the same amount as an increase of 2.31 percent of the share of rural green voters or will compensate an additional 4.78 percent of rural conservative voters. For the share of social democrats, green and liberal parties we find a (significantly) stronger political orientation effect in rural than in urban counties.

Overall, the estimation results in Tables 2 and 3 provide strong evidence for a negative impact of conservative political orientation on PV penetration. Furthermore, we find strong evidence that green political orientation - most pronounced in rural regions - has a large positive impact on PV penetration. The results also reveal a strong positive impact of socialist orientation on PV penetration which does not differ between rural and urban counties. Social democrat voters have a small positive impact on PV penetration at least in rural areas. The results for liberal voters cannot be robustly interpreted.

3.3. The overall effect of political orientation

The estimated coefficients give a good impression of the relative strength of a marginal change in voter shares of different parties. However, the coefficients alone do not allow for an intuition about whether the political orientation effect has overall been an impediment or a promoter of PV penetration in Germany in the past. In order to answer this question, we need to take the actual voter shares of all parties in all years and counties into consideration. Thus, we calculate the total political orientation effect for each year and county. To obtain this total political orientation effect we first multiply the coefficients of political variables in model 7a in Table 3 with the actual data of the respective political orientation variable, i.e. the respective share of votes, for each year and county.[7] Then, we add these products of all five political orientation variables for each county and year. Finally, we add the county specific PV penetration and subtract the total sample mean of PV penetration. The resulting value is the part of PV penetration that is predicted based solely on the fixed effects coefficient estimates of the political orientation variables.

Figure 2 shows the distribution of the total political orientation effect over all counties and years in the sample. The bulk of the distribution is below zero, which can be interpreted as

[7] We regard model 7a in Table 3 as the most reliable specification as it accounts for all of the control variables and the rural-urban split and has the highest R^2 of all models. Variables are obtained by subtracting the county specific mean and adding the total sample mean of the respective variable.

Table 3: Regression table

	Model 1a			Model 7a		
	Rural	Urban	Difference	Rural	Urban	Difference
Conservative	-0.28**	-0.27**	-0.0078	-0.14**	-0.10**	-0.032
	(-12.64)	(-14.19)	(-0.26)	(-7.12)	(-4.53)	(-1.10)
Soc. Dem.	0.063**	0.0089	0.054*	0.044*	-0.025	0.070**
	(3.12)	(0.55)	(2.09)	(2.37)	(-1.74)	(3.18)
Green	0.74**	0.25**	0.49**	0.29**	0.085**	0.20**
	(13.71)	(8.42)	(7.88)	(6.71)	(3.01)	(4.10)
Liberal	-0.071	-0.31**	0.24**	0.16**	-0.048	0.21**
	(-1.33)	(-6.82)	(3.44)	(3.77)	(-1.15)	(3.85)
Socialist	0.22**	0.29**	-0.062	0.12**	0.11**	0.0027
	(4.49)	(10.33)	(-1.09)	(3.15)	(3.24)	(0.05)
Income p.c.				0.67**	0.67**	0.67**
				(7.02)	(7.02)	(7.02)
Education				0.61**	0.61**	0.61**
				(9.28)	(9.28)	(9.28)
Population 30-60				0.52**	0.52**	0.52**
				(8.55)	(8.55)	(8.55)
N	5061	5061	5061	5054	5054	5054
adj. R^2	0.419	0.419	0.419	0.621	0.621	0.621

Note: t statistics in parentheses. * represents $p - value < 0.05$, and ** $p - value < 0.01$. .

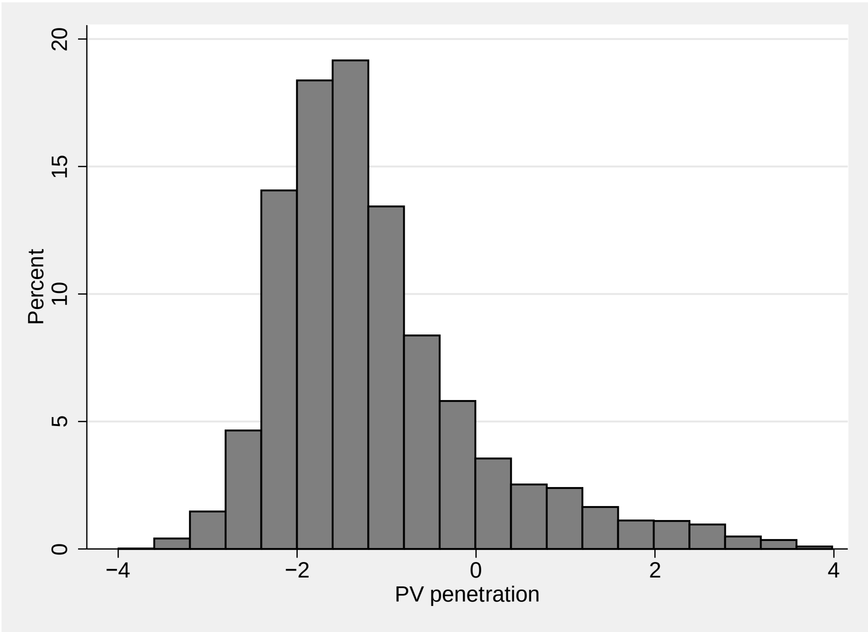

Figure 2: Distribution of total political orientation effect (all years and counties)

the total political orientation effect being negative in the majority of years and counties in the sample. Accordingly, PV penetration would have been considerably higher in most counties and years if political orientation had had no impact on PV penetration. The mean of the total political orientation effect is equal to -1.12, meaning that in the mean county and year we would have seen a 1.12 percent higher PV penetration if political orientation had no impact on PV penetration. Against the background of a mean PV penetration of 1.54 percent in our sample, this highlights the importance of the political orientation effect for German PV rooftop investments.

The estimation results suggest that the political orientation effect is negative for the counties North Rhine-Westphalia, Hessen, Baden-Württemberg, Bavaria, Saarland, Saxony. Accordingly, in these federal states the PV penetration would have been considerably higher if no political orientation effect had existed. In contrast, Brandenburg and Mecklenburg-Western Pomerania had an overwhelmingly positive political orientation effect. Hence, in these federal states, PV penetration would have been much lower without the political orientation of the inhabitants. The remaining federal states show a more balanced political orientation effect. Especially in Saxony-Anhalt and Thuringia, the effect of political orientation on PV penetration in the considered time span from 2000 to 2012 was only marginal.

Finally, Figure 3 shows the distribution of the total political orientation effect over all counties and years for each German federal state. The figure illustrates very heterogeneous distributions of the total political orientation effect across the German federal states. In some federal states, as for example in Bavaria, the political orientation effect shows a wide spread distribution, and

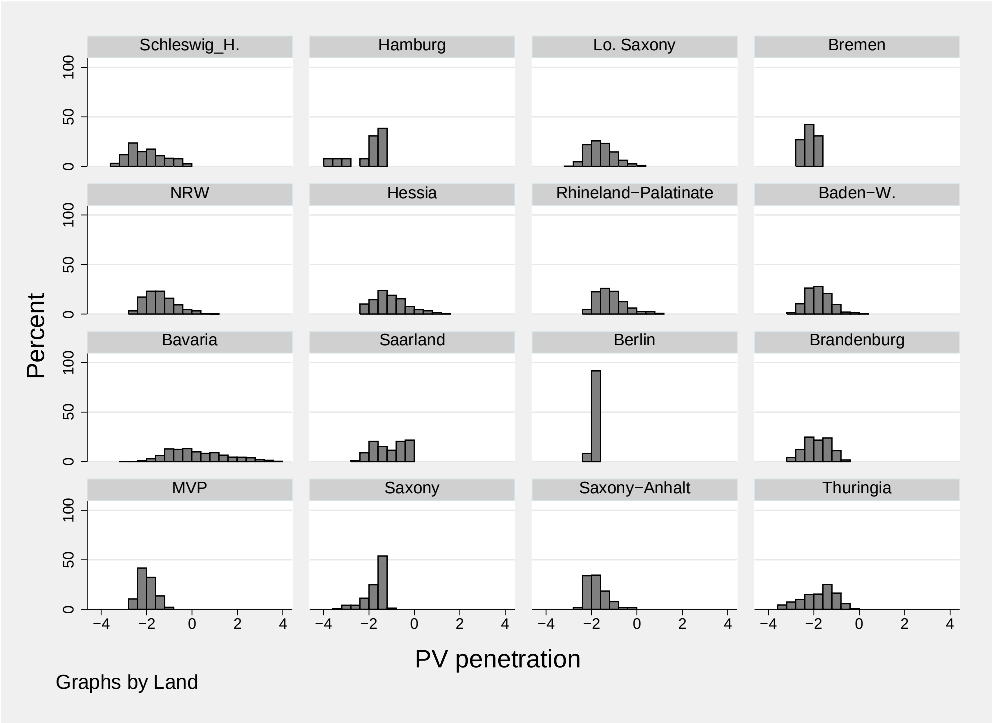

Figure 3: Distribution of total political orientation effect (all years and counties) separately depicted for each German Federal State

thus major differences among counties and years with both very negative and very positive values for the total effect of political orientation. In other federal states, the individual effects are closer together and point into one direction: For example in Mecklenburg-Western Pommerania, Saxony or Saxony-Anhalt the total effect of political orientation is negative for almost all counties and years. Figure **??** highlights the important role of political orientation for PV penetration across German counties. However, the pattern in the figure does not clearly resemble the distribution of PV penetration in Germany shown in Figure 1 in Section 1. Hence, even if the political orientation certainly plays an important role for PV penetration it is not the only one decisive factor.

4. Conclusion

In this paper we assessed whether non-monetary factors have an impact on green investments. We specifically answered the question of whether the political orientation of counties had an impact on the penetration of rooftop PV plants in Germany.

Our study is motivated by the strong heterogeneity of the penetration of rooftop PV plants that can be observed across German counties despite the fact that risk and return expectations of rooftop PV investments are very similar across Germany.

Using comprehensive panel data, we estimate the impact of non-monetary factors, more specifically, political orientation of German counties on county-level rooftop PV-penetration. We control for investment capability by including income per capita and for investment propensity by including the share of citizens with higher education as well as the share of the population that is between 30 and 60 years old, respectively.

We find a strong and robust impact of the political orientation of counties on PV penetration. While a high share of conservative voters in the population is associated with a low PV penetration, a high share of green voters is associated with a high PV penetration. The political orientation effects on PV penetration are often much more pronounced in rural regions than in urban regions.

Notably, the combined effect of the political orientation is negative for most counties with high PV penetration. Hence, political orientation impeded an even stronger heterogeneity in PV penetration. Thus, it can be concluded that political orientation is a driver of PV investment, however it can not explain the heterogeneity of PV investments across Germany. Accordingly, the motivating initial question of what drives heterogeneity in PV penetration remains to be unanswered.

Further research should address the question of regional heterogeneity in PV penetration using household level data and a structural economic model. Whith this, perceived risk and return as well as non-monetary household characteristics can be modeled more carefully.

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