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The adoption of solar cells in the US: A cross-section analysis

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Abstract

The amount of solar energy that falls on the earth's surface in one minute equals the total annual energy consumption of the entire world's population. The question is how to harvest the energy efficiently. Photovoltaic or solar cell is one of the few means of to harvest this energy. The main objective of this paper is to identify factors that determine the number of photovoltaic panel installation per a million people in the US and build a regression model to quantify their effect. Ten independent variables were studied and their effect was quantified. In addition, different statistical hypothesis tests were performed on the model to check its validity and the results are presented as follows.

Keywords

Econometrics, Solar Cell, United States of America

Cover Page Footnote

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1. Introduction

Finding an alternative source of energy is one of the most pressing issues of the current era. Carbon dioxide emitted from burning fossil fuels is creating a huge problem for the Earth's climate, which affects both current and future organisms. Global warming is one of the biggest environmental problems associated with fossil fuel use. It is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century, the beginning of the industrial revolution. Climate model projections estimated that the global surface temperature is likely to rise by about five times in the 21th century compared to the increase in 20th century. The effects of an increase in global temperature include a rise in sea levels, a change in the amount and pattern of precipitation, and a probable expansion of subtropical deserts. Other likely effects of the warming include a more frequent occurrence of extreme-weather events including heat waves, droughts, heavy rainfall, ocean acidification, and species extinctions due to shifting temperature regimes. Effects significant to humans include the threat to food security from decreasing crop yields and the loss of habitat from inundation[1].

Renewable energy sources are one of the ways to tackle these challenges and the sun is the most powerful energy source. Solar energy is the cleanest and most abundant renewable energy source available[2]. Modern technology can harness this energy for various applications such as generating electricity, providing light or a comfortable interior environment, and heating water for domestic, commercial, or industrial use [2]. The world's energy consumption rate is expected to double from 13.5 TW in 2001 to 27.6 TW by 2050 and triple to 43.0 TW by 2050[3]. Solar energy has the greatest potential for meeting these energy demands. The amount of solar energy that falls on the earth's

surface in one minute equals the total annual energy consumption of the world. In addition, the radiation intensity of the sun is equivalent to the intensity obtained by burning hundred liters of oil[4]. The question is how we can harvest this energy efficiently.

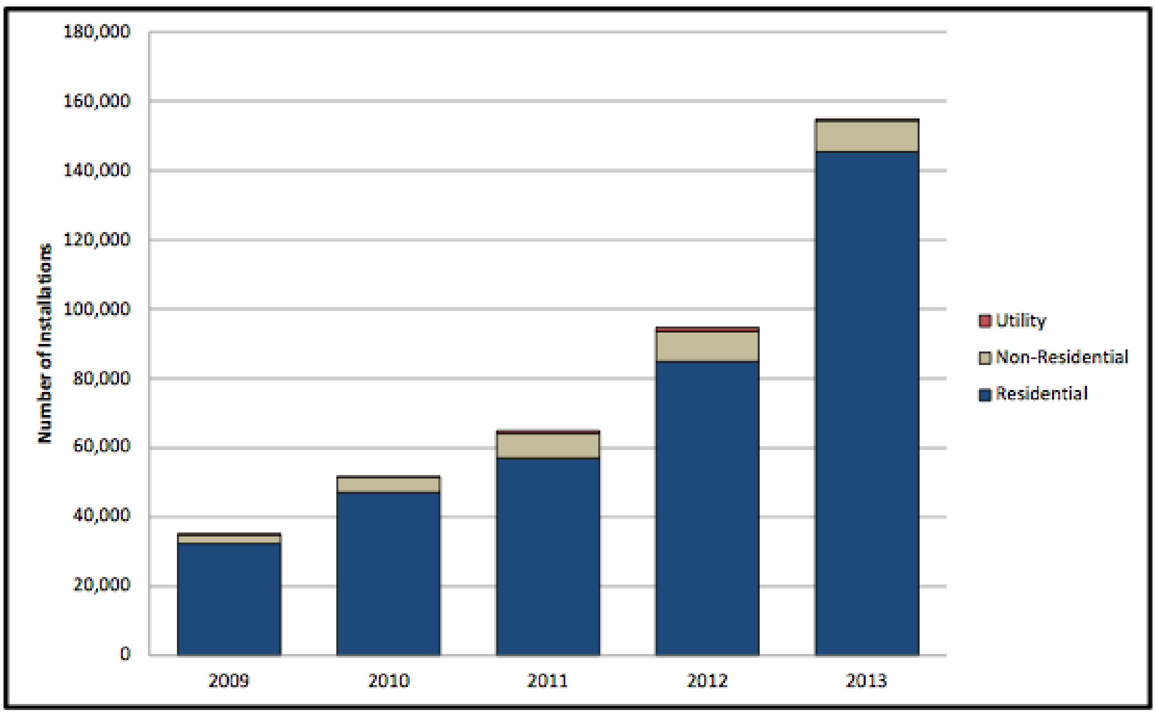
1.1 Various ways of harvesting solar energy

Photovoltaic (solar cells), solar water heating systems, solar power concentration and transpired solar collectors (solar wells) are the four main ways to harvest the energy from the sun[5]. Photovoltaic is installed on houses while others are usually installed in energy production sites. A photovoltaic cell is a semiconductor device that is carefully designed to efficiently absorb and convert light energy from the sun into electrical energy. In this paper, the terms photovoltaic (PV), solar panel and solar cells will be used interchangeably.

2. Literature Review

After their inventions in the 1950's, modern photovoltaics were first used to power satellites. In the past five years; however, the demand for photovoltaics in both utility and customer side of the meter has been increasing almost exponentially[6]. In the utility sector, the photovoltaic installations in 2010 quadrupled over 2009 installation. Grid connected to PV contribution to the utility sector grew from virtually none in 2006 to 15 percent in 2009 and 32 percent in 2010. In addition, the number of PV installation in 2010 increased by 45 percent over 2009[7]. In 2013, the number of PV panels in residential areas grew by 68 percent in the US due to the increased use of leases and third-party ownership. In this year, more than 145,000 residential PV panels were installed. Similarly, the number of PV systems used in utility grew by 47 percent and more than 75 percent of these

installations were in California, Arizona and North Carolina. 57 percent of photovoltaic installed in the US in this year was in California[6]. The overall trend in the number of PV installations in the US between the year of 2009 and 2013 is shown in the Fig.1. Since its first innovation, it took about four decades for the PV technology to have such significant impact in energy production in the US. The study of factors that could contribute for this change is essential in both understanding the current phenomenon and predict the future of PV systems for energy production. The ultimate goal is to harvest more solar energy and increase its contribution to the total electricity production. Figure 2 below shows that 31 percent of electrical energy production in the US is from PV panels and concentrating solar power[6].



NB: Non-residential refers to government buildings, retail stores and military installations

Figure 1. Number PV installations in the US between the year of 2009 and 2013[6].

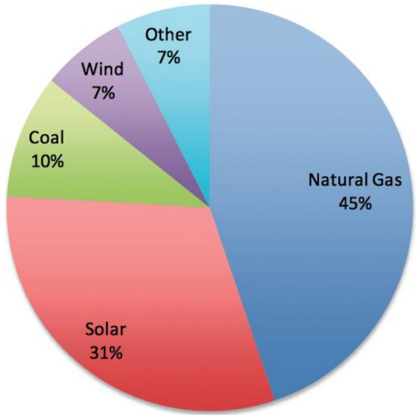


Figure 2. U.S. electric generation installed in 2013 by technology[6].

3. Empirical framework

The main objective of this paper is to discover factors that determine the number of photovoltaic panel installation per million people in the US and build a regression model to quantify their effect. The US is chosen for this study because it is the country with the highest per capita power consumption in the world[8]. This implies that the country must find a clean and efficient ways of obtaining energy for the well being of world climate. As mentioned earlier, the sun is the most powerful clean energy source. In addition, the fuel is free! Once the higher initial costs of a solar panel are recovered through reduced or avoided energy costs (that is, lower utility bills), solar panel will require expenditures only for maintenance[5]. Despite these benefits, the US stands fifth in the world in terms of the amount solar energy used[9]. Thus, determining factors that will affect the amount of solar energy consumption in the country will be helpful to suggest cost efficient and feasible ways to increase the number of photovoltaic panel installation thereby cutting down carbon dioxide and toxin emissions from either burning fossil fuels or running nuclear power plants.

A data set was obtained from 51 states to build the regression model in order to take the geographical, economical and political differences in to account. Given their geographical location, different states have different degrees of sunlight exposure. In addition, the average income of individuals varies with states and this has an impact on solar panel installation. The price of other energy sources also determines whether solar energy is preferred or not. In addition, the political stand of the states on renewable energy is different and it is reflected through their energy policies.

Technology is transforming at exponential rate[10] and the photovoltaic industry has been experiencing dynamic change in the performance and quantity of its products. However, the regression model aims to quantify the effect of ten independent variables, not including technology, on the number of photovoltaic panel installed in million people, which are discussed in the following sections. In order to increase the accuracy of the model, technology was not included as a variable and its effect on the ten independent variables was minimized. Analysts usually use a one-year period to estimate the impact of technology on photovoltaic industry[11] and in this time period the change in technology has the minimum influence on the dependent variable used for this study. As a result, all data sets are collected from one year; 2014, and thus it is the most recent and the independent variables have not changed significantly since. Therefore, the regression model built based on this data is the most accurate representation of the current status in photovoltaic industry.

4. Model Specification

The regression model that describe the number of photovoltaic panel installed in million people, PVIPMP, as function of different factors that affect it is given by

$$\boldsymbol{PVIPMP_i} = \beta_0 + \beta_{LE,i}LE_i + \beta_{PCI,i}PCI_i + \beta_{PV,i}P_{PVi} + \beta_{CE,i,}P_{CE,i} + \beta_{NG,i}P_{NG,i} + \beta_{PT,i}P_{PT,i} + \beta_{BIO,i}P_{BIO,i} + \beta_{U:R,i}P_{U:R,i} + \beta_{COMP,i}N_{COMP,i} + \beta_{EP,i}EP_i + \epsilon \qquad \text{Eq(1)}$$

where $PVIPMP_i$ is the number of PV installed per million people , LE_i is longitudinal efficiency in kWh/day, PCI_i is the per capita income, $P_{PV,\,i}$ is the average cost of photovoltaic and its installation, $P_{CE,\,i}$ is the cost of coal measured in dollars per BTU(dollars/BTU), $P_{NG,\,i}$ is the cost of natural gas measured in dollars/BTU, $P_{NP,\,i}$ is the cost of petroleum measured in dollars/BTU, $P_{BIO,\,i}$ is the cost of biomass in dollars/BTU and EP_i is the energy policy in state *i*. In addition, $\beta_{x,i}$ is the coefficient that describes how the unit change in the dependent variable x causes the change in PVIPMP everything else kept constant. ∈ is the residual error, which is difference between the true model and the model shown above.

4.1 More on the variables and Hypothesis about the coefficients

The number of PV installed per million people, $PVIPMP_i$, is the dependent variable for this study and it depends on different independent variables explained below. Fig. 3 shows the total number of PV panels installed in different states[12].

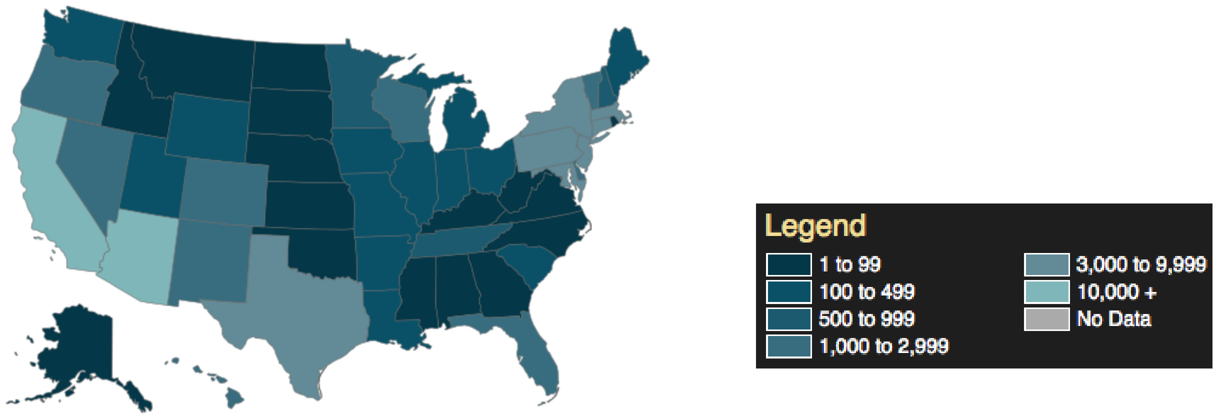


Figure 3. Solar panel installations in different state[12].

Arizona ranks first among all states in number of solar PV systems installed with 17338. It is followed by California then Massachusetts, which have 134,759 and 9766 PV systems respectively. South Dakota, Oklahoma and North Dakota are in the bottom of the rank with total PV panels of 16, 9 and 3 respectively.

4.1.1 Longitudinal efficiency of solar panel (LE)

This variable measures the efficiency of solar panel in a state in terms of the maximum energy it can produce per day. The efficiency of solar panel is determined by the amount of solar energy it receives in a day. However, due to the variation in geographical location (longitude) of states, the amount of solar energy per unit land is not the same for different states, as shown below. For example, according to the study performed by Florida Solar Energy Center, a 2kW photovoltaic can operate at its maximum efficiency, 8.5 kWh/day, only in the southwest desert and it is less in other parts of the US[13]. The model account for this difference and its effect on solar panel installation through a variable called LE. The more LE the more likely that the state will have more solar panel installation thus the coefficient β_{LE} is positive. As the image illustrates, solar

photovoltaic systems work just about anywhere in the US including the Northeast or in "rainy Seattle" where solar panels work with about 60% efficiency (5kWh/day)[13].

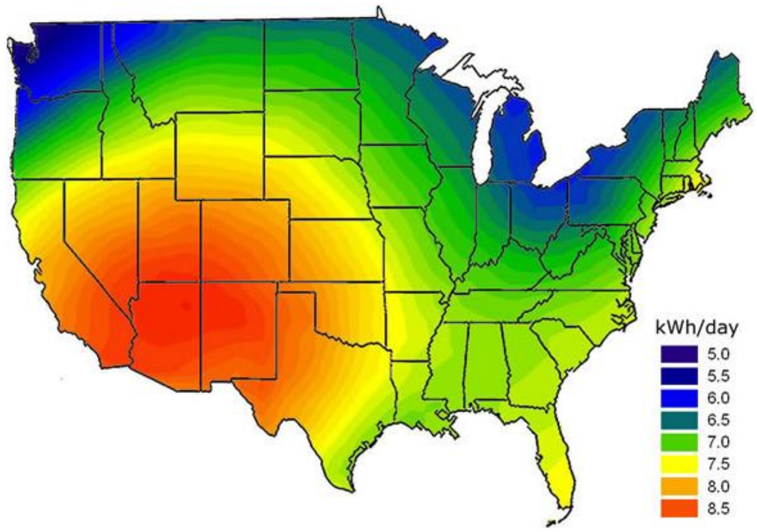


Figure 4. Longitudinal efficiency of solar panels across different states in the US[13]

4.1.2 Per capita income (PCI_i)

PCI is the variable that quantifies the purchasing potential of consumers. People in different states have different average income. The more the average income of individuals in state *i* is the more the they will be willing to install solar panels on their buildings. Therefore, the coefficient relating PCI with PVPMP, β_{PCI}, is positive. The PCI of each sates is found on US department of commerce site[14].

4.1.3 Average cost of photovoltaic and its installation (P_{PV})

P_{PV} is measured in thousands of dollars and the value stays relatively the same in one-year duration. However, the average cost of going solar is not the same for different state, as shown below[15]. State's political will to subsidize solar cell installation could be one potential cause for this difference. The more expensive the price is the less people would

want to install solar cells on their buildings. Thus, it has indirect relationship with PVIPMP. The coefficient, β_{PV}, is then expected to be less than zero.

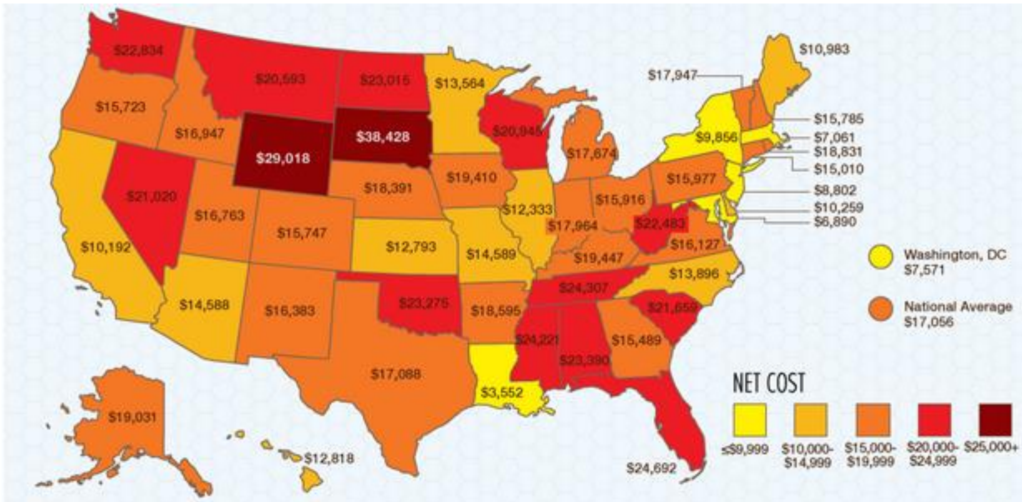


Figure 5. Average cost of solar installation in dollars at different states[15]

4.1.4 Cost of Coal (P_{CE}) , Natural gas (P_{NG}), Petroleum (P_{PT}) and Biomass (P_{BIO})

These costs are also measured in dollars per million Btu. Coal, nuclear power, petroleum and biomass are substitute good for renewable energy sources such as solar energy. The price of these goods is found from *U.S. Energy Information Administration (EIA)* website[16]. According to fundamental economic principles, substitute goods have positive cross elasticity which means the increase in cost of coal, nuclear power, natural gas and hydroelectric power production (price of the goods) will increase the demand for solar panels thereby increasing amount of photovoltaic installation. In other words, suppose the price of coal or nuclear power rises from P_1 to P_2, as shown below, because one of the inputs rises in price. This would cause people to consume less electricity from coal or natural gas; quantity decreases from Q_1 to Q_2. The demand curve for electricity from

solar energy using solar panels shifts for all price level, from D to D', leading to more of it consumed[17]. Thus, the coefficient β_{CE}, $\beta_{NG,}$ β_{PT} and β_{BIO} are positive.

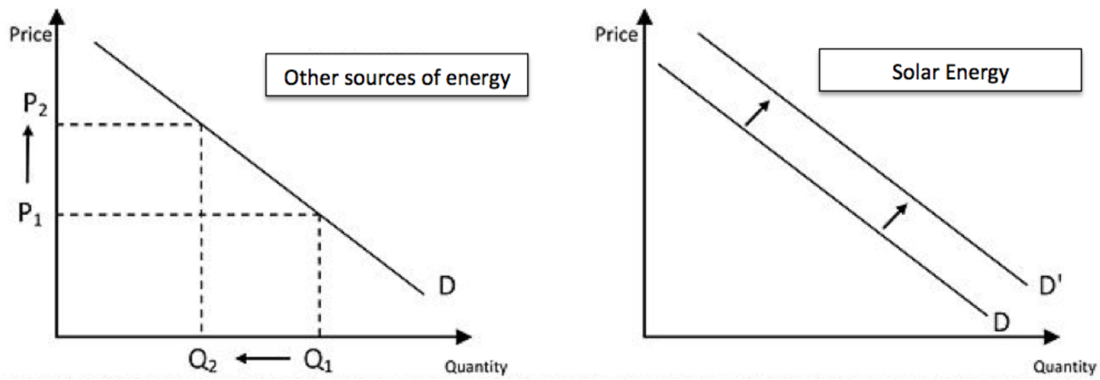


Fig. 6 Impact of price of coal and nuclear power on solar panel installation[17]

4.1.5 Urban to rural ratio (U:R)

Most of solar panels are installed in rural areas. Studies shows that a strong differential growth rate in rural applications of PV, which now accounts for nearly half of the total PV market[18]. One possible reason for this is the low population density in rural areas which makes the effective cost of grid installation very high. There are few people who depend on a grid in rural areas than urban places. This makes PV installation in rural areas relatively cheaper. As a result, the urban to rural ratio of states could be a variable that can affect the number of PV installation in a state. The higher the U:R ratio the smaller the PVIPMP is. Thus, $\beta_{U:R}$ *is* negative coefficient.

4.1.6 Number of solar companies per state (N_{COMP})

This variable is the total number of companies that either have office or provide service for PV customers in the state. Local solar companies are highly likely to provide a better

service at a cheaper price for the local people. This can be an incentive for people to buy more solar panels. Therefore, β_{COMP} is expected to be positive.

4.1.7 Energy policy (EP)

Energy policies are crucial in expanding the use of renewable energy sources. Renewable state energy policies are usually grouped in two categories. The first category includes tax incentives, grants, loans, rebates, and production incentives which provides financial incentives to encourage renewable energy. The second category contains rules and regulations, which mandate a certain action from an obligated entity[19]. Through incentives and subsides, energy polices play great role in increasing solar energy harvest. Different states have different perspectives about climate change and the need for clean energy. This difference is due to variation on political views and finical potential. EP is treated as dummy variable to measure its effect on the amount of solar panel installation. In general, states with total number of PV installations greater than 200 are assumed to have energy policy that advocates using solar energy and thus have EP values of 1. On the other hand, states with PV panels less than 200 are given a value of 0 for EP.

In summary, the following table shows the null and acceptable hypothesis for the independent variables used in the model.

Independent Variable	Null Hypothesis (Ho)	Acceptable Hypothesis (H_A)
LE	$\beta_{LE} \leq 0$	$\beta_{LE} > 0$
PCI	$\beta_{PCI} \leq 0$	$\beta_{PCI} > 0$
P_{PV}	$\beta_{PV} \geq 0$	$\beta_{PV} < 0$
P_{CE} ,P_{NG}, P_{PT}, P_{BIO}	$\beta_{CE} \leq 0$, $\beta_{NG} \leq 0$, $\beta_{PT} \leq 0$,	$\beta_{CE} \geq 0$, $\beta_{NG} \geq 0$, $\beta_{PT} \geq 0$,

	$\beta_{BIO} \leq 0$	$\beta_{BIO} \geq 0$
U:R	$\beta_{U:R} \leq 0$	$\beta_{U:R} \geq 0$
N_{COMP}	$\beta_{COMP} \geq 0$	$\beta_{COMP} \leq 0$
EP	$\beta_{EP} \leq 0$	$\beta_{EP} \geq 0$

Table.1 Null and acceptable hypothesis

5. Results

The regression includes fifty-one states or observations (N) and eight independent variables (K). The degree of freedom of the model is thus forty-two (N-K-1)[20]. The table of values for each variable is found on Appendix. STATA software was used to fit ordinary least square (OLS) regression on the number of photovoltaic installation in states and the result is shown below.

Source	SS	df	MS
Model	23898857.3	10	2389885.73
Residual	23458828.7	40	586470.718
Total	47357686.1	50	947153.721

Number of obs	= 51
F(10, 40)	= 4.08
Prob > F	= 0.0007
R-squared	= 0.5046
Adj R-squared	= 0.3808
Root MSE	= 765.81

PVIPMP	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
PCI	.0265702	.01599	1.66	0.104	-.0057468	.0588872
Ppv	-.0267001	.0215863	-1.24	0.223	-.0703277	.0169275
UR	-5.949353	10.0694	-0.59	0.558	-26.30037	14.40167
Ncomp	.6442456	.3265824	1.97	0.055	-.0158021	1.304293
Pce	19.52794	123.0616	0.16	0.875	-229.1888	268.2447
Png	42.42397	24.03678	1.76	0.085	-6.156169	91.0041
Ppt	175.6296	93.0697	1.89	0.066	-12.47128	363.7305
Pbio	93.55698	31.48318	2.97	0.005	29.92711	157.1869
LE	11.48886	192.8269	0.06	0.953	-378.2288	401.2065
EP	134.5795	304.8214	0.44	0.661	-481.4875	750.6466
_cons	-6054.12	3159.329	-1.92	0.062	-12439.36	331.1227

Table.2 STATA result OLS regression fit on the model

6. Discussions

The R-squared value is 0.5046, which means 50.46 percent of the total variation of the dependent variable (true value of PVIPMP) from the mean value ($\overline{\text{PVIPMP}}$) is expressed by the regression model. The following tests were performed on the model to check the validity.

6.1 t-test

A t-test performed to check the acceptability of the null generation is shown below. The critical value of t-distribution, t_c, for one sided test when the degree of freedoms is 42 and the level of significance is 5% is 1.6820[21].

Variables	**$t_k = \beta_{k,i}$/Std**	**Is $\|t_k\| > t_c$?**	**Does the calculated coefficient has the same sign with the alternative hypothesis (H_A)?**
LE	0.06	No	Yes
PCI	1.66	No	Yes
P_{pv}	-1.24	No	Yes
P_{CE}	0.16	No	Yes
P_{NG}	1.76	Yes	Yes
P_{PT}	1.89	Yes	Yes
P_{BIO}	2.97	Yes	Yes
U:R	-0.59	No	Yes
N_{COMP}	1.97	Yes	Yes
EP	0.44	No	Yes

Table.3 t-test for regression model

The null hypothesis is rejected when $|t_k| > t_c$ and t_k has the sign implied by H_A[20]. Therefore, it is possible to reject the null hypothesis related to P_{BIO}, P_{NG}, P_{PT} and $N_{COMP.}$ These are the only four variables that this model can describe the meanings of the coefficients of the variables. The value of β_{LE} we get from fitting OLS regression is 162.69 which means, for a kWh/day increase in longitudinal efficiency there are 162.69 more PV panels installed by a million people, everything else kept constant. Similarly, for a dollar/BTU increase in price of natural gas or petroleum, the number of PV panels installed by a million people increase by 42.42 or 175.63 respectively. In addition, for one more company in a state, the number of PV panels installed by a million people increase by 0.644. Therefore, it is possible to conclude that the price of petroleum has the greatest impact on the dependent variable of this study.

6.2 F-test of overall significance

The null hypothesis, H_0, of this test states that all the coefficients in the model except the constant term are zero and an alterative hypothesis states that the H_o is not true[20]. The constrained equation to which the overall fit is compared to is shown below which is basically the mean of the model.

$$PVIPMP_i = \beta_o + \epsilon_i \qquad \text{Eq(2)}$$

The F value from the STATA software is 4.08. The critical F-value for a numerator degrees of freedom equal to 8 (k) and a denominator degree freedom equal to 42 (N-K-1) is 2.168[22]. Since the calculated F-value is greater than the critical value, the model has a significant overall fit.

6.3 <u>Test for homoscedasticity</u>

One of the main assumptions for the ordinary least squares regression is the homogeneity of variance of the residuals. This means error term has a constant variance. If the variance of the residuals is non-constant then the residual variance is said to be "heteroscedasticy"[20]. One of the tests to check for homoscedasticity is called White's test. It tests the null hypothesis which states that the variance of the residuals is homogenous. Therefore, if the p-value is very small (very close to zero), the null hypothesis is rejected and the alternative hypothesis is accepted [23]. The alternative hypothesis states that the variance is not homogenous. STATA uses a command called **imest** to do White's test and the result is shown below.

Source	chi2	df	p
Heteroskedasticity	51.00	50	0.4341
Skewness	25.61	10	0.0043
Kurtosis	2.54	1	0.1107
Total	79.15	61	0.0590

Table 4. STATA result for White's test

Since the p value of this model is not very small, the null hypothesis cannot be rejected. In other words, there is no heteroscedasticy.

Another way to test for heteroscedasticy is to use chi-square test. If NxR^2, the sample size (N) times the coefficient of determination (the unadjusted R^2), is greater than the critical chi-square value then the null hypothesis can be rejected[19]. However, in this model NxR^2 is 24.75 and the chi-square value with the degree of freedom of 42 at 5% level of confidence is 58.124. Thus, NxR^2 is less than the critical chi-square value. As a result,

the null hypothesis cannot be rejected and thus there is no heteroskedasticity in the model.

6.4 Test for multicollinearity

Another assumption of OLS is that the model should not have multicollinearity. Multicollinearity is the existence of an explanatory variable with a perfect linear function of any other explanatory variable[20]. STATA uses a command called variance inflation factor (vif). 1/vif is called tolerance and this indicates the degree of collinearity. If tolerance value is lower than 0.1, then the variable is considered to be a linear combination of other independent variables and thus multicollinearity exist [23].

```
. vif
```

Variable	VIF	1/VIF
Pce	5.02	0.199088
Png	3.44	0.290337
Phe	2.94	0.340193
Pnp	2.19	0.456776
Percapitai~e	1.49	0.672990
EP	1.42	0.704223
Ppv	1.38	0.725118
LE	1.26	0.795715
Mean VIF	2.39	

Table 5. STATA result for multicollinearity

As shown on the table above, the tolerance of the independent variables is greater than 0.1. This asserts that multicollinearity is not observed in this model.

6.5 Test for specification

Specification is the process of converting a theory into a regression model. This process consists of selecting an appropriate functional form for the model and choosing which variables to include[20].

Specification error occurs when an independent variable is correlated with the error term. There are several causes of specification error and incorrect functional form. Firstly, a variable omitted from the model may have a relationship with both the dependent variable and one or more of the independent variables (omitted-variable bias). Secondly, an irrelevant variable may be included in the model. In addition, if the dependent variable is part of a system of simultaneous equations (simultaneity bias) or if measurement errors affect the independent variables speciation error will occur[20].

Ramsey RESET test is used to test specification. STATA use a commend call ovtest to perform the test.

```
. ovtest

Ramsey RESET test using powers of the fitted values of PVIPMP
       Ho:  model has no omitted variables
                 F(3, 37) =      7.94
                 Prob > F =      0.0003
```

The null hypothesis assumes that there is no omitted variable.

6.6 Test for autocorrelation

Since the model does not have a time series and is only studied for one year, 2014, autocorrelation does not exist in the model. The reason the year 2014 chosen is explained under the empirical framework section.

7. Conclusion

The results of this analysis shows that all the coefficients related to the independent variables have coefficients that are expected in alternative hypothesis. The positive coefficients of LE, PCI, NCOMP, Ep and the substitute goods indicate that PVPMP increase as the independent variables increase. From the ten independent variables, only four of them passed the t-test: PBIO, PNG and PPT and NCOMP. PPT has a greater impact on determining the amount of PV installed by a million people. Currently, the price of petroleum has decreased in all states of the US. For a dollar decrease in PPT, there will be around 176 less PV installed in a state. Because it is assumed that rational consumer will always buy a cheaper substitute good. The model was also tested for heteroscedasticy and multicollinearity, to confirm the classical assumptions of OLS regression. The error term has a constant variance (no heteroscedasticy) and no independent variable is a perfection linear function of any other independent variable (no multicollinearity). In addition, the regression has significant fit confirmed by using F-test. Autocorrelation does not exist in this study because the data is only for one year.

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Appendix

Table 1. Data table for the dependent variable and the ten independent variables in 51 states.

	PVIPMP[11]	Per Capita Income[13]	Price of Photovoltaics[14]
Alabama	6.58	36481	23390
Alaska	3164	50150	19031
Arizona	2919.2	36983	14588
Arkansas	51.09	36698	18595
California	3729.62	48434	10192
Colorado	555.18	46897	15747
Connecticut	2153.95	60658	15010
Delaware	2575.94	75329	7571
District of Columbia	2199.11	44815	10259
Florida	61.5	41497	24692
Georgia	5.73	37845	15489
Hawaii	1821.68	45204	12818
Idaho	30.09	36146	16947
Illinois	28.36	46980	12333
Indiana	61.86	38622	17964
Iowa	47.2	44763	19410
Kansas	9.84	44417	12793
Kentucky	5.27	36214	19447
Louisiana	76.27	41204	3552

Maine	111.24	40924	10983
Maryland	676.92	53826	6890
Massachusetts	1526.24	57248	7061
Michigan	25.49	39055	17674
Minnesota	105.6	47500	13584
Mississippi	20.54	33913	24221
Missouri	57.93	40663	14589
Montana	61.13	39366	20593
Nebraska	10.14	47157	18391
Nevada	628.62	39235	21020
New Hampshire	451.17	51013	15785
New Jersey	1008.27	55386	8802
New Mexico	948.98	35965	16383
New York	359.34	54462	9856
North Carolina	8.75	38683	13896
North Dakota	4.71	53182	23015
Ohio	22.77	41049	15916
Oklahoma	2.54	41861	23275
Oregon	534.46	39848	15726
Pennsylvania	325.83	46202	15977
Rhode Island	39.03	46989	18831
South	31.26	35831	13896

Carolina			
South Dakota	20.62	46039	38428
Tennessee	100.96	39558	24307
Texas	202.1	43862	17088
Utah	148.2	36640	16763
Vermont	2635.42	45483	17947
Virginia	5.95	48838	16127
Washington	32.44	47717	22834
West Virginia	50.64	35533	22483
Wisconsin	219.1	43244	20945
Wyoming	308.27	52826	29018

Continued table…

	U:R(%)[24]	Number of companies[23]	Coal Cost[18]	Natural gas[18]	Petroleum[18]	Biomass[18]	LE[12]	EP[11]
			Dollars/BTU					
Alabama	59.0	173	5.25	6.84	26.58	2.89	7	0
Alaska	66.0	156	4.04	8.19	27.22	16.03	5	0
Arizona	89.8	366	3.14	10.77	27.76	13.15	8.5	1
Arkansas	56.2	227	3.49	7.83	27.58	3.21	7.25	0
California	95.0	2121	3.54	7.05	28.79	6.78	8	1
Colorado	86.2	471	2.92	7.21	27.06	16.44	8	1
Connecticut	88.0	154	4.77	10.33	29.44	8.96	7.25	1
Delaware	83.3	58	4.77	12.34	28.08	12.24	7	1
District of Columbia	100.0	16	3.08	11.18	30.38	12.59	7	1
Florida	91.2	494	4.53	8.9	26.54	2.98	7.5	1
Georgia	75.1	638	4.28	9.22	25.83	3.02	7	1
Hawaii	91.9	114	3.59	44.19	29.11	1.79	7.25	1
Idaho	70.6	113	3.04	6.87	27.82	3.8	6.83	0
Illinois	88.5	641	4.17	7.24	27.09	6.5	7	1
Indiana	72.4	1108	6.2	6.94	26.2	4.82	6.75	1
Iowa	64.0	1080	2.62	6	26.63	3.23	7	0
Kansas	74.2	451	2.85	6.22	26.14	11.82	7.75	0
Kentucky	58.4	772	3.93	6.11	26.13	5.71	7	0
Louisiana	73.2	256	5.32	3.4	23.46	2.74	7.25	1
Maine	38.7	102	6.52	10.61	28.47	3.88	7	0
Maryland	87.2	485	2.89	10.39	28.52	5.2	7	1
Massachusetts	92.0	404	6.09	11.4	28.56	4.4	7.25	1

Michigan	74.6	510	5.84	9.17	27.38	3.94	5.25	0
Minnesota	73.3	520	3.29	5.97	27.23	4.1	6.8	1
Mississippi	49.4	234	4.65	5.8	26.39	3.01	7	0
Missouri	70.4	827	2.95	10.08	26.21	11.09	7.25	1
Montana	55.9	117	2.14	7.68	27.62	12.11	6.8	0
Nebraska	73.1	504	1.87	5.53	27.58	4.49	7.5	0
Nevada	94.2	105	3.29	8.44	27.96	15.2	8	1
New Hampshire	60.3	94	4.77	11.64	28.23	9.13	7	1
New Jersey	94.7	637	4.77	9.36	26.64	7.12	7	1
New Mexico	77.4	221	2.86	7.24	26.25	16.52	8.5	1
New York	87.9	1111	4.7	10.09	27.23	5.86	6.8	1
North Carolina	66.1	732	4.27	8.36	28.37	3.55	7	0
North Dakota	59.9	163	4.31	5.16	26.85	2.64	7	0
Ohio	77.9	567	5.91	7.33	27.36	5.8	6.25	1
Oklahoma	66.2	275	3.88	8.25	26.67	3.35	7.75	0
Oregon	81.0	159	3.08	8.15	28.4	5.62	7	0
Pennsylvania	78.7	547	5.78	10.25	29.02	5.5	6.5	1
Rhode Island	90.7	40	4.77	12.29	29.04	9.79	7	0
South Carolina	66.3	219	4.35	6.55	25.99	2.87	7	0
South Dakota	56.7	222	2.76	5.97	27.05	10.05	7.25	0
Tennessee	66.4	325	4.12	6.99	26.86	3.27	7	1
Texas	84.7	1507	3.95	4.07	22.12	3.31	7.5	1
Utah	90.6	211	2.67	6.93	27.99	12.75	8.25	1
Vermont	38.9	77	4.77	11.27	29.33	9.33	7	1

Virginia	75.5	670	5.01	8.52	27.95	3.66	7	1
Washington	84.1	158	5.87	9.99	27.03	4.12	5	1
West Virginia	48.7	26	5.36	7.36	28.95	11.69	7	0
Wisconsin	70.2	450	4.07	7.33	27.41	4.2	6.4	1
Wyoming	64.8	38	1.91	5.6	26.77	14.91	7.5	0

N.B. *The average longitudinal efficiency is determined by using (X1:Y1, X2:Y2), where X is the estimated percentage that the efficiency of the photovoltaic is Y kWh/day*.