Solar bait: How states attract solar investments from large corporations

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Abstract
Technological development and favorable policies and regulations during the last decade have enabled significant growth in the use of solar panels for electricity generation. In addition to residential and utility scale generation of solar energy, opportunities for generation of solar on commercial properties has also been recognized. In this study we examine firms' decisions to install solar panels on their properties using state-level data. Particularly, we are interested in the effects of state-level characteristics, including policies and regulations, on firms' decisions to invest in solar generation. The results suggest that certain state level policies, like feed-in-tariffs and tax incentives, can be used to incentivize firms to install solar panels on their properties. The strongest result we observe across empirical specifications is that firms' decision to install solar on their properties in a particular state is affected by the citizens' environmental attitudes measured in terms of ownership rates of personal electric vehicles.

Highlights:

- Installation of solar panels on commercial properties is examined across states in the US.
- Prevalence of environmental attitudes affects solar installation on commercial properties.
- Some state level policies can affect solar installation on commercial properties.

1 Introduction

Commercial solar installations represent a tangible investment in a state's economy and have the potential to create jobs (Wei et al. 2010). Motivated by environmental quality concerns, energy independence, and employment generation prospects, many states have adopted solar-friendly policies and subsidy programs to increase solar adoption and incentivize companies to add solar photovoltaic (PV) units to their facilities (Shrimali and Jenner, 2013).

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The stakes in this game of attraction are high. Nevertheless, thus far only a small fraction of the total solar potential of corporate properties has been realized. Even Walmart, an avid corporate solar adopter, generates solar power at only 7% of its facilities. High initial cost has generally been argued to be the primary barrier for adoption (Shrimeli and Jenner, 2013).

The Solar Energy Industries Association (SEIA) "Solar Means Business" Reports compile data on solar generation installations for major commercial solar adopters. These are private companies that invest in solar generation capacity in the U.S. The SEIA data accounts for nearly 1,000 MW of solar capacity installed by private companies through 2015. The report covers an estimated 16% of non-residential and non-utility scale solar installations (SEIA, 2016).[4] Assuming no sample-selection bias, this figure suggests that the total amount installed by commercial entities through 2015 is approximately 6,250 MW, or enough to power the equivalent of 1 million homes[5] per year. The report finds that major corporations installed more solar capacity in 2016 than they did in 2015, and that 2013 was the year in which the most commercial solar was installed so far. The SEIA report suggests that the reduction in commercial solar installations from 2013 levels is due to "difficulties in obtaining financing for smaller commercial entities and state level policy instability" (SEIA, 2016). Commercial solar installations are concentrated on the East and West Coasts, near population centers, and are placed on all types of corporate buildings, from retail to manufacturing centers. Figure 1 provides an overview of aggregate solar installation capacities through 2015 on commercial properties across United States. The figure indicates that the amount of solar capacity installed varies across states both in terms of total installed capacity as well as population weighted capacity, which suggests that state-level factors are important in determining where companies

[4] These data are either given to SEIA by corporations or solar installation companies, and are also collected from public data such as press releases and state regulatory bodies. This dataset is comprised largely of major retailers and contains some of the larger commercial solar installations. Thus, these data overstate the average commercial solar system size.
[5] Based on the SEIA conversion of 1,100 MW per 193,000 homes (SEIA, 2016).

install solar. For instance, West Virginia and Pennsylvania have similar solar insolation rates. Yet, the SEIA data reports zero solar installations on commercial properties in West Virginia, but 25 Pennsylvania installations totaling 15,964 kW. The variability of PV installed capacity on commercial properties across US begs the question: why do corporations choose to install solar in some states and not others?

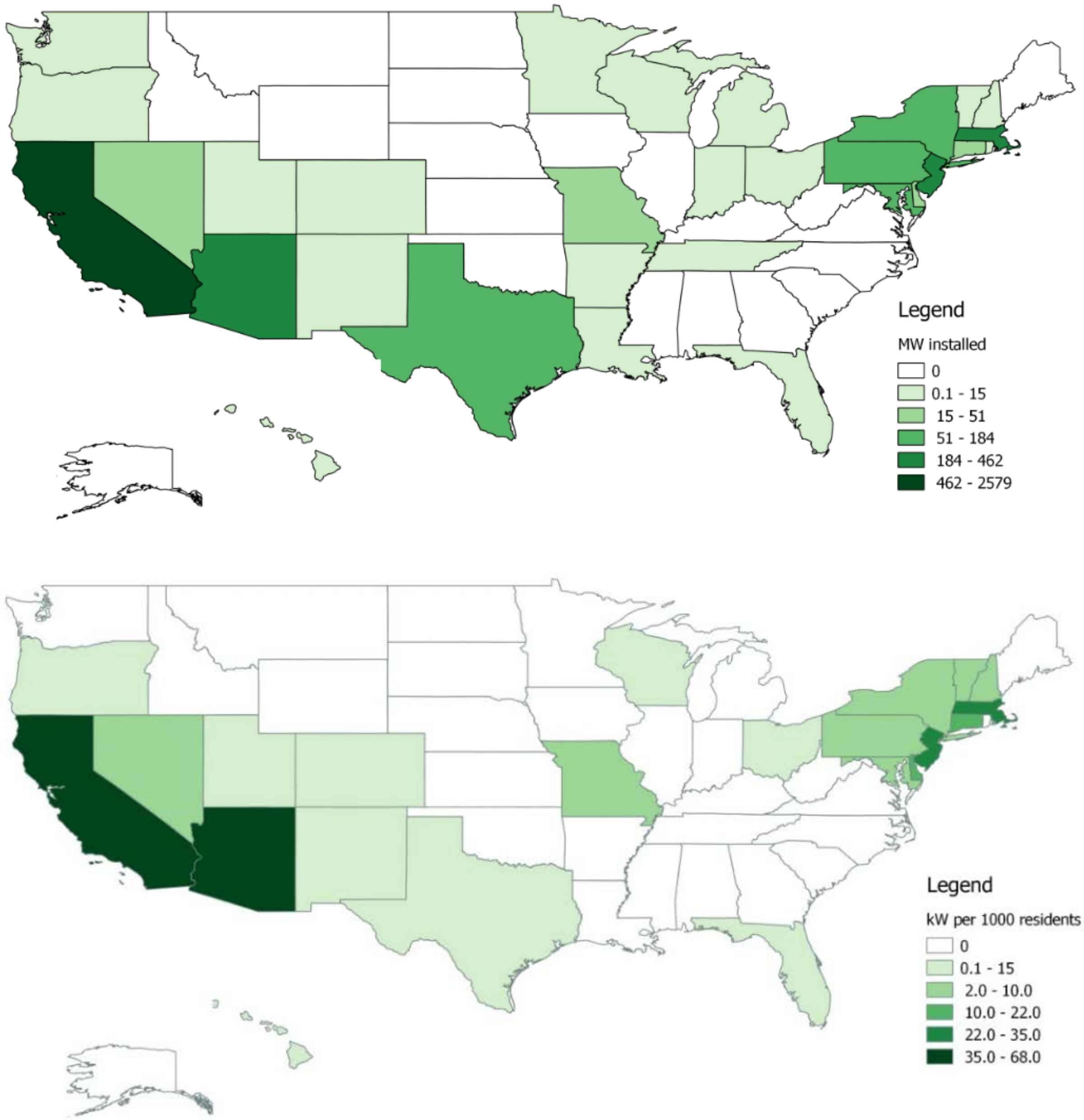

Figure 1: Commercial solar capacity installed 2002-2015, total and per capita (SEIA, 2016)

The objective of this paper is to shed light on this question through empirical examination. Specifically, we are interested in state level environments that may encourage companies to install solar PV systems on their properties. We use the SEIA Solar Means Business dataset to model the firm's decision of where and when to install PV systems by firms who have a revealed propensity to invest in solar PV systems on their facilities. All firms in our dataset have invested in at least one solar generation facility in at least one state. Therefore, the scope of the analysis in this study is limited to the firms who show interest in solar power and have revealed their willingness to invest in solar PV on the properties. We construct and estimate various statistical models that relate the decision to install solar in a particular state in a specific year to state-level characteristics and state policy variables.

Prior studies have examined the effects of various policies, incentive programs, and other factors on residential (Crago and Chernyakovskiy, 2016; Matisoff and Johnson, 2017) and cumulative (Sarzynski et al. 2012) adoption of solar technology in energy generation. However, the literature on installation of solar on commercial properties is sparse relative to the abundant literature on residential solar adoption. The commercial solar energy adoption research includes two non-exclusive directions. One approach is to investigate decisions to install solar on commercial properties empirically, including examination of costs and benefits of installation or examination of observed decisions in terms of quantifiable incentives. The other approach is to frame the solar PV installation decision as a marketing/firm-image issue. Bazen and Brown (2009) analyze the feasibility of installing solar panels on poultry farms in Tennessee. They compare the costs of an installation to the benefits of reduced power expenditure and any financial incentive programs that are in place. They find that in 2009 the net present value of investing in solar generation was negative, however if the price of solar fell by around 10%, then investing in solar became a financially feasible proposition. Current solar prices are nearly 50% lower[6] than the 2009 prices that Bazen et al. (2009) used in their analysis, suggesting that the net present value of installing solar on Tennessee poultry farms would now be positive at the 2009 price of electricity. Borchers et al. (2014) is the only work to explicitly consider the effects of state-level policies on the adoption of non-residential solar. The authors model the decision of farms to adopt renewable energy generation, either solar or wind, as a function of state-level variables including incentive policies, and farm characteristics. They find that the impact of state-level policies on the farm's adoption decision is limited, although net-metering and interconnection policies do have a small positive effect on the probability that a farm invests in renewable energy generation. A case-study from NREL (National Renewable Energy Laboratory) compares the solar financing decisions of two major commercial solar installers, IKEA and Staples (Feldman and Margolis, 2014). The report shows that depending on a firm’s cash flow outlook and internal discount rates their preference in regards to owning their solar installation or using its power via a power purchase agreement (PPA) will vary. The report suggests that the existence of state policies that allow for PPAs might be an important factor affecting solar uptake rates. Beckman and Xiarchos (2013) draw attention to the importance of understanding the decision of the scale of solar generation adopted, as well as the decision to adopt versus not adopt. The authors investigate why some California farmers adopt larger solar arrays than others. They find that larger farms, in terms of total value of production and acre value, tend to install larger solar arrays, however the prevailing price of electricity is not found to influence the scale of solar capacity installed. In contrast, the decision to adopt versus not adopt is driven by electricity price, internet connection on the farm, and environmental practices.

Corporate renewable energy and energy saving initiatives can also be studied in terms of corporate public relations strategies and brand marketing. Menon and Menon (1997)

[6] Based on price data from the SEIA (2016).

discusses how environmental initiatives can be melded with a profit-motivated business plan to create “enviropreneurial" strategies. These strategies can increase profits by marketing to environmentally conscious individuals, who continue to make up an increasing share of the marketplace, while improving environmental outcomes. This is an example of profit-motivated corporate responsibility. In its purer form, corporate responsibility is motivated by a desire to maintain good relations with the public and avoid legal issues, or by environmentalism intrinsic to the firm. Trendafilova et al. (2013) showed how these concerns have been translated into environmental action in the case of professional sports corporations. Perhaps the most notable example of this is the Philadelphia Eagles' stadium, which runs completely off of renewable energy sources from a combination of solar panels and wind turbines. Hori et al. (2014) showed how community concerns and social norms have been translated into corporate energy savings initiatives in Asian developing nations.

This paper adds to this literature by being the first to explicitly investigate the multi-state firm’s decision of *where* to invest in solar technology, given that the firm is planning to make such an investment. A multi-state firm has the option of placing solar PV units in any state in which they operate. Our analysis empirically examines factors that influence the decision to choose one state over another. In particular, we are interested in the role of state policies and programs in comparison to state characteristics, such as population and insolation.

The results of this analysis suggest that multi-state firms take into account a variety of factors in their decisions to add solar panels to their properties in different states. In particular, both types of factors discussed in the previous literature, financial incentives and public perception, are found to drive the choice of where to install. Some of these financial factors are within the control of the state, such as their choice to enact the solar policies described in the next section, while other important factors are characteristics inherent to the state, such as solar intensity. Hence, states have the ability to attract more commercial solar investment with solar-friendly policies, but their expectations of policy efficacy should be tempered if inherent factors make the application of solar less desirable in their state. We find evidence that public perception/green marketing factors play a role, whereby states with more 'environmentally-oriented' citizens have a greater propensity of companies installing solar in their state.

2 State incentive programs

In addition to, and in accordance with, federal policies and programs like the clean power plan, production and investment tax credits, states have initiated various policies and programs to encourage renewable energy generation in general and solar energy generation in particular. The extent of implementation of such policies varies across states. Table 1 provides distribution of existing state level policies across states as of 2015. In this study we include these state-level policies and programs as control variables to examine firms' investments in solar PV installations at state scale. In addition to state level policies and programs we also include additional controls like GDP, insolation, sales tax, coal production, environmental sentiment, electricity sales, and electricity market regulation.

Renewable portfolio standards (RPS) are one of the most prominent policies implemented by states, and have received most attention in academic literature (for example Wiser et al. 2011; Yin and Powers 2010; Bhattacharya et al. 2017; Bowen and Lacombe, 2017). RPS policy specifics can differ across states in terms of the required proportion of electricity to be generated from renewable sources and can also be accompanied with "solar carve-out" specifications requiring certain proportions of electricity to be generated using solar energy specifically (Gaul and Carley, 2012; Sarzynski et al. 2012). RPS policies often lead to the creation of Renewable Energy Credits (Yin and Powers, 2010) and Solar Renewable Energy Credits (SREC) (Burns and Kang, 2012), whereby an entity can sell a certificate they obtain by producing electricity from renewable and solar energy sources respectively in a market setting. The credits can be applied towards mandated RPS requirements by utility companies.

Net metering is another policy enabling owners of distributed solar energy generating units to offset costs of electricity consumed from the grid (Eid et al. 2014, Sarzynski et al. 2012)

State	***Net Meter***	***RPS***	***SREC***	***Feed in Tariff***	***Tax incentive***	***PACE or loan financing***	***Grant or rebate***	***Solar access***	***Interconnection standards***	***Power purchase agreement***
Alabama	-	-	-	x	-	-	-	-	x	-
Alaska	x	-	-	-	-	x	x	-	x	-
Arizona	x	x	-	-	x	-	-	-	-	x
Arkansas	x	-	-	-	x	x	-	-	x	-
California	-	x	-	x	x	-	-	x	x	x
Colorado	x	x	-	-	x	x	x	-	x	x
Connecticut	-	x	x	-	x	x	-	-	x	x
D.C.	x	x	x	x	x	x	x	-	x	x
Delaware	x	x	x	x	-	-	x	x	x	x
Florida	x	-	-	-	x	-	x	-	x	-
Georgia	x	-	-	-	-	-	x	x	x	x
Hawaii	x	x	-	x	x	x	-	-	x	x
Idaho	-	-	-	-	x	-	x	-	-	-
Illinois	x	x	x	x	-	x	x	x	x	-
Indiana	x	x	-	x	x	-	-	x	x	-
Iowa	-	x	-	-	x	-	-	-	x	x
Kansas	x	x	-	-	x	-	-	-	x	-
Kentucky	x	-	-	-	x	-	x	x	x	-
Louisiana	x	-	-	-	x	x	-	-	x	-
Maine	-	x	-	-	-	x	-	x	x	-
Maryland	-	x	x	x	x	-	x	x	x	x
Massachusetts	x	x	x	x	x	x	x	-	x	-
Michigan	-	x	-	-	-	x	-	-	x	x
Minnesota	-	-	-	x	-	x	x	x	-	-
Mississippi	-	-	-	-	-	-	-	-	-	-
Missouri	x	x	-	-	x	x	x	x	x	-
Montana	-	x	-	-	x	x	-	-	-	-
N. Carolina	x	x	-	-	x	x	x	-	x	-
N. Dakota	-	x	-	-	x	-	-	x	-	-
Nebraska	x	-	-	-	x	-	-	-	x	-
Nevada	-	-	-	x	x	x	-	-	-	x
New Hampshire	-	x	-	-	x	x	x	-	-	x
New Jersey	-	-	x	x	x	x	x	x	-	x
New Mexico	x	x	-	-	x	x	x	-	x	x
New York	x	x	-	-	x	x	x	-	-	-
Ohio	x	x	x	x	x	x	x	-	x	x
Oklahoma	x	x	-	-	-	-	-	-	-	-
Oregon	-	x	-	-	x	-	x	-	-	x
Pennsylvania	x	x	x	x	-	-	-	-	x	x
Rhode Island	x	x	-	-	x	x	x	-	x	x
S. Carolina	x	x	-	-	x	x	x	-	x	-
S. Dakota	-	x	-	-	x	-	-	-	x	-
Tennessee	-	-	-	x	x	x	-	-	-	-
Texas	-	-	-	-	x	-	-	-	-	x
Utah	x	x	-	-	x	x	-	-	x	x
Vermont	-	x	-	x	x	x	x	-	-	-
Virginia	x	x	-	-	x	x	-	x	x	x
Washington	-	x	-	x	x	-	-	-	x	-
West Virginia	x	x	-	-	-	-	-	x	x	-
Wisconsin	-	x	-	-	x	-	-	-	x	-
Wyoming	x	-	-	-	-	-	x	-	x	-

Table 1: State-level solar policies in 2015 from DSIRE database

States have also implemented various additional financial incentive policies to encourage solar energy generation. Feed-in-tariffs guarantee minimum compensation for each kWh produced using solar technology (Mabee et al. 2012). Tax incentives include: property tax incentives, which offer tax credits or exemptions for properties with installed solar technology; sales tax incentives, which reduce sales taxes associated with purchase and/or maintenance of solar technology; and personal tax incentives, which reduce personal tax liability in the form of exemptions or credits applied to personal state taxes (Sarzynski et al. 2012). Rebates are payments to entities that purchase solar technologies, while grants provide financial assistance for eligible purchasers of solar technologies.

States also set up rules and regulations intended to support solar energy adoption including access rights, which protect the right to purchase, maintain and operate a solar generation facility (Caffrey, 2010); interconnection standards, which establish guidelines for integration of solar generation into electricity grid (Krasko and Doris, 2013; Shrimali and Jenner, 2013); and Power Purchase Agreements (PPAs), which enable third party financing of in-state solar projects such that electricity generation using solar PV systems is not subject to regulation as a utility.

3 Data

Data on commercial solar installations come from the SEIA “Solar Means Business" Report which collects information on solar installations by major companies from 2002-2015. These data cover an estimated 16% of the total non-residential and non-utility scale solar installations in the U.S. (SEIA (2016). After dropping incomplete observations, we are left with a dataset of 1,727 specific solar installations from 117 companies, which we dub the “full SEIA data.” We summarize these data with the total commercial solar capacity installed (kW), and the number of commercial solar installations in each state/year by the sample of 117 firms. The totals for each state over our sample period (2002-2015) are given in Figure 2. Commercial solar capacity and installations have a strong upward trend over time, likely due to improved PV technology, declining costs and favorable federal policies. The aggregate solar capacity installed in each state from the full SEIA data is visualized in Figure 1.

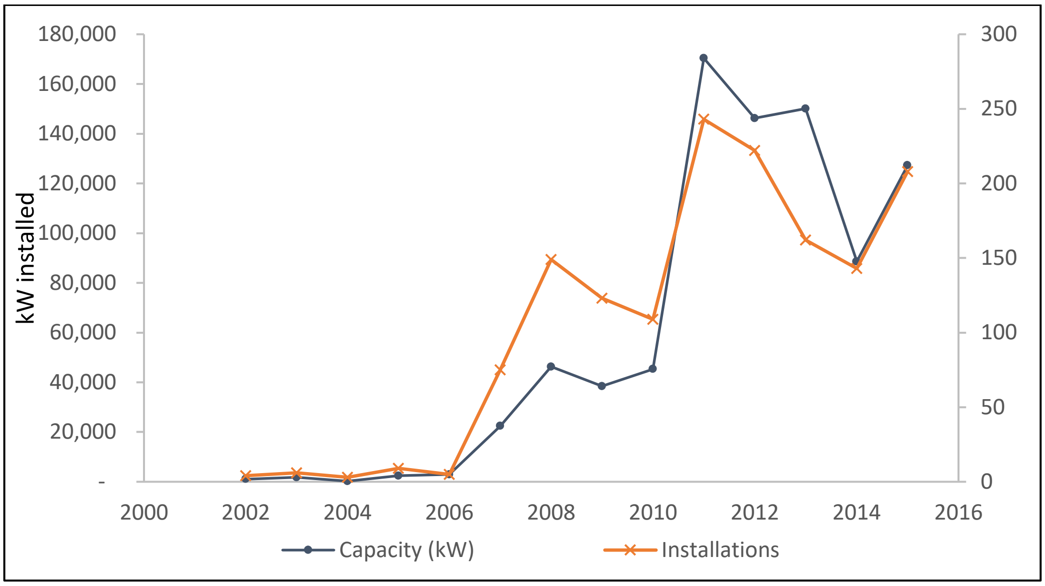

Figure 2: Commercial solar capacity installed and number of installs by year from full SEIA data

Our data on the state-level incentive and regulatory programs in each state come from the DSIRE database (Prasad and Munch, 2012; Shrimalli and Kneifel, 2011; Crago and Chernyakhovskiy. 2017; Li and Yi, 2014). This database, funded by US Department of Energy, is updated regularly by North Carolina State University (NCSU, 2017). From this database, we extract indicator variables, which take the value of 1 if a given incentive/regulation was present in a state in a given year. Specifics of many of the policies and rules can, and do, differ across states (Burns and Kang, 2012; Byrne et al. 2007). For example, RPS targets and timing differ across states. We standardize the policy variables across states by only focusing on whether a form of a given policy or program is present in a given state-year or not. A similar approach was used in the related literature (Crago and Chernyakhovskiy, 2017; Li and Yi, 2014; Sarzynski et al., 2012). To account for potential policy lags, where a change in policy would begin to have an effect sometime after the actual change in policy, we create variables which sum the number of years a policy has been in place in a given state. The policy variables are summarized and described in Table 2, with the indicator variables being named after the policy they represent. Corresponding cumulative variables have a “sum" added to the name of the indicator variable. For example, Arizona's net metering policy began in 2009, so the variable *netmtr* takes a value of 1 in Arizona in years 2009-2015. The corresponding cumulative variable *netmtrsum* takes a value of 1 in 2009, a value of 2 in 2010, 3 in 2011, etc. Including both *netmtr* and *netmtrsum* in our regression models allows us to ascertain the effect of a net metering policy, in general, and the additional effect of having a net metering policy in place for an extra year.[7]

To augment the policy information taken from DSIRE we also obtain other state level characteristics that may influence the level of commercial solar installation in each state. We generate the variable *elec_sales* using data in each state/year from the U.S. Energy Information Administration (EIA) “sales to ultimate consumers,” “total electricity industry” dataset. The variable *coalpc* gives short tons of coal mined in each state/year per capita. This variable was generated for this project using EIA “Aggregate coal mine production for all coal types” dataset, and dividing by the U.S. Census annual population estimate in each state. The variable *tax_sales* gives the state sales tax rate as a percentage. Higher sales tax rates can increase the cost of purchasing solar technology and thus we expect to see a negative relationship between solar capacity and sales tax rate. The variable *elect_price* is price of electricity and comes from the EIA “Average price, total electricity industry” dataset and is averaged across all sectors.

[7] The DSIRE database also contains some information on the level of incentive policies, for instance, how much is paid-out for state rebate programs. However, these data are not given for every incentive program, and are recorded in varied units, which makes it difficult to include them in our statistical models.

Variable	Description	Mean	Std. Dev.	Min	Max
gdppc	Gross domestic product per capita	48,661	18,214	29,056	170,687
elec_sales	electricity sales to customers in 1000's mwh	71,962	67,988	5,352	392,337
tax_sales	average sales tax in percent	4.95	1.9	0	8.25
elect_price	avg electricity price (cents/kwh)	9.39	3.65	4.26	34.04
dereged	=1 if the state has a deregulated electricity market	4.62	1.04	2.47	7.65
insol	Average annual solar insolation (kWh/m^2/day)	0.98	0.49	0.4	2.22
insol_sd	Std. dev. of average annual solar insolation	0.33	0.47	0	1
coalpc	aggregate coal mine production per capita (short tons)	19.65	105.83	0	856.42
pevs	personal electric vehicles per 1000 inhabitants in 2015	0.77	0.81	0.09	4.68
net_mtr	was net metering present in this state/year, 1=yes	0.42	0.49	0	1
rps	was renewable portfolio standard present in this state/year, 1=yes	0.51	0.5	0	1
srec	was SREC present in this state/year, 1=yes	0.11	0.31	0	1
fit	was feed-in-tariff present in this state/year, 1=yes	0.2	0.4	0	1
tax_incent	was a personal, sales or property tax incentive present in this state/year, 1=yes	0.65	0.48	0	1
fin	was a PACE or loan financing program in place in this state/year, 1=yes	0.35	0.48	0	1
grant_rebate	was a grant or rebate program in place in this state/year, 1=yes	0.34	0.48	0	1
access	was solar access policy present in this state/year, 1=yes	0.22	0.42	0	1
interconnect	was interconnection standard present in this state/year, 1=yes	0.51	0.5	0	1
ppa	are PPAs allowed in this state/year, 1=yes	0.17	0.38	0	1

Table 2: Explanatory variable descriptions and summary statistics

We also follow Crago et al. (2017) and add a variable to capture the environmentalist sentiment of a state's populace. The variable *pevs*, measures the prevalence of personal electric vehicles in the state for the year 2015.[8] We also account for the average annual solar intensity in each state with the variable *insol* which was constructed from the NREL "Concentrating Solar Power" database for the year 2012. Thus, this variable does not vary within each state over the sample period, however we account for month-to-month variation of solar intensity in each state with the variable *insol_sd*. The explanatory variables used in the statistical model are summarized and described in table 2.

[8] Data from the energy.gov fact #936 dataset https://energy.gov/eere/vehicles/fact-936-august-1-2016-california-had-highest-concentration-plug-vehicles-relative

Combining the various data sources listed above we generate panel datasets in various forms. The specific form and included observations in each dataset depend on the specific research question being addressed. These research questions and the corresponding analyses are presented next.

4 Empirical Methods

The goal of this study is to investigate the factors that enable states to attract investment in commercial solar PV projects. In all models we account for state policies using indicator variables that take the value of 1 if a given incentive or regulation is present in a state in a given year. We also include variables that capture the number of years that a policy or regulation has been in place in a given state. This second group of variables allows for temporal dynamics in the effect of polices on solar adoption. For example, the longer a policy is in place, the more confident the investors may be in the state's supporting environment and in their decision to invest in solar. It could also be possible that the existence and the benefits of particular policies may take time to be recognized by decision makers potentially interested in solar PV installations. Conversely, the effectiveness of policies that create price supports for solar investment, such as RPS with solar-carve-outs and the subsequent SREC markets, might fade as SREC prices are shown generally to decrease and exhibit volatility over time (Lee et al. 2017). All models contain a time trend variable to account for the general trend of increasing solar capacity installed over the sample period, which is likely driven by changes in federal policy and the falling price of solar technology.

4.1 State level analysis of commercial solar investment

Our first objective is to investigate the factors that determine the overall level of commercial solar investment in a given state. This sheds light on our primary research question of "why do some states have more solar installed than other states?" The goal here is to identify and compare the effects of state-level characteristics, such as state policies, and energy market variables on the level of solar PV installations by commercial entities. To accomplish this the SEIA data are summed over firms in each state and year to generate the dependent variables *capacity* and *installations*, which relate the total kW of commercial solar installed by state and year, and the number of commercial solar installations in a given state and year, respectively. Hence, in this analysis the observations are at the state and year level, across all 50 states and D.C. from 2002-2015. This gives 14 observations per state, with $51 \cdot 14 = 714$ total observations.

To model commercial solar capacity installed we use a two-part model (Belotti et al., 2015). The use of the two part model (TPM) is motivated by the fact that we have a high proportion of observations where the dependent variable is equal to zero. We specify our TPM with the first stage as a logit model that predicts the probability of an observation being greater than zero given a set of explanatory variables (x), and the second stage as an OLS regression that predicts the level of the outcome (y), kW of commercial solar installed, given that the outcome is greater than zero. The intuition for this specification is that the distributions reflecting decisions to invest in solar PV or not and the decisions about how much to install could be determined by different data generating processes. The overall expectation of our outcome is given as follows.

$$E(y|x) = \Pr(y > 0|x) \cdot E(y|y > 0, x)$$

Next, we model the number of installations in a given state and year as a function of state-level variables. As this dependent variable contains only integers restricted to the non-negative domain, it is preferable to model it using count data models, such as the Poisson model (Cameron and Trivedi, 1998). However, there is a large number of zero values in the dependent variable that indicate no commercial solar installations in a given state and year. Thus, we also consider a zero-inflated Poisson (ZIP) model to account for the large number of zero observations. We compare the Poisson model to the zero-inflated Poisson model using the Vuong test (Voung, 1989).

4.2 Firm level analysis of the probability to invest in solar PV panels

Our next objective is to examine the determinants of where and when a company planning a solar investment will choose to invest in a solar system. This research question and approach is distinct from that commonly applied to solar adoption research both at the commercial level (e.g. Borchers et al. 2014; Beckman and Xiarchos, 2013) and at the residential level (e.g. Krasko and Doris, 2013; Crago and Chernyakhovskiy, 2017), which ask *why* certain agents adopt solar and others do not. Instead, we investigate the choice of *where* and *when* to adopt solar for those who do choose to adopt.

We define our dependent variable *invest* to be equal to 1 if a specific company invested in solar in a given state/year, and 0 otherwise. With this dependent variable, we model the probability that a firm chooses to invest in solar in a specific state and year. This analysis assumes that the firm plans to make a solar investment, and that these multi-state firms have different potential locations where this investment can be made. The firm then chooses the location and timing of the solar investment. We hypothesize that state characteristics, such as solar-related policies and energy market factors, will play a role in firms choosing where to install.

The analysis in this section is based on the subsample of 32 large companies that had installed at least five PV systems in different states[9]. The purpose of limiting companies included in the data is to mitigate some of the complications that can arise from the regional concentration of smaller firms, and to increase the variation in our dependent variable, which

[9] We do not list the companies in this sample due to privacy concerns, but they are all large corporations who operate in multiple states.

allows us to identify the parameters of the model, and to exclude relatively minor and spatially concentrated firms[10].

Two subsamples are used in this analysis. The first estimation sample is a balanced panel where each company has observations for each state and year in the sample period (2002-2015), giving 714 observations per company and a total observation count of 22,848. In this sample we know whether a company installed solar in a given state or year, but we observe no installation do not know if this is due to the company choosing not to install solar in that year, or due to the company not being present in that state during that year. This allows for only a limited interpretation of econometric results. To address this challenge we define a second "trimmed" estimation sample, which only contains observations where we can be reasonably sure that a specific company is present in a given state. Specifically, we keep all annual observations for a given state and company combination if the company installed any solar in that state throughout the sample period or if we were able to verify that the company operates in that state via publicly available information. Thus, assuming that a company that was present in a state at one time from 2002-2015 was present in that state throughout the sample, we can interpret the results in terms of the decision of a company to install or not install solar in a given state and year. The trimmed estimation sample results in an unbalanced panel with 6,020 state-level and company-level observations by year.

Since our dependent variable, *invest*, is binary we can employ the well-known probit model, whereby the explanatory variables are related to the probability of a company investing in a given state and year. We include fixed effects terms at the company level to control for the

[10] Inclusion of regional or local companies can introduce a bias into the firm level model of the decision to invest in solar because observations with no solar installations can be due to absence of the company from a given state rather than due to the decision not to invest in solar PV units. For this reason, we narrow our firm level analysis to the sample of large firms. Still, in the estimation sample just 1.56% (357 of 22,848) of the observations take a value of one for the dependent variable. Nevertheless, many of our parameter estimates exhibit statistical significance, suggesting that the low level of variation in the dependent variable is not a major cause for concern.

differences among companies, such as their size, wealth level and affinity for solar investment. Thus, the probability that a given company invests in a specific state/year is a function of the characteristics of that state and year, as defined by our explanatory variables shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**, and company fixed effects. We include a time trend variable to account for the general increase in solar installations over time due to falling solar prices and other exogenous energy market factors.

5 Results

Table 3 provides the results from state level analysis using the two part estimation approach and ZIP model. The results are provided in terms of marginal effects, which relate the change in $E(y|x)$ in response to a marginal change in the specified explanatory variable. Thus, the marginal effect estimates for the TPM are a combination of the estimates from the first and second stages of the two-part model. The results from the TPM indicate that the states with greater number of personal electric vehicles and states with longer history of PACE or other financing programs supporting solar PV projects have a greater capacity of solar energy installed by companies. Grants and rebates as well as the length of the period that tax incentive financial support programs have been in place also have a positive effect on installed capacity. Policies and regulations, like RPS, net metering, etc., don’t seem to affect the capacity of solar energy installed by companies on their properties.

For count data analysis, based on the Voung test (1989) we fail to reject the null hypothesis of no zero inflation at the 1% level. Thus, the ZIP model is the preferred specification, which we estimate via maximum likelihood estimation. This specification identifies noticeably more statistically significant determinants of solar energy adoption by commercial entities in terms of number of installation projects than the TPM does in terms of capacity installed. This may suggest that state-level policies and characteristics have a stronger effect on the firm’s decision to install vs. not install solar in a given state than on the decision of how much solar to install, which could be driven by company level factors. Beckman and Xiarchos (2013) found a similar result in their study of California farms. The results in table 3 are presented in terms of marginal effects, which relate the expected increase in the annual number of commercial solar installations in a state in response to marginal changes in the respective explanatory variables. Insolation, electricity market deregulation, solar renewable energy credits, feed in tariffs, financing programs, and tax incentives policies are positively correlated with the number of commercial solar installation project within the state. State characteristics like insolation and ownership of electric vehicles also are positively correlated with the number of commercial solar energy projects.

Table 4 presents the marginal effects estimates from probit models with the binary dependent variable indicating whether a specific company installed solar PV panels in a given state and year. The marginal effects relate the change in the probability that any one company will install solar in a state and year in response to a marginal change in the respective explanatory variable. The model is estimated using two different subsamples. Using the "full sample" of 22,848 observations, marginal effects can be interpreted in terms of the effect on the probability that a company is present in the state *and* chooses to invest solar in the state. The intermingled nature of this interpretation does not allow for strong statements regarding the quantitative results pertaining to the propensity to invest in solar without implied assumptions about presence. The estimation using the "trimmed" sample addresses this issue by limiting the analysis only to the state-company combinations where we can be reasonably sure that the company has a presence in the given state.[11] It is reassuring that generally the

[11] It is important to recognize that while this approach makes an effort to address the problem of zeros due to absence of some of the companies from some of the states, the approach is not a perfect solution. Some of the zeros in this estimation may be still due to lack of available facilities in a given state rather than lack of willingness to invest in solar panels. For example, if a company has only 2 facilities in a state and installed solar PV in both of those facilities in some year(s), then zeros observed in other years are not due to lack of willingness to invest in solar. Nevertheless, given lack of available data on the number of facilities per state over time for each company, this approach represent the best feasible robustness check for the company level analyses.

results from the full sample and from the trimmed sample are in agreement. Using both samples, we observe the signs and significance of the marginal effect estimates to be consistent with prior expectations. GDP per capita has a negative effect possibly as a reflection of higher wages and costs of installation. Electricity price has positive effect, which suggests that the economic benefits from installing solar panels in terms of savings from the electricity bills matter. Insolation, deregulated electricity markets, number of personal electric vehicles, net metering and feed-in-tariffs also have positive effects on the probability that a company installs solar PV panels.

	TPM		ZIP	
	dep. var. is *capacity*		dep. var is *installations*	
Variable	**Marg. Eff.**	**Std. Err.**	**Marg. Eff.**	**Std. Err.**
trend	173.7	(113.3)	0.444***	(0.0768)
gdppc	-0.00173	(0.0273)	0.0000263	(0.0000218)
elec_sales	0.00124	(0.00262)	0.00000506**	(0.00000209)
tax_sales	235.4	(149.3)	-0.0328	(0.0905)
elect_price	-33.62	(81.15)	0.187***	(0.0452)
insol	492.9	(365.3)	2.015***	(0.299)
insol_sd	-281.8	(796.8)	1.173***	(0.432)
dereged	161	(1020.1)	2.797***	(0.798)
coalpc	2.712	(37.24)	-0.0851	(0.0643)
pevs	1099.6**	(510.5)	0.980***	(0.254)
net_mtr	-757.1	(933.5)	0.864*	(0.482)
rps	48.62	(793.1)	-0.339	(0.384)
srec	-1187.7	(1249.2)	3.575***	(0.709)
fit	963.8	(795.1)	2.164***	(0.450)
tax_incent	-202.2	(657.7)	0.870***	(0.337)
fin	-191.3	(514.9)	-0.420	(0.380)
grant_rebate	1184.6**	(574.6)	0.753**	(0.312)
access	-676.3	(996.0)	0.742	(0.555)
interconnect	-568.2	(935.7)	-0.957**	(0.396)
ppa	-81.48	(684.3)	-0.0975	(0.357)
netmtr_sum	65.79	(103.3)	-0.0223	(0.0566)
rps_sum	-36.79	(68.22)	-0.0950*	(0.0520)
srec_sum	248.4	(294.5)	-0.0582	(0.131)
fit_sum	61.21	(168.5)	-0.344***	(0.0938)
tax_insent_sum	123.6**	(59.86)	0.0177	(0.0405)
fin_sum	186.4**	(85.79)	0.317***	(0.0609)
grant_rebate_sum	-45.12	(63.06)	0.0336	(0.0549)
access_sum	78.51	(79.88)	0.107*	(0.0596)
interconnnect_sum	-33.68	(91.76)	-0.00218	(0.0522)
ppa_sum	-167.6	(132.7)	-0.116	(0.106)
N		714		714
1st stage psuedo R-sq		0.45		0.45
2nd stage Adj. R-sq		0.27		0.31
Akaike IC				1695

Table 3. Two part and zero inflated Poisson model results for annual state level solar capacity installed (kW) and number of installation projects

Variable	Full sample of 32 large firms Marg. Eff.	Std. Err.	Trimmed Sample Marg. Eff.	Std. Err.
trend	0.00171***	(0.000621)	0.00879***	(0.00216)
gdppc	-0.000000196***	(6.49e-08)	-0.000000499*	(0.000000263)
elec_sales	2.38e-08	(1.46e-08)	6.77e-08	(5.41e-08)
tax_sales	0.00108*	(0.000604)	0.00209	(0.00219)
elct_price	0.00104***	(0.000303)	0.00376***	(0.00113)
insol	0.00647***	(0.00136)	0.0187***	(0.00464)
insol_sd	0.00254	(0.00280)	0.00488	(0.0101)
dereged	0.0179***	(0.00405)	0.0441***	(0.0137)
coalpc	-0.000203	(0.000199)	-0.000984	(0.000788)
pevs	0.0102***	(0.00177)	0.0215***	(0.00632)
net_mtr	0.0111***	(0.00329)	0.0248**	(0.0119)
rps	-0.00442	(0.00277)	-0.00690	(0.00940)
srec	0.00766	(0.00514)	0.00601	(0.0184)
fit	0.00865**	(0.00407)	0.0386**	(0.0151)
tax_incent	0.00190	(0.00303)	-0.00404	(0.0102)
fin	0.00461	(0.00312)	0.0134	(0.0113)
grant_rebate	0.00406	(0.00294)	0.0109	(0.0105)
access	0.00394	(0.00389)	0.00996	(0.0137)
interconnect	-0.00768**	(0.00374)	-0.0142	(0.0124)
ppa	-0.000693	(0.00287)	0.000547	(0.0103)
netmtr_sum	-0.000473	(0.000461)	-0.00137	(0.00163)
rps_sum	-0.000427	(0.000421)	-0.00126	(0.00142)
srec_sum	0.00217**	(0.000914)	0.00491	(0.00382)
fit_sum	-0.00247***	(0.000784)	-0.00854***	(0.00324)
tax_insent_sum	0.000973***	(0.000343)	0.00256**	(0.00120)
fin_sum	0.000763*	(0.000423)	0.00218	(0.00156)
grant_rebate_su	0.0000906	(0.000381)	-0.000204	(0.00147)
access_sum	0.000422	(0.000394)	0.000610	(0.00137)
interconnnect_su	0.000240	(0.000430)	0.00136	(0.00151)
ppa_sum	-0.000198	(0.000716)	-0.00249	(0.00258)
N		22848		6020
Psuedo R-sq		0.35		0.30

Table 4. Probit results for company level analysis of solar PV installation decisions: dependent variable is *invest* which is 1 if the company installed solar in a given state and year and 0 otherwise

6 Discussion and conclusions

Similar to Crago and Chernyakhovskiy (2017), we observe that across various specifications and samples insolation has a positive effect on solar PV panel installation, and we also find some evidence of the positive effect of electricity price. These results are expected as firms install solar panels in locations where most solar energy can be generated and where most savings can be realized from avoided electricity expenditures. The effectiveness of policies in terms of attracting solar energy installation varies. We find that having RPS does not have a significant effect on solar energy installation by companies. However, when an RPS includes a solar-carve out with an SREC market this has a strong positive effect on the annual number of commercial solar installations. This result differs from Menz and Vachon (2006) who find significant effect of RPS on renewable energy generation including wind, from Shrimali and Kniefel (2011) who find positive effect of RPS on solar energy generation, and from Li and Yi (2014) who find that RPS have a significant positive effect on solar PV installation in the cities. However, our results are consistent with the argument that RPS have the largest effects on low cost renewable generators such as wind rather than distributed solar generation (Matisoff and Johnson 2017). Feed-in-tariffs and tax incentives appear to be positively correlated with company installations of solar generation units. This result is consistent with the findings of Sarzynski et al. (2012) and Shrimali and Jenner (2013) in terms of the importance of cash incentives for adoption of solar PV panels. We find that companies are motivated by financial incentives in their decisions to install solar generation units. Expected return-on-investment from a solar array is an important consideration for a firm when choosing where to install solar. However, loan financing, grants and rebate programs do not appear to be statistically significant, similar to the findings of Li and Yi (2014). Deregulation of electricity market has a positive effect on the decision to install solar in a particular state. Although power purchase agreements are not found to be statistically significant in this analysis, third party ownership under deregulated electricity generation system may be the explanation for the observed positive correlation between deregulation and solar energy installation. Deregulation in most cases enables third party ownership which may facilitate solar panel installation (Overholm, 2015; Drury 2012).

With respect to net metering we find some evidence that this policy increases the probability a company will install in a given state, and increases the number of commercial installs per year. However, these results are not as strong as one might expect as found by Krasko and Doris (2013). One explanation for our result may be that incentives of commercial entities adopting solar generation may differ from incentives of non-commercial adopters like residential units and utilities. Residential solar energy adopters mostly sell energy back to the grid during the day when domestic consumption of electricity is low and generation is high. In contrast, commercial adopters tend to use electricity during the day. As a result, only small amounts of electricity might be sent back to the grid making net metering less significant in the companies' decision to install solar.

The results across all specifications suggest that the prevalence of environmental attitudes of the state population, measured in terms of the number of personal electric vehicles in a state, is positively correlated with the probability that firms install solar energy generation units in their facilities within the state. This result suggests that firms may be interested in public perception of renewables in the locations where they install. One reason may be that the firms' installation of solar energy generation units supports businesses' efforts to increase the effectiveness of green marketing and image campaigns. The robustness of this variable's statistical significance across different specifications suggests that environmental/green marketing oriented motives are as significant as direct monetary incentives in business' decisions to install solar panels on properties.

This study uses a sample of multi-state companies that have adopted solar in at least a few states. One can generalize the results to the companies that are not included in our sample by making the reasonable assumption that the decision making process as to where to generate solar power is similar across multi-state companies. Some firms may not yet have considered investing in solar, or may have decided against it in the near-term and will thus not be in our sample dataset. However, if and when these firms do decide to invest in solar they will face a similar decision problem as to where to put their solar capacity as the firms that have already decided to invest in solar in terms of evaluating opportunities across different states with different policies and characteristics. Thus, subject to careful consideration of the caveats associated with this assumption, the results in this study may be relevant to a larger subset of firms than those that appear in our sample.

Nevertheless, the results in this analysis should be interpreted with care taking into account the limitations implied by the nature of the data. First, only 16% of non-residential and non-utility scale PV installations are included in these data. It is unclear whether this sample can be considered to be representative of all commercial scale PV installation as the data consist of voluntary submissions by companies. Analysis with similar sample selection for the case of residential solar adoption can be found in Crago and Chernyakovskiy (2016). It is likely that our sample includes most of the largest commercial solar adopters. Therefore, the extrapolation of the results to smaller commercial entities should be performed with caution.

We largely eliminate this sample selection problem when we transition to the company-state-year panel structure and limit the data to the most avid 32 installers. The results from the ensuing probit models are thus only applicable to larger multi-state companies. However, the structure of the data implies that some of the observations may correspond to company-state-year combinations where the company may not be present in a given state and year. This limitation may be more applicable for smaller companies than for larger companies which are likely to be present in most state and year combinations this so limitation does not pose a serious shortcoming. Nevertheless, we analyze the data of only those company-state-year combinations where we can be reasonably sure that the company is present in that state and year.

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