Title
Impacts of the Solar Investment Tax Credit On State-Level Solar Outcomes

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IMPACTS OF THE SOLAR INVESTMENT TAX CREDIT ON STATE-LEVEL SOLAR OUTCOMES

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ABSTRACT

In this paper, I investigate the effects of the U.S. federally implemented Solar Investment Tax Credit (ITC) on states' solar energy installation and utilization. In particular, I compare relative trends in solar installation and utilization between states with initially higher levels of solar and states with initially lower levels of solar, before and after the implementation of the Solar ITC. My findings demonstrate that states with initially higher levels of solar prior to 2006 — the year the Solar ITC took effect — experienced rapid, significant growth in solar installation and utilization relative to states with initially lower levels of solar, on average. These results suggest that the Solar ITC had a larger effect on solar installation and utilization in states with initially higher levels of solar compared to states with initially lower levels of solar, on average.

1. INTRODUCTION

In the last decade, the United States solar industry has experienced rapid growth in the installation of solar energy, driven by the implementation of the Solar Investment Tax Credit (ITC). Initially proposed under the Energy Policy Act of 2005, the Solar ITC took effect on January 1, 2006 (SEIA). Under this federal tax credit, residential (Section 25D) and commercial and utility (Section 48) investors can claim a 30% tax credit against their investment in solar energy systems (SEIA). The way such a tax credit works is through a dollar-for-dollar reduction in the income taxes that a person or company would otherwise pay the federal government. In particular, the Section 25D residential ITC allows a homeowner to apply the credit to his or her personal income taxes; eligible homeowners are those who have purchased solar systems outright and have had them installed on their homes (SEIA). In the case of the Section 48 commercial and utility credit, the business that installs, develops and/or finances the project claims the credit (SEIA).

Historically, main barriers to the expansion of solar energy have been the following: 1) high capital costs to install solar, and 2) low efficiencies of solar cells (Goswami; SEIA). The primary goal of the Solar ITC is to stimulate investment in solar energy by reducing the cost of installation, thereby providing a solution to the first barrier. In turn, rising demand for solar energy and expanding solar markets have led to advancements in solar cell efficiencies, offering a solution to the second barrier. Economic intuition suggests that such a policy mechanism results in increased investment in solar energy systems. Implicit in this mechanism is an aim to promote the utilization of solar energy over other more emissions-intensive energy sources: by providing an investment tax credit for solar, the federal government has effectively lowered the cost of solar relative to other energy sources, thus making solar a more competitive source of energy on the market.

To date, the Solar ITC has proven to be an important federal policy mechanism to incentivize the installation of both rooftop and utility-scale solar energy in the United States and acted as an economic engine to stimulate advancements in the efficiency and cost curves of solar. As seen in Figure 1, over the last ten years the average price to install solar photovoltaic (PV) has fallen by more than 60%; during this same time period, yearly installed solar capacity has grown at a compound annual growth rate of over 60% (SEIA).

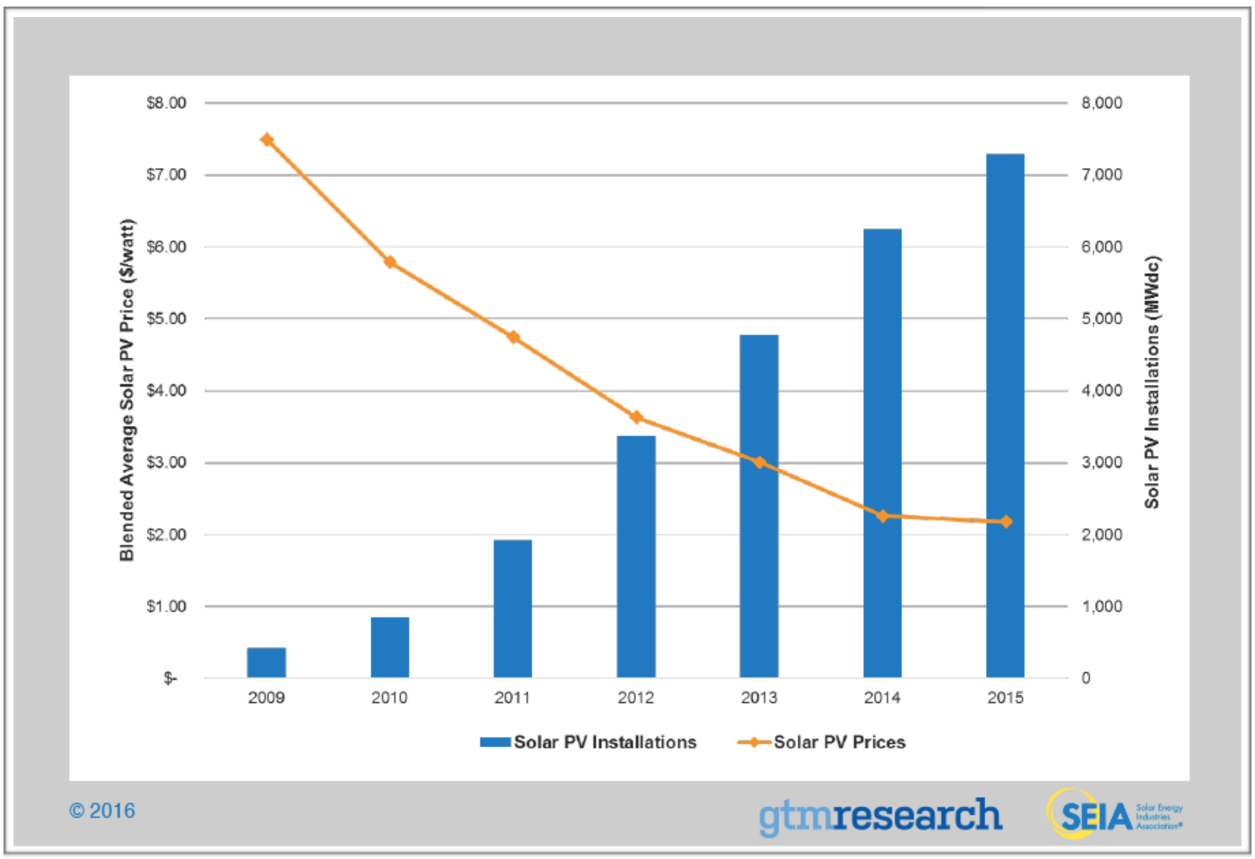


FIGURE 1
Figure 1 shows the yearly decline in average solar photovoltaic (PV) prices (in $/watt) between 2009 and 2015 and the complementary rise in solar PV installations (in MWdc) during this same time period. This chart is originally a product of GTM Research, and is provided by the Solar Energy Industries Association (SEIA).

Such rising economies of scale have driven the solar industry to expand into new markets and install thousands of solar systems nationwide. Since the first Solar Job Consensus was released in 2010, employment in the solar industry has nearly tripled to over 260,000 workers (The Solar Foundation). In 2016, one out of every 50 new jobs added in the United States was created by the solar industry, representing 2% of all new jobs (The Solar Foundation). These statistics and other data provided by the Solar Energy Industries Association (SEIA) and the Solar Foundation provide a broad look into the rising demand for solar energy and how this growth has expanded into other markets.

In this paper, I will study the impacts of the Solar ITC on state-level solar installation and utilization. The rest of this paper is as follows. Section 2 discusses existing literature on federal energy tax credits; Section 3 describes the data used; Section 4 outlines the empirical approach and strategy; Section 5 examines key results and implications; Section 6 concludes the paper.

2. LITERATURE REVIEW

Previous literature has studied the impacts of various federal renewable energy tax credits on renewable energy deployment. In particular, Trieu Mai et al. of the National Renewable Energy Laboratory at the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy examined the impacts of extensions in renewable energy tax credits in 2015 on renewable energy deployment in the United States (see *Impacts of Federal Tax Credit Extensions on Renewable Deployment and Power Sector Emissions*). Specifically, these researchers look at the Consolidated Appropriations Act of 2016, which extended solar and wind tax credit deadlines by five years from their prior scheduled expiration — but which also included scale downs in the value of the tax credit in the latter years of the five-year extension period (Mai, Trieu, et al). They explore two central questions: 1) How the recent (2015) federal tax credit extensions might impact renewable energy deployment in the contiguous United States in the years to follow?, and 2) How any changes in renewable energy deployment as a result of these extensions may impact carbon dioxide (CO2) emissions in the power sector? To do this, they employ a scenario analysis approach in order to estimate the impacts of the tax credits under two distinct natural gas futures. Under the first scenario, “base natural gas prices” from the EIA Annual Energy Outlook 2015 Reference are used; under the alternative natural gas future scenario, a “lower natural gas price” based on the EIA Annual Energy Outlook 2015 High Oil and Gas Resource case is used (Mai, Trieu, et al). Under both sets of natural gas price scenarios, these researchers find that scenarios in which the renewable tax credits were extended showed greater forecasts of renewable technology investments through the early 2020s when compared with scenarios in which these renewable energy tax credits were not extended. In all scenarios, nearly all of the estimated growth in renewable energy capacity is expected to come from new solar and wind capacities (Mai, Trieu, et al). Finally, the authors demonstrate that scenarios in which the tax credits are extended through the 2020s show lower carbon dioxide emissions from the U.S. electricity system compared with scenarios in which the tax credits are not extended.

In Severin Borenstein and Lucas Davis’s *The Distributional Effects of U.S. Clean Energy Tax Credits* (2015), socioeconomic characteristics of federal income tax credits recipients — as opposed to investment tax credits — are examined. Since 2006, households in the United States have received more than $18 billion in federal income tax credits to “weatherize” their homes, install solar panels, buy hybrid and electric vehicles, and other “clean energy” investments

(Borenstein, Severin, et al). Using data on the tax expenditures of households in the United States, Borenstein and Davis find that these federal income tax credits have gone primarily to higher-income Americans. In particular, the bottom three quartiles of the U.S. income distribution have received about 10% of all credits between 2006 and 2015, while the top quintile has received roughly 60% (Borenstein, Severin, et al). Of the various clean energy programs examined, the sharpest gap in distributional effects between income quartiles is found in programs aimed at electric vehicles, where the top quartile has received about 90% of all of these credits (Borenstein, Severin, et al). In general, this paper shows that this distributional pattern is similar across years and reflects that higher-income taxpayers are disproportionately more likely to claim credits and do so for significantly larger amounts than lower-income taxpayers. Borenstein and Lucas's findings build on previous work of Hasset et al. (2009), which finds that the implementation of a carbon tax for the top income quartile would pay about four times as much as the bottom quintile (Hasset et al). Borenstein and Lucas demonstrate that federal income tax credits for "clean energy" can be inefficient and unequal on distributional grounds, suggesting that a carbon tax would be a more effective policy measure to implement (Borenstein et al).

In Stephen Comello and Stefan Reichelstein's *The Federal Investment Tax Credit for Solar Energy: Assessing and Addressing the Impact of the 2017 Step-Down* (2015), impacts of the anticipated ITC step-down on the competitiveness of solar energy across the U.S. are assessed. Since the implementation of the federal solar ITC, solar photovoltaic installations have been deployed at rapid rates in United States; yet, this credit is scheduled to step down from 30% to 10% at the beginning of 2017 for corporate investors in solar energy systems (Comello, Stephen et al). Their analysis focused on five key states: California, Colorado, New Jersey, North Carolina. In these states, they find that the anticipated ITC step down in 2017 would increase the levelized cost of solar power by significant margins, raising what Comello and Reichelstein call the 'specter of a cliff' for the solar industry (Comello, Stephen et al). The solution proposed to avoid such a scenario identifies an alternative phase down scenario that would instead reduce the value of the ITC gradually over time and ultimately eliminate it by 2024. In this alternative phase down scenario, Comello and Reichelstein show that solar PV would remain broadly competitive conditional on the solar industry's ability to maintain the pace of cost reductions demonstrated in past years (Comello, Stephen et al).

This body of existing literature and others have mainly focused on projections of broader renewable energy growth and their secondary impacts on carbon emissions, disruptions in the solar market as a result of sharp ITC step-down during periods of dramatic solar growth, and the distributional effects of such tax credits on socioeconomic grounds. What I attempt to add to this literature is an examination of state-level changes in solar installation and utilization as a result of the Solar ITC by comparing trends in solar before and after the tax credit. In addition, I show that while there was significant growth in solar in years after the ITC relative to years before, the overall levels of solar as a share of total net generation from all energy sources do not appear meaningfully impact factors pertinent to solar investors, such as average electricity prices and other electricity sales outcomes.

3. DATA AND DESCRIPTION OF KEY VARIABLES

The data used to conduct this study come primarily from the U.S. Department of Energy's (D.O.E.) Energy Information Administration (EIA) and the U.S. Department of Commerce's Bureau of Economic Analysis (BEA); in addition, statistics on solar growth come from the Solar Energy Industries Association (SEIA), GTM Research and The Solar Foundation. All solar-related data, contained in forms EIA-767, EIA-861, EIA-861S, EIA-906, EIA-920, and EIA-923, provide detailed recordings of annual net electricity generation by state by energy source; existing nameplate capacity and net summer nameplate capacity by state by energy source; estimated emissions by state; retail sales, revenue, and number of customers by state by energy source; and average electricity prices by state. These data are measured for the Total Electric Power Industry. Data on average GDP per capita by state by year come from the Bureau of Economic Analysis. All of these data span the years 2001-2015, and are recorded at the state-level.

TABLE 1

Pre-2006 Solar Installation and Utilization

	Mean	Std. Dev.	Number of Obs.
Solar Share of Net Generation (SSNG)	0.0056373	0.039642	204
Solar Net Generation	10854.32	76313.08	204
Solar Nameplate Capacity	10.03922	62.62043	204

Post-2006 Solar Installation and Utilization

	Mean	Std. Dev.	Number of Obs.
Solar Share of Net Generation (SSNG)	0.1501743	0.605933	459
Solar Net Generation	138461.6	903645.7	459
Solar Nameplate Capacity	83.4902	482.4422	459

Table 1 above provides summary statistics for solar installation and deployment in the period before the Solar ITC (i.e. 2002-2005) as well as the period following the implementation of the Solar ITC (i.e. 2007-2015). Here, solar installation and deployment is measured using three variables: Solar Share of Net Generation (SSNG), Solar Net Generation, and Solar Nameplate Capacity. Solar Net Generation is a state's net generation from solar thermal and photovoltaic (PV) energy sources, measured in megawatthours (MWh). Similarly, Solar Nameplate Capacity, also known as the rated capacity or installed capacity, is the intended full-load sustained output of a facility; this variable is used to classify the power output of a power station and is measured in megawatthours (EIA). Finally, SSNG is the percentage of a state's Total Net Electricity Generation from all energy sources that is accounted for by their Solar Thermal and Photovoltaic (PV) Net Electricity Generation.

4. Studying The Impact Of The Solar ITC: Approach And Empirical Strategy

The Solar Investment Tax Credit (ITC) is currently one of the largest federal policy mechanisms in place to stimulate investment in solar energy systems, offering residential and commercial and utility investors a tax credit equal to 30% of the basis that is invested in solar property which have commenced construction through 2019 (SEIA). Previous research has studied the impacts of the Federal Investment Tax Credit on aggregate renewable energy deployment and power sector emissions in the United States, the distributional effects of clean energy tax credits, and the relative competitiveness of solar energy in anticipation of an ITC step-down (Mai, Cole, Lantz, Marcy, and Sigrin (2016); Borenstein and Davis (2015); Comello and Reichelstein (2015)). To my knowledge, these studies and others do not examine the impact of the Solar ITC on state-level solar installation and utilization trends before and after the ITC, the exercise I carry out here.

A major obstacle to the analysis of the impact of the introduction of the Solar ITC is distinguishing the impact of the federal investment tax credit from other co-incident, secular changes occurring around the time of the ITC's implementation. In this section, I will discuss the paper's approach to tackling this issue.

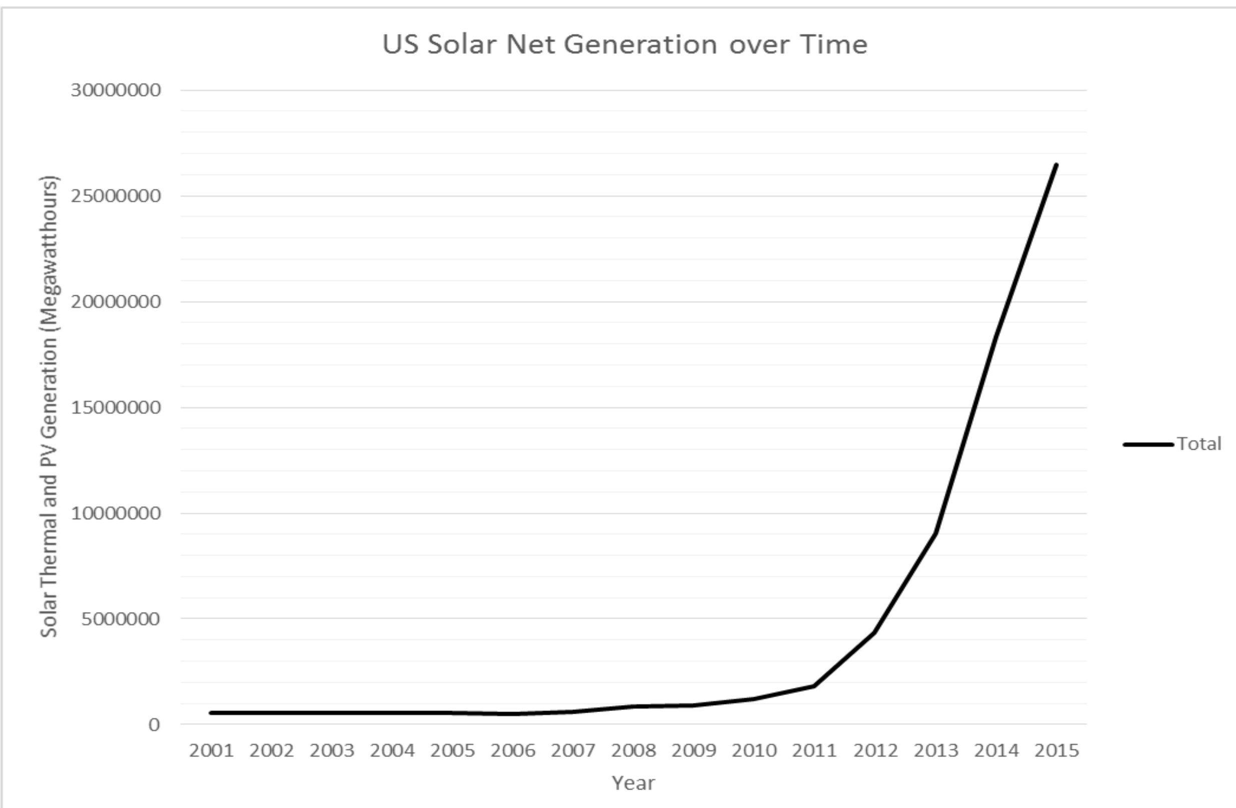


FIGURE 2

Figure 2graphs the national time series pattern of solar net generation in the United States for the Total Electric Power Industry. Prior to 2006, the level of solar net generation is nearly insignificant relative to the total net generation from all energy sources. We observe rapid growth in solar net generation at the national level in years after 2006 (the year of the implementation of the Solar ITC).

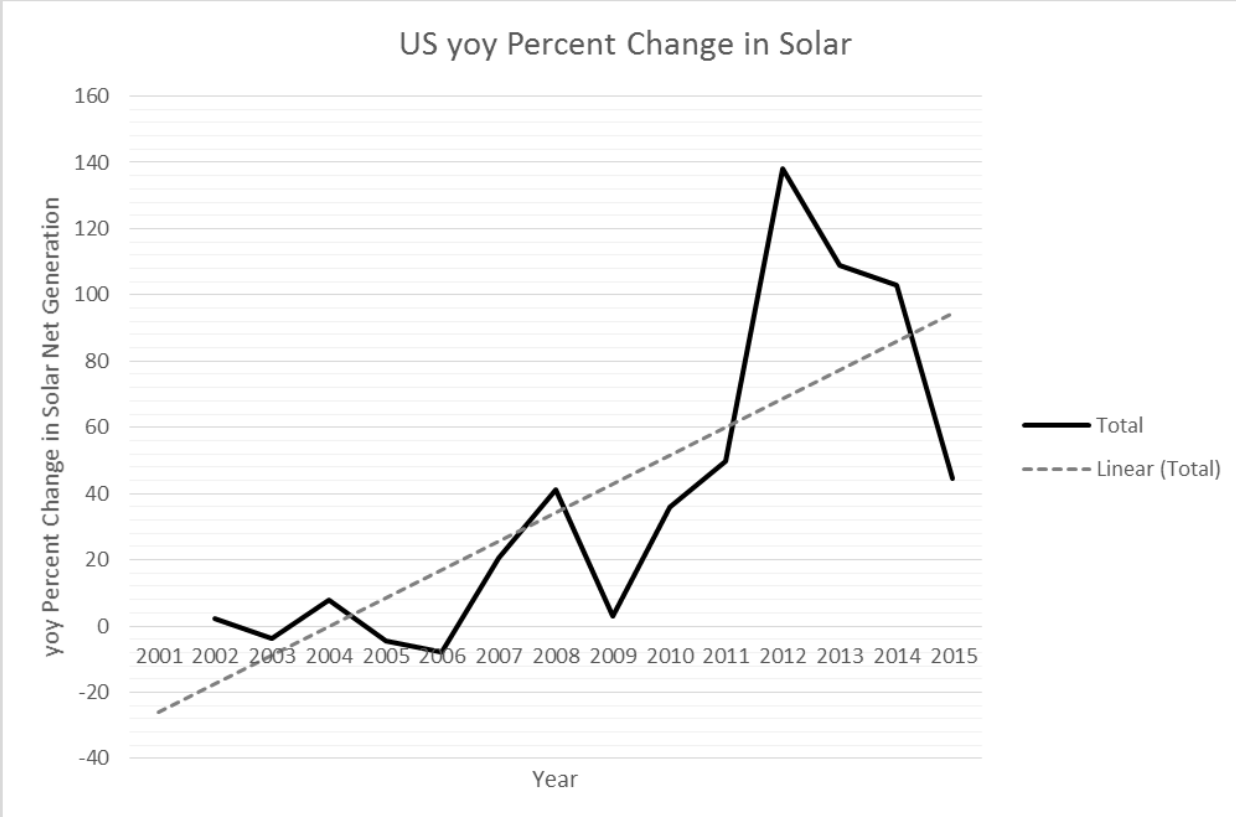


FIGURE 3

Figure 3 graphs the national time series pattern of the year-over-year percentage change in U.S. solar net generation for the Total Electric Power Industry. Prior to 2006, these growth rates are slightly positive with a relatively flat trend. However, after 2006, we observe an overall strong upward trend in the year-over-year change in solar net generation, indicating that on average, growth rates of solar net generation in the US were increasing from the previous year's growth rate.

The Solar ITC had significant impacts on solar energy deployment and solar-related markets. As seen in Figures 2 and 3 above, in years following the implementation of the Solar ITC in 2006, solar net generation (in megawatthours) and the year-over-year percent change in solar net generation rose significantly at the national level. From Figures 4, 5, and 6, we can observe that these impacts varied across states and census divisions, on average. Broadly speaking, solar net generation and solar share of net generation (calculated as 100% multiplied by the ratio of solar net generation to total net generation from all energy sources) are higher in the Pacific Contiguous and Mountain divisions than the West North Central and West South Central. Consistent with our census division measures, at the state-level, states such as

California, Nevada, and Arizona all have significantly higher levels of solar net generation and solar share of net generation than states such as South Dakota, Kansas, Oklahoma, or Arkansas. Pre-2006 variation in solar net generation among states is minimal; the level difference between high and low solar states remained relatively consistent and there were a cohort of states without meaningful amounts of solar net generation. In the years following 2006, there are significant level increases in solar net generation among states as well as significant variation in the rate of increase of solar net generation between states.

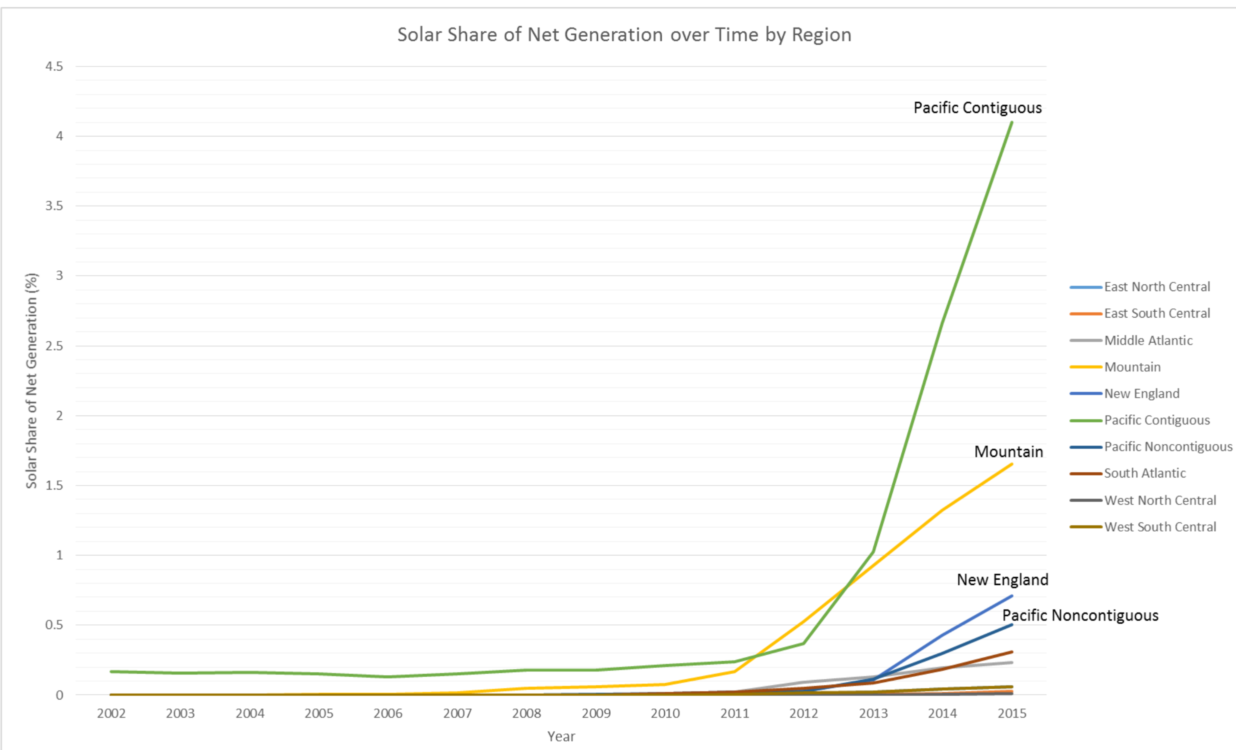


FIGURE 4

Figure 4 graphs the region-level time series patterns of the solar share of net generation by census division for the Total Electric Power Industry. Prior to 2006, region level differences in solar share of net generation were relatively small and these differences remained relatively constant between 2002 and 2005. In the years following the introduction of the Solar ITC in 2006, we observe large, increasing differences in solar share of net generation between census divisions and significant positive growth in solar share of net generation in the Pacific Contiguous and Mountain census divisions relative to other census divisions.

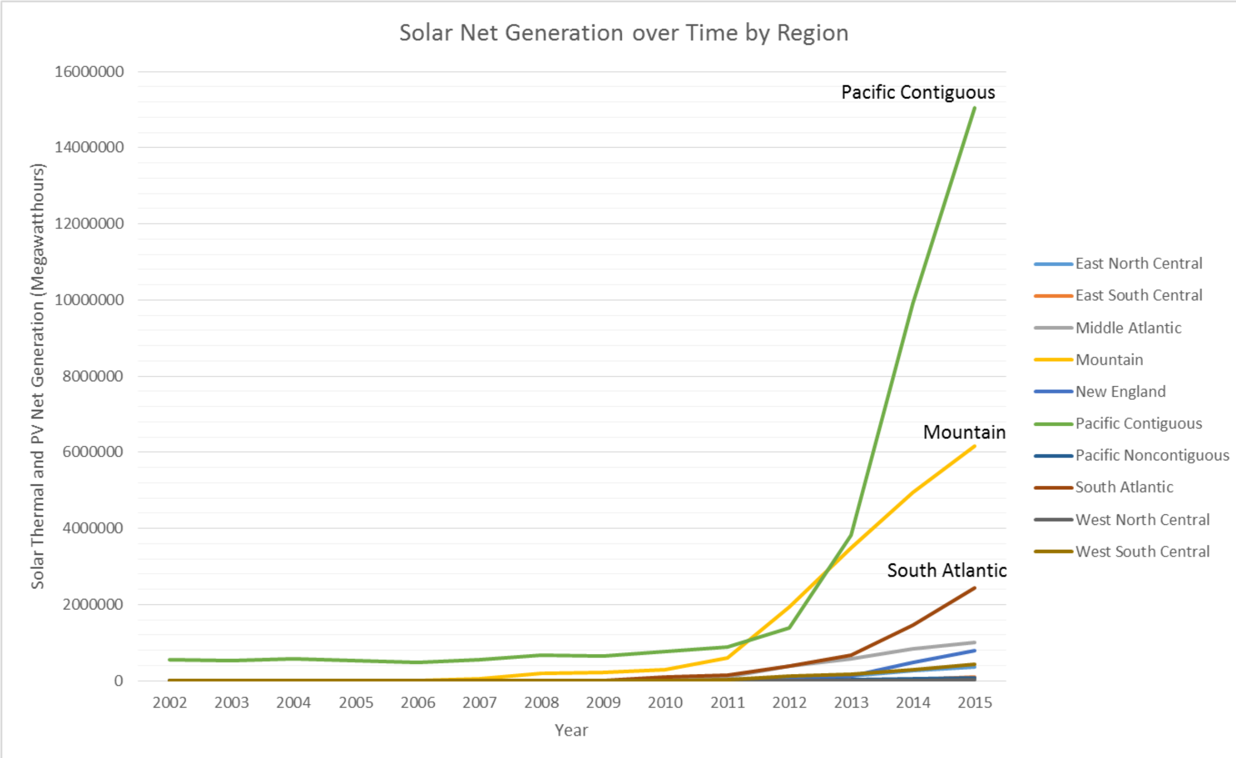


FIGURE 5

Figure 5 graphs the region-level time series patterns of solar net generation in the United States for the Total Electric Power Industry. Prior to 2006, region-level differences in solar net generation were relatively small and these differences remained relatively constant between 2002 and 2005. In the years following the introduction of the Solar ITC in 2006, we observe large, increasing differences in solar net generation between states and significant positive growth in solar net generation in census divisions including the Pacific Contiguous, Mountain, and South Atlantic.

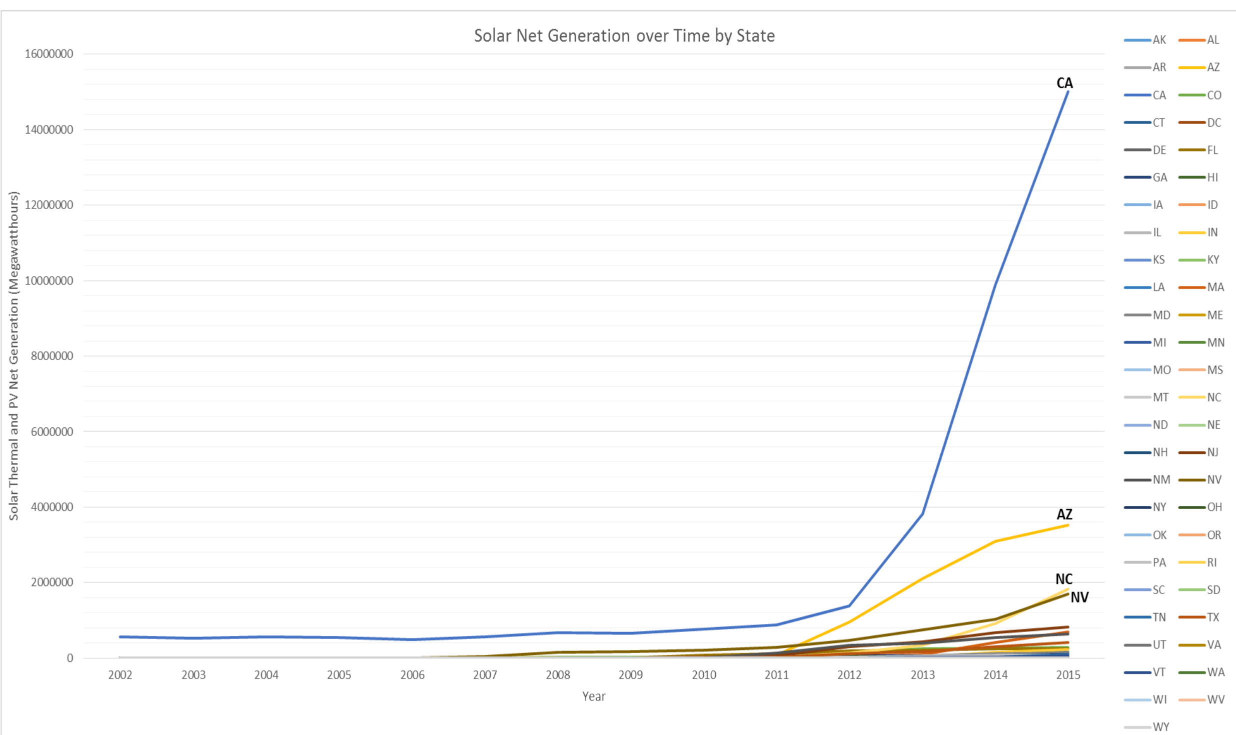


FIGURE 6

Figure 6 graphs the state-level time series patterns of solar net generation in the United States for the Total Electric Power Industry. Prior to 2006, state level differences in solar net generation were relatively small and these differences remained relatively constant between 2002 and 2005. In the years following the introduction of the Solar ITC in 2006, we observe large, increasing differences in solar net generation between states and significant positive growth in solar net generation in states including California, Arizona, North Carolina, and Nevada.

3.2 Empirical Strategy

The empirical strategy is to compare solar installation and utilization outcomes before and after implementation of the Solar ITC in areas of the country where the tax credit had a larger effect on the solar share of net generation to areas of the country where it had a smaller effect. As our baseline (pre-2006) measure of solar share of net generation (SSNG), I will use the 2001 SSNG levels. As our reference year, I will use 2006 so that our results can be interpreted relative to the year the Solar ITC was implemented. The main analysis of this paper will focus on the following outcome: Solar Installation and Utilization. Ancillary to this, I will examine changes in the Retail Sales of Electricity. Using the initial SSNG of states, we can compare trends in outcomes between states with initially higher SSNG and initially lower SSNG before and after 2006. By controlling for entity and time specific factors as well as socioeconomic variation at the appropriate specification level, I attempt to discern the true effect of the Solar ITC on solar-related outcomes between states given their initial differences in SSNG (see Cameron and Miller (2015); Borenstein and Davis (2015)). This analysis is done for the Total Electric Power Industry.

The empirical approach is to discern the effect of the Solar ITC by looking at whether there is a break in the level or trend in these outcomes around the time of the Solar ITC's introduction in 2006. Figure 7 shows the national time series patterns for each of these variables.

Prior to 2006, national solar net generation levels remained relatively low with a flat trend. However, in the years following 2006, we observe a dramatic rise in the levels of solar net generation as well as in the rate of increase of solar net generation.

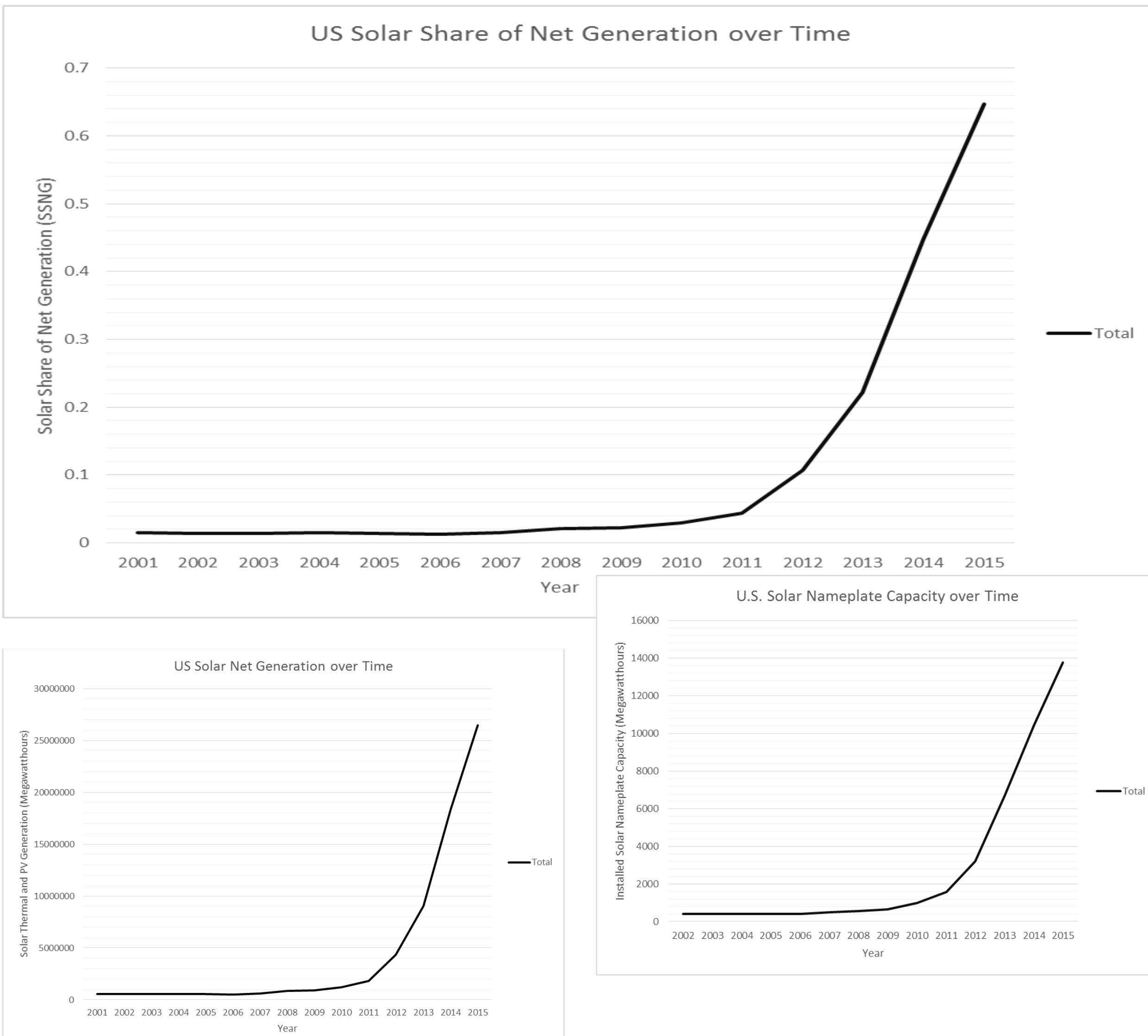


FIGURE 7

Figure 7 graphs the national time series patterns for outcomes of interest for the Total Electric Power Industry. The main outcome, Solar Installation and Utilization, is measured using three variables: solar share of net generation, solar net generation, and solar nameplate capacity. The pattern of this outcome is positive and increasing over time.

These national time series patterns gives us evidence that there are indeed pronounced trends in solar installation and utilization at the national level. However, extrapolating off of time series patterns alone can be problematic; indeed, there may be numerous factors working in concert to produce the trends we observe. Thus, these national time series patterns are used as evidence of general aggregate-level trends from which I will drill deeper into the state-level, where we can then control for the variation in characteristics among geographically similar states.

5. The Impact Of The Solar ITC On Solar Installation And Utilization And Retail Sales Of Electricity

4.1 Econometric Model

The empirical strategy is to compare changes in solar installation and utilization between states where the Solar ITC had a larger effect on the solar share of net electricity generation (SNNG) and states where it had less of an effect, respectively. Below, I have described the approach used for observational units are at the state-level. The basic estimating equation will take the following form:

$$(1) \qquad y_{it} = \alpha_i{*}(CensusDivision_i) + \gamma_t{*}(Year_t) + \sum \lambda_t (SSNG_i){*}(Year_t) + X_{it}\beta + \varepsilon_{it}$$

$$\log(y_{it}) = \alpha_i{*}(CensusDivision_i) + \gamma_t{*}(Year_t) + \sum \lambda_t (SSNG_i){*}(Year_t) + X_{it}\beta + \varepsilon_{it}$$

The dependent variable is the outcome *y* in state *i* and year *t*. I chose to estimate the equation in logs for some outcomes that vary considerably with the size of the state, and in level amounts for other outcomes where the change in magnitude is a more telling measure. *(CensusDivision$_i$)* are a series of fixed effects at the census division level that control for any fixed differences within states of the same census division over time. I estimate the above regression controlling for average census division fixed effects and for varying census division specific linear trends. *(Year$_t$)* are a series of year fixed effects that control for any common year effects for the U.S., such as business cycle conditions. $SSNG_i$ measures the relative percentage point increase in solar share of net generation in state *i* associated with the implementation of the Solar ITC. In the main specification I present, I define the dependent variable $SSNG_i$ as the percent of total net generation that solar net generation accounted for in state *i* in 2001.

The key variables of interest are the interactions of the year fixed effects with the *SSNG* variable, i.e. $(SSNG_i)*(Year_t)$. The pattern of coefficients on these variables — the λ_t's — shows the flexibly estimated pattern over time in the dependent variable in areas where the Solar ITC had a larger effect on solar installation and utilization relative to areas where the Solar ITC had less of an effect. The change in the trends of these λ_t's before and after the introduction of the Solar ITC can therefore provide an estimate of the Solar ITC's impact on the dependent variable. Using 2006 as the reference year, I allow the data to show if there are any differences in pre- and post-ITC period trends of outcomes to gauge whether the Solar ITC may have played a role in changing the pattern of these outcomes over time. To account for possible serial correlation in regression model errors independent across states but correlated within states, I cluster at the state-level (Cameron, Colin et al).

The empirical approach is to look for a break in the level or trend of solar-related outcomes that were affected by the Solar ITC around the time of it's implementation in 2006. The identifying assumption, or counterfactual, is that absent the Solar ITC, any pre-period trends in average state-level solar installation and utilization would have continued on the same level or trend. I use the period 2002-2005 as the pre-period years to provide support of this identifying assumption. In addition, I control for differences in average GDP per capita at the state-level to account for socioeconomic differences between states that may potentially constrain states' solar utilization due to high capital costs of solar. I estimate regression (1), controlling for average census division trends as well as varying census division specific trends. In Table 2, I provide estimates from both regressions. *(1)* denotes the regression controlling for average census division trends, and *(2)* denotes the regression controlling for varying census division trends. The results are consistent between both regressions. For the analysis below, I focus my discussion on the results from regression *(2)*, as the level of fixed effects is finer here.

4.2 Results and Implications

The core empirical findings of this paper are presented in Table 2 and Figures 8-11, which show the λ_t's from estimating equation (1) for six different dependent variables: solar share of net generation, solar nameplate capacity, and installed solar nameplate capacity (i.e. Solar Deployment and Utilization), and revenues, average electricity price, and the number of customers (i.e. Retail Sales of Electricity). These λ_t's are the coefficients on each of the year effects interacted with the impact of the Solar ITC on solar share of net generation of the state. The pattern of these λ_t's over time allows for the identification of changes in the dependent variable in states where the Solar ITC had a larger impact on solar share of net generation *relative* to states where the Solar ITC had less of an impact on solar share of net generation. The dashed lines indicate the 95% confidence interval for each coefficient.

TABLE 2

Regression Results for Total Electric Power Industry

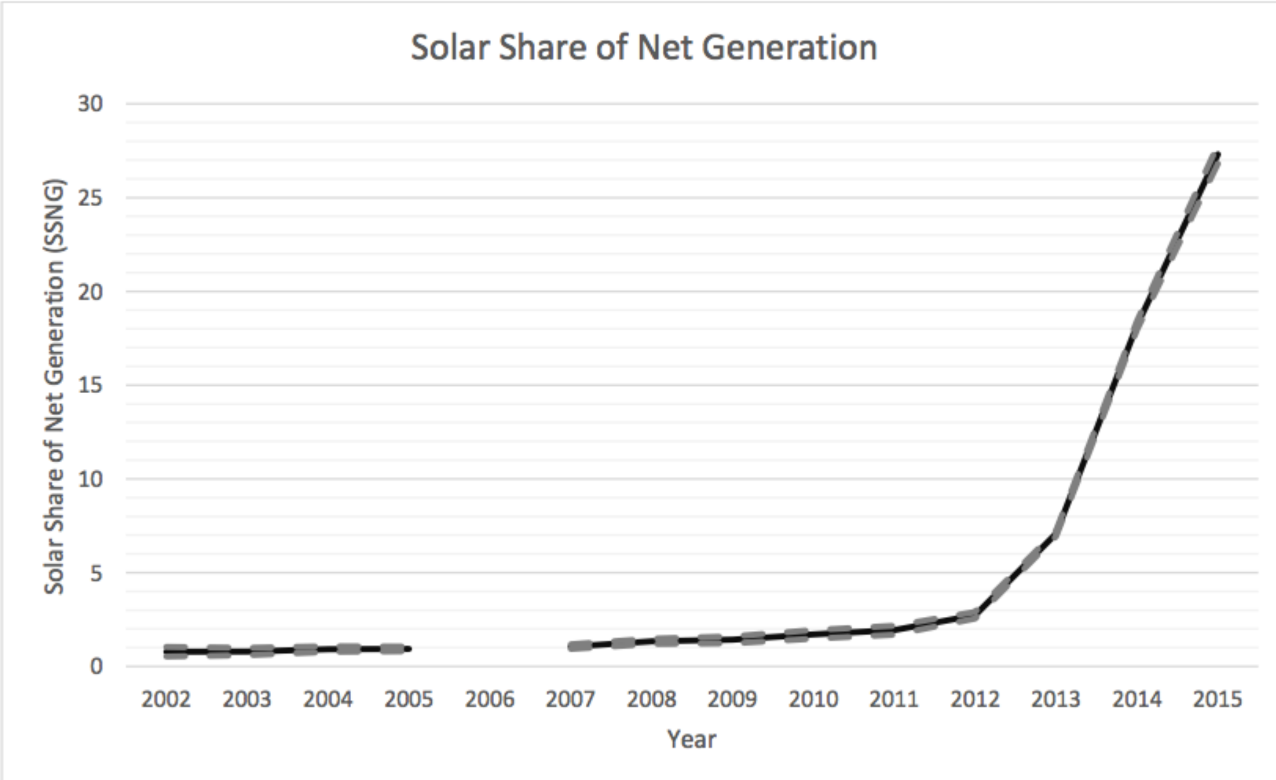
Model 1: Main Results with Varying Specifications

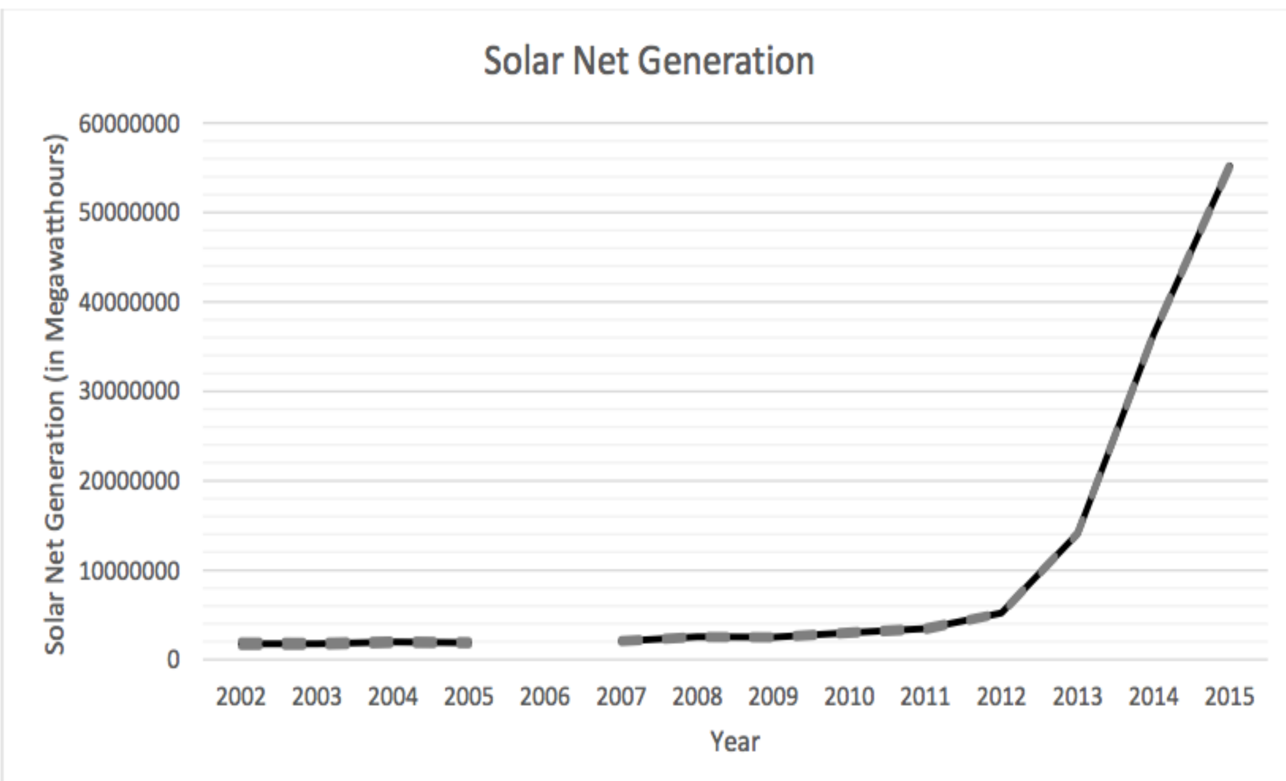
	(1)			*(2)*		
	Solar Installation and Deployment			Solar Installation and Deployment		
	SSNG	Solar Net Generation	Solar Nameplate Capacity	SSNG	Solar Net Generation	Solar Nameplate Capacity
SSNG*Year_2002	1.334643***	2138582***	1537.417***	0.7816937***	1781394***	1317.641***
	0.1010	98875.87	77.77645	0.1253092	165081	128.4726
SSNG*Year_2003	1.262538***	2063490***	1509.48***	0.7949765***	1761477***	1323.676***
	0.1017	99513.54	70.84995	0.0985395	146060.3	114.3208
SSNG*Year_2004	1.301677***	2203229***	1510.575***	0.9194638***	1956366***	1358.729***
	0.1024	100058.2	71.16254	0.074856	128812.7	102.807
SSNG*Year_2005	1.229183***	2078095***	1533.933***	0.9322542***	1886343***	1416.022***
	0.1029	100420.2	71.46981	0.0583297	114106.7	92.28328
SSNG*Year_2007	1.184231***	2151643***	1535.567***	1.05873***	2070647***	1485.83***
	0.0976	100497.3	70.85222	0.0623854	95923.75	75.1894
SSNG*Year_2008	1.380167***	2560746***	1585.141***	1.340954***	2535486***	1569.695***
	0.0857	98627.51	70.57193	0.0716805	93172.48	69.32444
SSNG*Year_2009	1.371409***	2468232***	1726.91***	1.41921***	2499161***	1746.009***
	0.0837	97356.58	69.96242	0.0934023	95814.22	65.66989
SSNG*Year_2010	1.57022***	2904028***	1794.957***	1.704335***	2990710***	1848.356***
	0.0791	96640.38	69.3278	0.1134139	103463.2	63.77158
SSNG*Year_2011	1.710436***	3310125***	2291.906***	1.930671***	3452438***	2379.535***
	0.0671	93556.27	66.78656	0.118388	109657	59.10234
SSNG*Year_2012	2.427512***	4989899***	4284.86***	2.733265***	5187469***	4406.508***
	0.0762	86106.24	69.90968	0.0876789	66433.36	39.01434
SSNG*Year_2013	6.685467***	13800000***	12394.66***	7.076482***	14100000***	12550.23***
	0.1464	138144.4	91.59459	0.0707656	47011.87	35.75633
SSNG*Year_2014	17.72597***	36100000***	21295***	18.20215***	36400000***	21484.47***
	0.2538	211687.8	113.8152	0.1156678	90400.15	39.20931
SSNG*Year_2015	26.746***	54800000***	25688.56***	27.30727***	55200000***	25911.9***
	0.4185	274373	154.2026	0.2478201	137565.1	76.09111
usgdppercapita	-7.33E-07	-0.6754863	-0.000382	-5.18E-07	-0.5413741	-0.000306
	6.12E-07	0.5207663	0.0003003	5.47E-07	0.437868	0.0002672
R-sq.	0.59	0.91	0.91	0.65	0.92	0.92

*Note: *** denotes 1% Significance Level*

Consider first the results for solar share of net generation, shown graphically in the top graph of Figure 8. Prior to 2006, there is a flat trend over time in the λ_t's and these coefficients are all slightly above zero. This flat trend in λ_t's indicates that prior to 2006, states with a higher solar share of net generation (SSNG) and states with relatively lower SSNG had relatively similar growth rates of SSNG. From Table 2**,** we observe that the λ_t's prior to 2006 are positive and statistically significant at the one-percent level, indicating that states with initially higher SSNG did have higher SSNG than states with initially lower SSNG in years before 2006. However, the value of these coefficients is near zero, implying that states with initially higher SSNG had only marginally higher SSNG in the pre-period years relative to states with initially lower SSNG. After 2006, the trend in the λ_t's is increasing over time, and these coefficients are statistically significant and positive at the one-percent level. These results suggest that in the years following 2006, SSNG starts to grow faster in states with initially higher SSNG (this is the state's 2001 SSNG) relative to states with initially lower SSNG. From Table 2, we can see that nearly all of our coefficients are statistically significant and positive. Such findings indicate that states with initially higher SSNG prior to the Solar ITC experienced significant, greater growth in SSNG levels in the years after the implementation of Solar ITC compared to states with initially lower SSNG.

The bottom two graphs in Figure 8 below show that the same basic result holds for the two other variables used to measure solar installation and utilization, namely solar net generation and installed solar nameplate capacity. The pattern of coefficients for solar net generation follows the same trend as SSNG.


Solar Share of Net Generation
Solar Share of Net Generation (SSNG)
30
25
20
15
10
5
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year


Solar Net Generation
Solar Net Generation (in Megawatthours)
60000000
50000000
40000000
30000000
20000000
10000000
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

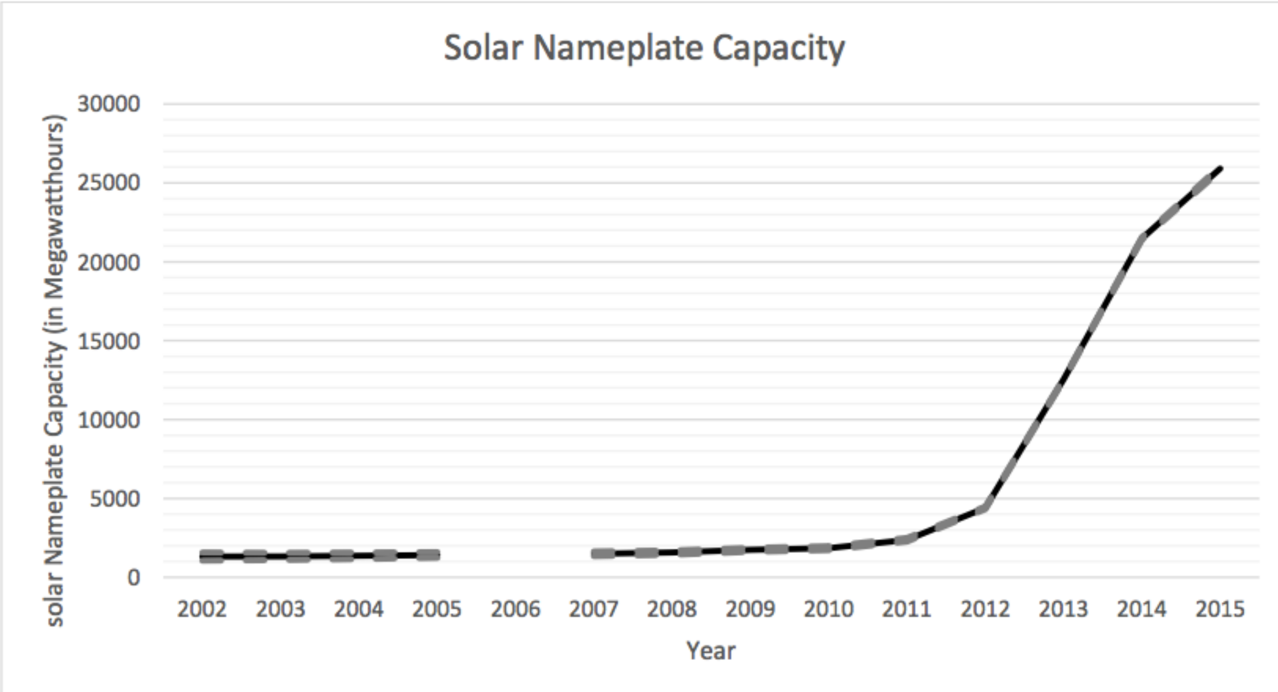


FIGURE 8

Figure 8 graphs the pattern of coefficients — the λ_t's — on the interaction term *(SSNG$_i$)*(Year$_t$)* for 3 variables. The first row graphs the flexibly estimated pattern of coefficients for SSNG and the second row provides the pattern of λ_t's for Solar Net Generation in megawatthours (MWh). The bottom row graphs the pattern of λ_t's for Installed Solar Nameplate Capacity in MWh.

A nearly identical pattern in the trend of λ_t's holds when examining installed solar nameplate capacity as well. Such results are consistent with our first finding for the solar share of net generation (SSNG). This consistency is as we would expect, given that all three variables are essentially different proxies for measuring changes in solar installation and utilization.

Our results have pertinent implications both for policy-makers and residential, commercial, and utility solar energy investors. I find that in the years prior to 2006, states with an initially higher solar share of net generation (SSNG) had only a marginally higher percentages of SSNG compared to states with initially lower SSNG, on average; further, the values of these coefficients are relatively small compared with the coefficients we observe in the post-period years. Overall, this suggests that states that initially installed and utilized solar as a greater mix of their net electricity generation did not have meaningfully higher generation from solar relative to other energy sources, when compared with states that initially had lower SSNG, on average. However, in the post-ITC period between 2007-2015, our increasing trend in λ_t's suggests that states with initially higher SSNG experienced greater growth rates of SSNG when compared with states who initially had lower SSNG. This finding implies that states with initially higher SSNG prior to the implementation of the Solar ITC were the very states who took most advantage of the tax credit to invest in more solar energy systems, on average. Measuring the effect of the Solar ITC on states' solar net generation and installed solar nameplate capacity yields the same results. Thus, it seems this policy stimulated significant, noticeable growth in solar investment in precisely those states which already had a relatively larger propensity to invest in and install solar energy systems prior to the implementation of the Solar ITC, when compared to states with initially lower levels solar installation and utilization.

4.3 Ancillary Results and Implications

It is apparent that the Solar ITC had significant impacts on states' solar installation and utilization, on average. Ancillary to this analysis, it is of interest to examine how such changes in state-level solar installation and utilization and differences in rates of solar installation and utilization affected other relevant outcomes. In particular, I will examine trends in Retail Sales of Electricity in the Total Electric Power Industry using three measures: the log average electricity price, the log of revenues, and the log of customers.

TABLE 3

Regression Results for Total Electric Power Industry

Model 1: Ancillary Results with Varying Specifications

	(1)			*(2)*		
	Retail Electricity Sales			Retail Electricity Sales		
	Log of Average Electricity Price	Log of Revenue	Log of Customers	Log of Average Electricity Price	Log of Revenue	Log of Customers
SSNG*Year_2002	2.964512***	7.927124***	6.556241***	2.639893***	7.607659***	6.520486***
	0.2028471	0.7949985	0.8790522	0.2072943	0.964846	1.019763
SSNG*Year_2003	2.73007***	7.806482***	6.659966***	2.455953***	7.537042***	6.629952***
	0.2016595	0.7983252	0.8786273	0.1999195	0.9379723	0.9948957
SSNG*Year_2004	2.477777***	7.662585***	6.661969***	2.25416***	7.443184***	6.637707***
	0.2019033	0.7978637	0.8763797	0.1962461	0.9088874	0.9694084
SSNG*Year_2005	2.322016***	7.461045***	6.713608***	2.148893***	7.291704***	6.695111***
	0.2031797	0.8014138	0.8788317	0.1954047	0.885175	0.9497454
SSNG*Year_2007	2.248405***	7.427211***	6.74812***	2.176349***	7.357702***	6.740959***
	0.2066457	0.7999732	0.8777678	0.2002752	0.8343058	0.9088474
SSNG*Year_2008	1.879429***	7.12413***	6.725086***	1.85796***	7.104345***	6.723464***
	0.2089217	0.7982704	0.874807	0.2063327	0.811156	0.8883954
SSNG*Year_2009	2.070843***	7.274229***	6.628493***	2.100029***	7.303924***	6.632245***
	0.207563	0.7966106	0.8726233	0.2098381	0.7904097	0.8705292
SSNG*Year_2010	1.943413***	6.969988***	6.592713***	2.023189***	7.049398***	6.601998***
	0.2060018	0.7983681	0.8708049	0.2146903	0.7753717	0.8549816
SSNG*Year_2011	1.887963***	6.961033***	6.581191***	2.01831***	7.090223***	6.596053***
	0.2079595	0.7948293	0.8692269	0.224547	0.7577221	0.841513
SSNG*Year_2012	2.00352***	7.093779***	6.623446***	2.184383***	7.27295***	6.644019***
	0.2098232	0.7976974	0.8726399	0.2353979	0.7485117	0.8346008
SSNG*Year_2013	2.101194***	7.22876***	6.674301***	2.332548***	7.457999***	6.700645***
	0.2099385	0.7993709	0.8754255	0.2470936	0.7409675	0.8291072
SSNG*Year_2014	2.185159***	7.347994***	6.696402***	2.466996***	7.627333***	6.728539***
	0.2105371	0.8008187	0.8774479	0.2605261	0.7356766	0.824699
SSNG*Year_2015	2.228885***	7.434121***	6.762992***	2.561197***	7.763586***	6.800938***
	0.2097182	0.8032925	0.8782588	0.2739284	0.7355243	0.8214119
usgdppercapita	0.00000243***	-0.00000942*	-0.0000162***	2.45e-06***	-0.00000949*	0.0000163*
	7.30E-07	4.87E-06	4.58E-06	7.47E-07	4.90E-06	4.61E-06
R-sq.	0.8	0.54	0.57	0.99	0.99	0.99

*Notes: *** denotes 1% Significance Level, * denotes 10% Significance Level*

Graphically, looking first at the log of average electricity price in Figure 9 below, we observe a downward trend in the λ_t's prior to 2006. From Table 3, we see that these pre-period coefficients are all positive and statistically significant at the one-percent level. In combination, these results suggest that the average electricity price was higher in states with initially higher levels of SSG relative to states with lower SSNG, and that this difference in average electricity price was decreasing over time prior to the implementation of the Solar ITC. In the years following the implementation of the Solar ITC, the pattern of λ_t's is increasing with time. From Table 3, we observe that these coefficients are all positive and statistically significant at the one-percent level.

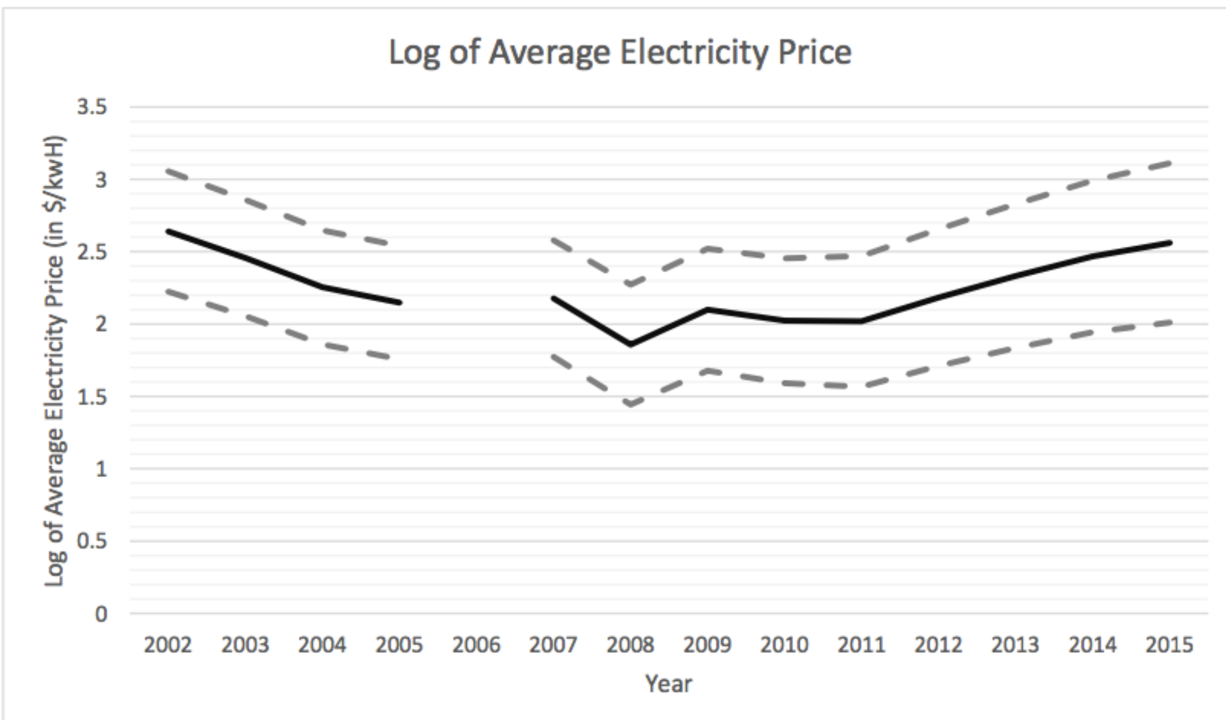


FIGURE 9

Figure 9 graphs the pattern of λ_t's for the log of Average Electricity Price in the Total Electric Power Industry. This units of measurement for this variable are $/kWh.

Together, these findings suggest that on average, states with initially higher levels of SSNG — i.e. the states where the Solar ITC had the largest effect on states' SSNG, on average — continued to have higher average electricity prices relative to states where the Solar ITC had less of an effect on their SSNG, between 2007 and 2015. However, unlike the decreasing pre-period trend in these coefficients, in the years after the implementation of the Solar ITC we see that the relative difference in average electricity prices between states where the Solar ITC had a large effect on SSNG and states where it had less of an effect is increasing over time.

Intuitively, the expectation is that states where the Solar ITC had a larger effect on SSNG would experience decreasing average electricity prices relative to states where the Solar ITC had less of an effect on SSNG. The basic mechanism through which this works is the following. As states invest more heavily in solar energy systems, their net generation levels and energy mixes from solar energy rise. In turn, their demand for electricity from energy suppliers within the Total Electric Power Industry falls. As a result, we expect that these suppliers of electricity will lower their average electricity prices to out-compete a now relatively cheaper source of electricity (Comello, Stephen et al). However, what I find graphically and in the regression results suggests that the increase in solar installation and utilization as a result of the Solar ITC did not have much of an affect on curbing average electricity prices in states where the Solar ITC had a larger effect on SSNG relative to states where it had less of an effect. In fact, in the years after the implementation of the Solar ITC, differences in average electricity prices between states where the Solar ITC had a larger effect on SSNG and states where it had less of an effect rose, on average. This positive trend in the years 2007-2015 suggests that the Solar ITC did not have an effect on reducing the differences in average electricity prices between states with higher SSNG and states with lower SSNG. Such lack of meaningful impacts to the trend of average electricity prices post-ITC may be attributable to the fact that the actual percentage of SSNG in many states was relatively low compared to other energy sources. As a result, even with a statistically significant increase in average state-level SSNG, the overall level of SSNG in these states was not large enough, on average, to meaningfully reduce average electricity prices between states with higher SSNG and states with relatively lower SSNG.

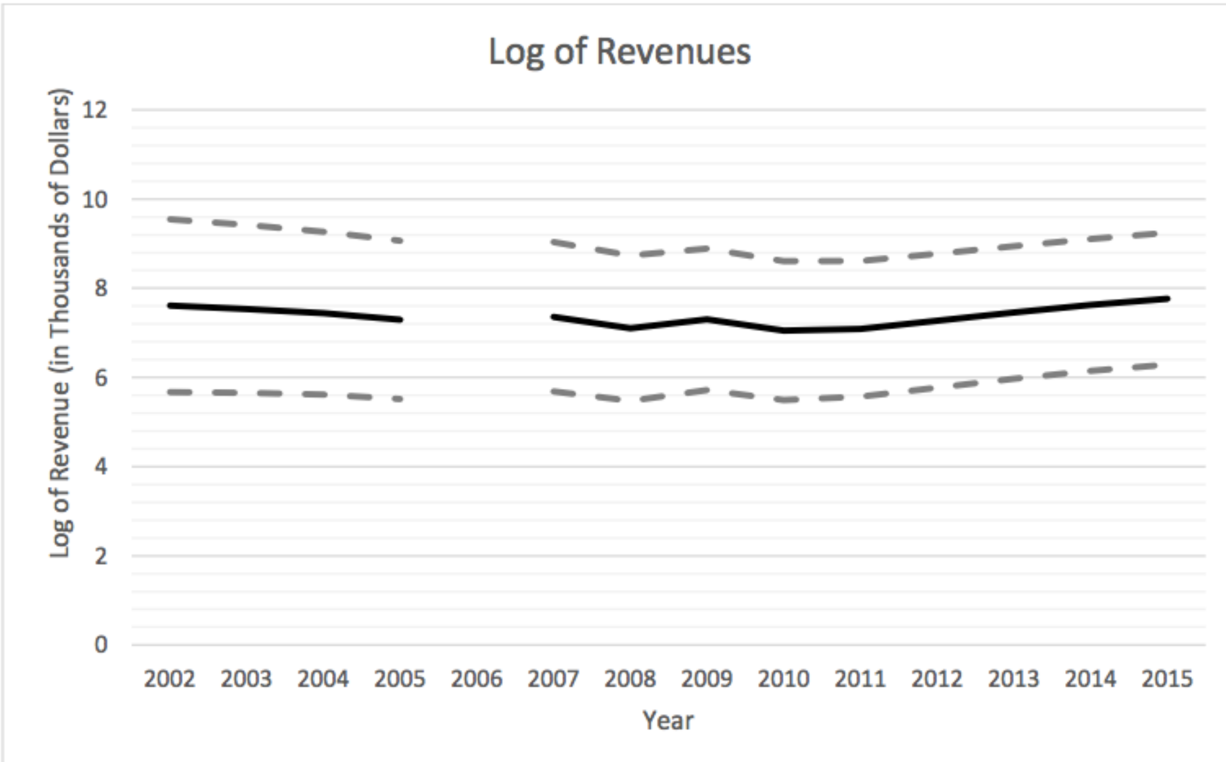


FIGURE 10
Figure 10 graphs the pattern of λ_t's for the log of revenues in the Total Electric Power Industry. Revenues are measured in thousands of dollars.

The next outcome of interest used to measure responses to an increase in states' SSNG as a result of the Solar ITC is the log of revenue. Here, revenue is measured in thousands of dollars for electric and power suppliers in the Total Electric Power Industry (SEIA). It is apparent that the Solar ITC had significant impacts on states' solar installation and utilization, on average. Graphically, looking at trend in the λ_t's for the log of revenue outcome in Figure 10 above, we observe a slight downward trend in the λ_t's prior to 2006. From Table 3, we see that these pre-period coefficients are all positive and statistically significant at the one-percent level. In combination, these results suggest that the difference in revenues between states with initially higher SSNG and states with initially lower SSNG was decreasing over time prior to the implementation of the Solar ITC. In the years following the implementation of the Solar ITC, the pattern of λ_t's is fairly flat. From Table 3, we observe that these coefficients are all positive and statistically significant at the one-percent level — as well, they are approximately equivalent in value to the coefficients in the pre-period years. Together, these findings suggest that on average, states with initially higher levels of SSNG — i.e. the states where the Solar ITC had a larger effect on states' SSNG, on average — continued to have higher levels of revenue relative to states where the Solar ITC had less of an effect on their SSNG, between 2007 and 2015. Further, in the years after the implementation of the Solar ITC we see that the relative difference in revenues between states where the Solar ITC had a large effect on SSNG and states where it had less of an effect is fairly constant over time. Intuitively, the expectation is that states where the Solar ITC had a larger effect on SSNG would experience decreasing average revenues relative to states where the Solar ITC had less of an effect on SSNG. The basic mechanism through which this works is similar to that which was discussed for average electricity prices. As states invest more heavily in solar energy systems, their net generation levels and energy mixes from solar energy rise. In turn, their demand for electricity from energy suppliers within the Total Electric Power Industry falls. As a result, we expect that these suppliers of electricity may suffer in their bottom lines as more individuals, businesses, and utilities within a state install more solar energy systems (Bergmann, Ariel et al). However, what I find graphically and in the regression results suggests that the increase in solar installation and deployment as a result of the

Solar ITC did not have much of an effect on revenues in states where the Solar ITC had a larger effect on SSNG relative to states where it had less of an effect, on average. In fact, in the years after the implementation of the Solar ITC, differences in revenues between states where the Solar ITC had a larger effect on SSNG and states where it had less of an effect remain fairly constant, on average. This flat trend in the years 2007-2015 imply that the Solar ITC did not have much of an effect on reducing the differences in revenues between states with higher SSNG and states with lower SSNG. Such lack of meaningful impacts to the trend of revenues post-ITC may be attributable to the fact that the actual percentage of SSNG in many states was relatively low compared to other energy sources. As a result, even with a statistically significant increase in average state-level SSNG, the overall level of SSNG in these states was not large enough, on average, to meaningfully change the trend of revenues between states where the Solar ITC had a larger effect on SSNG and states where it had less of an effect.

The last outcome of interest I examine is the log of customers for the Total Electric Power Industry. Figure 11 below plots the pattern of the λ_t's for this outcome. Prior to 2006, the slope of these coefficients is just slightly positive, suggesting that the trend in the growth of customers purchasing electricity was marginally higher for states with initially higher SSNG relative to states with initially lower SSNG. Similar to the pattern of coefficients for the log of revenues in Figure 11, the trend of the λ_t's in the years after the implementation of the Solar ITC are flat. This result implies that the difference in the growth of customers purchasing electricity between states where the Solar ITC had a larger effect on SSNG and states where it had less of an effect remained roughly constant over time in the years following the implementation of the

Solar ITC, on average. Like our results for revenues, the results of this regression suggest that although the Solar ITC did indeed significantly impacts states' SSNG, the change in solar installation and utilization did not result in any meaningful differences in the trend of customers when compared to the pre-period trend, on average.

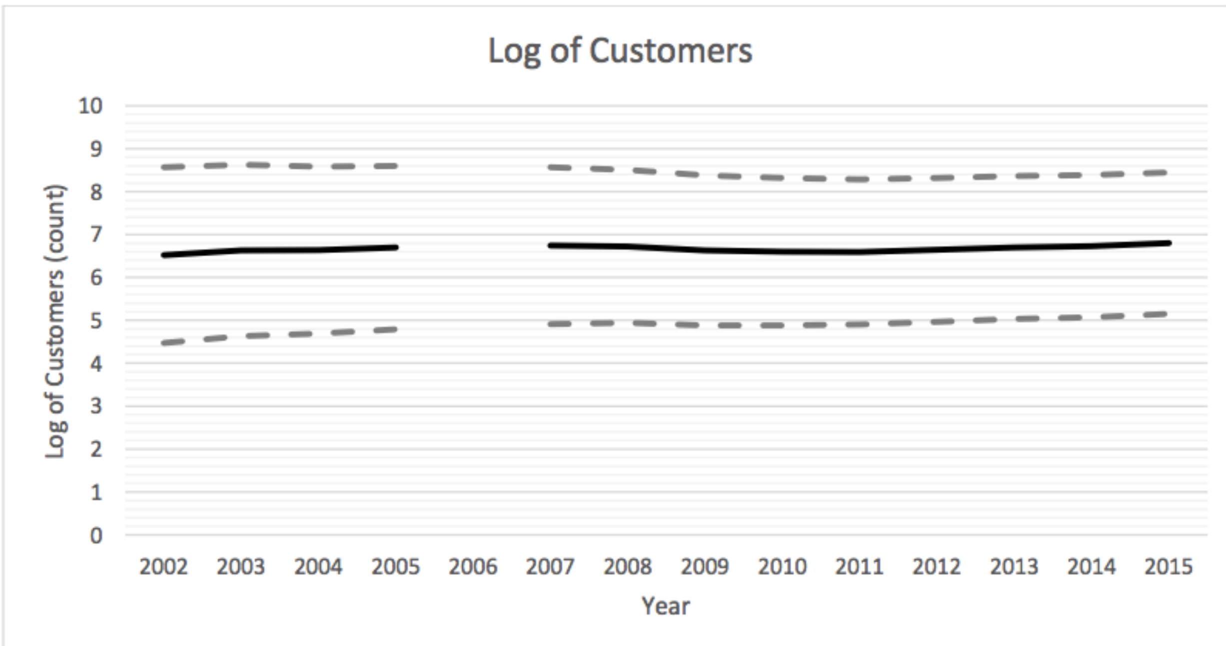


FIGURE 11
Figure 11 graphs the pattern of λ_t's for the log of customers in the Total Electric Power Industry. Customers are simply counted.

6. CONCLUSION

The implementation of the Solar Investment Tax Credit (ITC) has driven rapid growth in the installation and utilization of solar energy systems in the United States. My results suggest that the Solar ITC significantly impacted solar energy installation and utilization at the state-level primarily in those states which already had higher levels of solar installation and utilization compared with states which had lower levels, on average. States with initially higher baseline levels of SSNG — i.e. their 2001 measures of SSNG — prior to the implementation of the Solar ITC did not meaningfully higher growth in solar installation and utilization *relative* to states with initially lower SSNG in the pre-ITC period. In the years following the implementation of the Solar ITC, I find that states with initially higher SSNG experienced significantly higher growth in solar installation and utilization compared to states with relatively lower initial SSNG. These results suggest that the Solar ITC had a larger effect on solar installation and utilization in states which initially had higher levels of SSNG and less of an effect on states with initially lower levels of SSNG. Ancillary to this, I examine changes in the trends of various Retail Sales of Electricity outcomes between states in which the Solar ITC had more of an effect and states in which it had less of an effect. Broadly speaking, I find no meaningful changes in average electricity prices, revenues, and customers between states where the Solar ITC had more of an effect on SSNG and states where it had less of an effect. These findings may imply that although the Solar ITC did significantly increase solar installation and utilization, it did not raise these levels by meaningful enough amounts to impact trends in these electricity sales outcomes.

Some limitations to my analysis include the use of census division level fixed effects, rather than state-level. Issues with puzzling and sometimes missing state-level regression output could not be solved in time to include these results in my analysis. In future study, it would be useful top refine the fixed effect to the state-level. Some further areas of research that may be explored in later years as more data is collected, but that I was unable to do, include assessing impacts of the Solar ITC on solar employment. Currently, the most accurate and well-balanced panel data available on solar employment come from The Solar Foundation, but these data only go back to 2006. In the case of my analysis — where examining pre-period trends is of interest — this data did not go back far enough to conduct the desired tests. However, one potential area for further research here involves comparing the growth rate of these jobs since the introduction of solar relative to the growth rate of jobs directly competing with the solar industry. Similar to data on solar job employment, well balanced data on the dollar amount invested in solar energy by state by year was unavailable or could not be found. One final area of future analysis involves a sector-level analysis of the effects of the Solar ITC on residential solar, commercial solar, and utility solar separately. Comparing differences between states at a sector-by-sector level may provide useful information for policy makers as to the effectiveness of such tax credits and the types of investors who most utilize them. For the avenue of research, I spent much time gathering and aggregating data from various sources to build the appropriate sector-level dataset. However, I was unable to find complete data on state-level solar net generation and total net generation by sector dating back to pre-period years. These limitations, roadblocks, and areas for improvement should be considered when assessing the results presented in this paper.

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