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The Effect of Financial Incentives and Regulatory Policies on the State-Level Size and Cost of Solar Photovoltaics

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I. Abstract:

This work evaluates the impact that regulatory policies, financial incentives, population, income and sunlight, have on the cost and size of the residential United States solar photovoltaic state-level market. My hypothesis is that the greater number of state level financial incentives and regulatory policies will be consistent with: (1) higher numbers of solar photovoltaic installations in the state, which is a proxy for market size; and (2) lower per kilowatt hour costs for solar photovoltaic energy in the state. Aspects of these hypotheses present the demand and supply function of solar Photovoltaic markets. Supply is measured by the size of solar markets while demand is represented in unit price per kilowatt hour of solar photovoltaic installations. A review of the literature shows that solar markets are growing and replacing coal fired power plants in growing numbers, as a response to Climate Change initiatives (Annual Energy Outlook, 2017). However, given market forces alone, solar energy is still too expensive to compete with traditional energy sources. Thus, government intervention is necessary in order to establish and maintain a competitive marketplace. My findings suggest that financial incentives are effective in increasing size of solar markets. Results also indicate that solar PV cost expressed in price per kilowatt is not determined by government policy, or other descriptive statistics captured in this study. Policy makers therefore may want to consider these factors as opportunities when crafting legislation aimed at growing solar photovoltaic market size, and minimizing costs. Possible avenues for this could be carbon taxing, or a consumption tax of traditional forms of residential energy usage.

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I. Introduction

Understanding that energy consumption in homes is necessary for people and families with anything modern convince and minimum quality of life, analyzing the sources of energy is an important facet to meeting these goals. With the negative impact of coal and natural gas production being further expounded, in the form of Carbon Dioxide emissions, finding traditional alternatives is an important objective of the government (Energy Outlook, 2017). Solar Photovoltaic (PV) cells represent a promising alternative to traditional sources. Markets alone preclude their adoption; federal, state and local governments incentive solar Photovoltaic panel adoption. This realization sets up an important question: by how much does government policy affect size and costs of solar PV markets and panels?

Literature from Kwan (2012) suggests that the adoption of solar Photovoltaic panels is determined by a number of social, economic and political factors. Through a study of ZIP codes and the 2000 census, Kwan (2012) derives the cost of electricity, income and amount of sunlight a sun receives all increase chances that homes have a solar array. Bornstein (2008) finds that costs of solar arrays are still over a lifetime, more expensive per unit cost, a difference of nearly $0.23 per unit more than the traditional alternative. Jung & Tyner (2014) combine these works and compiling a comprehensive policy analysis in Indiana, and reach similar conclusions. current policies indicate a 50-50 chance of solar panels becoming cost competitive, while with the inclusion of certain policies, the cost competitiveness jumps significantly. An analysis of policy across states by Burns & Kang

(2012), who find that the existence of Solar Renewable Energy Credits across several Northeastern states provides a stronger market for solar PV energy.

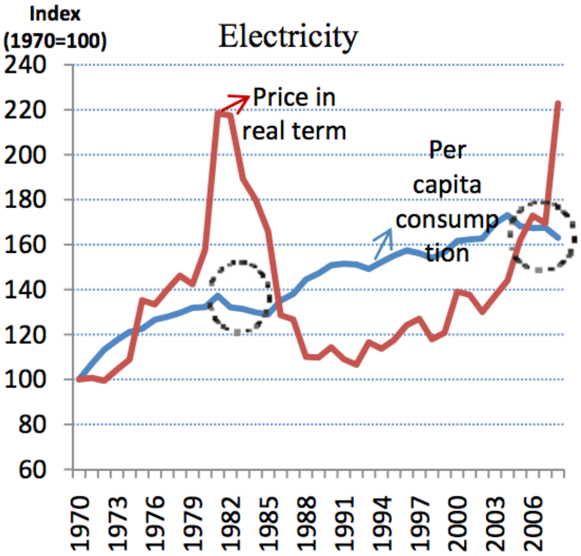
The purpose of this paper is to determine to what extent government policy at the state and local level is enhancing the size of solar photovoltaic markets and depressing the prices. To assess this impact, I use a qualitative approach in analyzing the number of programs each state has, and calculate their effect, in addition to other qualitative variables in explaining the size and cost of solar PV panels. The measure of size and cost together create a demand and supply sided model, which is represented with size of markets standing in place of supply, and cost of kilowatt hour standing in place of demand. The sum of these presents a simple supply and demand model.

The contributions of this work are threefold. First, this work tries to create a relationship between the supply and demand of solar Photovoltaic cells. Second, this paper attempts to determine demand mechanisms at the state level by using a count of polices. Third, this paper endeavors to find determinates of cost that outside factors of production. After determining these factors, this work attempts to prescribe policy towards alleviating these concerns.

My findings suggest that factors of production, thus the cost of solar photovoltaic panels, are not determined by the government policies and regulations measured. On the other hand, demand factors, as measured by the size of the market, are determined by the amount of financial incentives states offers families and homes. Section 2 reviews analytical framework pertaining to a supply and demand model. Section 3 reviews relevant literature given the scope of this work. Section 4 outlets the methodology of two regressions I use to measure my independent variables. Section 5 outlines the origins, and contours of the data. Section 6 details my findings, of both regression, and relates them to current literature, while section 7 connects the findings to policy implications. Section 8 a list of tables which represent my final regression outputs. Finally, section 9 is a collection of relevant graphs.

II. Analytical Framework of Energy Demand and Solar Markets

Residential demand for energy is commonly theorized as a perfect demand inelastic good.



Demand inelastic goods do not experience a change in quantity when a substantial change in price occurs. Supported by current trends, a study by the state of Hawaii on elasticity of energy prices finds that between 1970 and 2008, consumers in Hawaii are not very sensitive to changes in electricity prices (Hawaii Facts and Figures, 2013). The figure blow shows that as prices fluctuate, both in high and low extremes, demand per-capita does not fluctuate in relation to price shocks. In fact, demand grows due to the increase in population. The interaction of demand and price are representative of an inelastic good, where a significant price change, does not result in a large consumption change.

Solar PV energy could represent a credible threat to this elasticity dynamic. Currently, however costs differences in production are two vast to create a truly competitive market. The 50-state average cost of a kilowatt of conventional energy is $0.128[1]. Compared to an average cost of over $6.00[1] for an equal amount of solar PV energy, there realistically is no competition between the sources of energy. This dynamic is quickly changing however, solar PV energy is improving its

[1] See Table 2.

efficiency and has been the beneficiary of many accommodative government policies. These policies help to bring down the cost of solar energy, or at least defray them over the lifetime of the equipment the size and power of market has been growing, and in 2016 an 95% increase of installations of solar PV coupled with several other factors represents as growing and competitive market (Green Tech Media, 2017). The public resistance to further natural gas extraction Kuhr (2014), in addition increased funding of renewable energy programs all promote a situation for solar energy to grow.

Policies affecting the cost of solar PV power is influencing both the supply and demand of solar PV panels. Demand will rise or fall with a change in relative prices (Whelan & Msefer, 1996). My research question analyzes demand of solar PV energy by looking at the cost of solar PV panels per kilowatt hour in each state. A low cost of solar PV power will certainly indicate a competitive marketplace between the technology and conventional energy sources, while a high cost certainly discourages demand. Supply, defined as an ability and willingness to produce goods, is representative in my research as the size of the market. Thus, it is measured in my study as the number of solar panels in each state, is a derivate of how much solar PV panels are supplied in each state. As with supply and demand, the size of solar markets is surely connected to the cost per kilowatt hour. this represents a basic supply and demand function, as the cost per unit of solar PV panels is related entirely to how many are bought. Understanding the dynamic each aspect plays in the others determinants is important for both my work, and the larger policy goals.

III. Literature Review

<u>The Residential Solar Market in the United States</u>

The current solar PV[2] market in the United States are represented in a litany of variables. Defined by social, economic, environmental, and political variables solar PV panels are more likely to be adopted given certain demographic conditions. Kwan (2012) studies the zip code level data from the 2000 census. Across several socioeconomic factors, Kwan studies how economic and political dimensions affect the distribution of residential solar panels. The logistical model used by Kwan (2012) returns results in percentage point increases given the presence of certain conditions. Geographically, Kwan (2012) finds two large clusters of PV arrays, the New Jersey-New York-Connecticut region and California. When considering numbers, for every kilowatt hour increase in sunlight, homes with solar PV installations increase by 89.2 percent. High electricity costs also were observed to increase PV panels adoption by 85.1 percent, as the high cost makes PV panels profitable sooner. Incentives then provide the next biggest increase in PV installations; with every dollar increase in government incentives there is an increase in the residential solar PV share by nearly 35%. Additionally, home values are significant indicator of solar PV installations. With every added $1,000 a home is valued, the likelihood of solar PV panels increases 0.3%. Outside of markets and monetary metrics, social factors play an additional role in understanding solar PV instantiations. Being in the age group 45-54 increases solar PV shares by nearly 12% (Kwan, 2012). While when considering political affiliation, democratic party members increased PV likelihood 12%. While many factors clearly determine PV installation patterns, Kwan finds that amount of solar radiation (sunlight) received, the cost of electricity, the amount of incentives, home value, the median

[2] The technology is simple, but effective. A semiconductor lives within each solar panel, and when photons inside sunlight strike the solar panel, some of the electrons are freed, and move along the semiconductor from a positive to a negative node. The number and size of the solar panel scales the amount of energy created. A household array can be rather small, but solar panels on top of warehouses can power the equivalent of 1,000 homes (NREL).

household income in the ZIP code, education, and race all are correlated toward areas where there are more solar panels (Kwan, 2012).

Kwan's study of financial marks and the number of solar PV panels is a strong supplement to my work. His analysis of both the amount of solar energy, as the number of Kilowatt hours, and the cost of electricity as effecting the size of solar PV markets are integral pieces of my own regression. He finds that high costs of electricity, and that high amounts of solar energy are positively related to sizes of the solar market. However, his use of social factors such as political parties and race in trying to tease out a relationship between the factors and solar PV installations provide highly contextualized results. In relation to the research question, this paper provides a strong base for answering how size of solar markets is effected by factors others than the financial inventive and regulatory policies. Kwan finds that factors such as amount of sunlight and cost of electricity are affecting the amount of the solar PV energy in a zip code, and thus a state. His findings of a positive relationship of the financial measures are motivation not only for my study.

Contours of State and Local Policy

While state and local governments have separate and unique incentives toward increasing the amount of solar PV in their territory, they each fit into a handful of categories: investment tax credit, subsidies, renewable energy portfolio, public investment, net metering, and regulation. All increase the amount of solar PV energy in use for electricity generation; however, there are important differences within each policy.

Investment Tax Credits allow for part of the installation costs to be deducted from a household's tax bill. With the combination of state and federal policies, projects have benefited greatly from these rebates. The federal policy provides 30% tax deduction, while certain state and local policies can increase the deduction to nearly 50% (Bauner & Crago, 2015). Up-front deductions from the original price, subsidies for solar PV energy act no differently than subsidies for farms or technologies. It could take the form of grants, or, rebates. A rebate program in California set aside nearly $3.3 billion to develop PV in California by 2017. After a rocky start, the program has regained traction, and since 2008 has remained effective (Timilsina, Kurdgelashvili, & Narbel, 2011).

A form of regulation, Renewable Energy Portfolios (RPS) are requirements at the state and local level that stipulate that utilities must get a certain amount of energy via renewable sources. Also, known as Tradable Green Certificates, 31 out of 50 have some sort of RPS, which range from 10%-40%. New Jersey had the first RPS in the United States with a goal of 6.8% by 2008, and updated it in 2010 with a goal of 20.38% renewable energy by 2021 (Timilsina, Kurdgelashvili, & Narbel, 2011). SRECs create a market for renewable energy, which Susaral and Friedrich (2013) identify as a major strength in European markets. A facet of RPS are Solar Renewable Energy Credits (SREC). A certificate is won by homeowners for each 1000kWhs they produce, and these certificates are sold to utilities so utility companies can meet renewable energy standards set by states. Burns and Kang (2012) study how this policy affects solar implementation across a variety of states. Northern states such as Massachusetts and New Jersey are well-matched for these sorts of programs, as they have higher energy prices, the SREC credits are worthwhile quickly. When compared to Ohio, and other states such as in the Midwest, low energy prices are preventing SRECs from tipping the scales for homeowners.

Net metering is a strategy in which households sell excess electricity generated back to the utility and grid. This program is often used in combination with RPS to allow energy companies to maintain standards. The price at which energy is sold to the grid varies, but is generally the retail tariff. While typically net metering is only available to residential panels until they meet their yearly consumption, this policy helps both the resident through the abatement of costs and the utility in terms of meeting RPS. Public investment represents the least market-based approach to PV implementation. In the United States, the Energy Policy Act of 2005 allocated $800 million in bonds to be issued by 2007. The success of the program was strong enough that the policy was extended, and between 2009 and 2012, nearly $225 Million in bonds were allocated toward the installation of solar PV. Strict government mandates represent a separate method to increase PV energy. Israel implemented a renewable energy mandate for all new water heaters in the 1980's. The city of Berlin suggested a similar policy in 1990, but it failed. However, Barcelona in 1999, then the rest of Spain in 2006 adopted a renewable water heater policy. Although the policy failed in Berlin, the renewable solar water heater has been an effective tool other cities and countries. This sort of regulation certainly can be extrapolated toward larger energy sinks, in order to increase solar PV usage while decreasing the amount of conventional energy needed. Although each of these policies has seen success independently of one another, Timilsina, Kurdgalashivil and Narbel (2011) find that a mix of policies has created the best results. In Germany and Italy, a mix of policies was most effective. The mix of net metering, subsidies and other policies creates the best situation for the growth of solar energy markets (*Timilsina, Kurdgalashivil and Narbe, 2011)*.

My research question attempts to measure the effect government policy has on the prices of a kilowatt of solar PV energy. The literature suggests that government policy, either regulation or incentives, decrease the price per kilowatt. Further, the more policies and the wider variety that are in place, the better the marketplace for solar PV energy is, meaning it is cheaper for the end consumer, and thus more competitive with conventional energy. I hope to find similar results, that the number of both financial incentives and regulatory policies affect the cost per kilowatt hour, making it cheaper. Although the literature draws strong connections between government policy and the effect of price, the applicability toward my research question is limited. The paper who draw conclusion from European countries and cities are not applicable to my study of the United States. There are many different reasons this conclusion. For one, the public's is much more in favor of renewables in general, and government has reflected this by engaging in many more and aggressive policies toward increasing solar PV for homes.

Government policy has created many market and regulatory methods by which solar energy becomes cheaper, and easier to implement. The policies outlined above have disparate impacts. Bauner and Crago (2015) attempt to understand how the costs and policy are understood within the context of two different decision making methods. Through a close study of Massachusetts, the combination of policies decrease the cost of a typical 6-kW system nearly 50%. Even after this steep reduction in price, less than one percent of homes in Massachusetts own solar panels (Bauner and Crago, 2015). Possible reasons for this are high costs and relatively uncertainty in the future of energy prices, solar PV prices and policies. Their work finds that financial incentives have the best chance at increasing the adoption rate and time of solar PV energy, although their effectiveness is muted, as homeowners are unsure about the continuation of funding and other aspects of financial incentives. Bauner and Crago continue, and find that market development, as well as peer-to-peer marketing can be effective in reducing uncertainty, and thus increasing solar PV markets.

Policies are multifarious and implemented differenced in each state. As a result, I will study each policy listed above, as they are important factors in changing the cost of residential solar energy. In addition, the policies interact with one another to bring prices even lower. The literature from which this information comes is strong in both quality and quantity. In addition to a detailed definition of several policies, the authors provide significant case studies to illustrate the effect of each individual policy. In addition to case-specific examples, the authors use econometrics to prove that in future or alternate settings, the policies mentioned above can significantly increase solar PV adoption. The data and example driven studies of government policy on solar PV implementation create a wealth of information and motivation for my research.

Current Solar Markets

Borenstein (2008) analyzes the market for solar energy in California, which is the oldest and most concrete solar PV market. This study is a good example of how markets in other states can grow. Using the Leveled Cost of Energy Calculations (LCOE) methodology.[3] Borenstein finds in California solar PV installations are not currently cost effective in a competitive market. Borenstein also finds that in 2007, the cost of conventional electricity to residential homes was $0.15/kWh, while for solar energy generation, the cost reached nearly $0.32/kWh. Although the 2007 publication provided a substantial argument against implementing solar PV panels in California without government policy, retesting of the methodology and hypothesis illustrates an improving case. Utility companies in California can expect to charge higher prices for conventional energy, given higher fixed costs associated with further extraction of fossil fuels, as well as increased regulation (Jung and Tyner, 2014). When incorporating these costs, LCOE methodology indicates that in 2014, solar panels in California will be even with conventional methods, and cost the same as conventional methods currently cost the residential consumer. Forecasting to 2020, costs could be as low as $0.11/kWh of solar PV energy (Jung and Tyner, 2014). This relationship and trend is found elsewhere in the literature, in other states and countries. Using Borestien (2007) and his calculation of LOCE methodology, solar PV energy is still $0.10 per kilowatt hour more than traditional

[3] LCOE is a method for comparing different types of energy. Metrics such as cost occurring during overall life cycle are measured across alternative opts. LOCE represents the minimum price at which electricity must be sold at to ensure the investment pays off. "The leveled cost of electricity IS the constant dollar electivity price that would be required over the life of the plant to cover all operating expenses, payment of debt and accrue interest on initial project expensive and the payment of an acceptable return to investors (Visser, 2014)

alternatives. His findings also suggest a similar relationship, and he surmises that a gap of nearly $361 would need to be covered in order to incorporate all of the social externalities and create a competitive marketplace. These findings agree that the price difference is huge, only households who are able to pay may consider solar PV as a realistic alternative.

Research in the Midwest and Atlantic regions has been confined to state analysis, and these case studies find similar results. Jung and Tyner (2014) assess the parameters of solar PV energy in Indiana with different government policies. The breakeven price of solar panels was tested using several real and hypothetical government policies and market circumstances. The current renewable energy policy in Indiana can only make solar PV energy as cheap as traditional energy 50% of the time (Jung & Tyner, 2014). The policy options such as state and federal tax credits, financing, and net metering make solar panels a rational decision for half of the population. The article continues, and adds in prospective policy measures to determine if new government policy can further influence equilibriums. The two most logical and likely policies to be enacted are compensation for depreciation, as well as a carbon tax; both of which have an effect of increasing the percentages for likelihood of making financial sense. If both policies are included in the equation, 100% of PV systems are likely to be cost effective. Even if only one initiative is included, over 90% of solar energy is cost effective. Entirely dependent on government intervention, solar PV implementation in Indiana occurs only with government policy. My research will focus on how the government policy can most effectively create solar PV markets in the United States, using many of the policies that have been enacted in Indiana. The Jung & Tyner paper again finds that policy and regulation at the government level is one of the few effective ways traditional energy is competitive with solar energy. Further than that, their work finds that government intervention is in fact the only reason solar energy is competitive with the price of conventional energy in Indiana. I hope to find similar results for every state, not just Indiana.

An interesting characteristic of the current dynamic between solar PV markets and fossil fuel energy production is discussed by Cai Et al. (2013), who discovered a feedback regarding the impact of PV implementation for residential arrays. Households have steadily been increasing PV usage as prices fall, infrastructure improves, and government policy helps with costs. This increase in purchases of solar energy results in a net decrease in the purchase of electricity from utility companies. With no decease in structured costs, utilities have no choice but to increase prices for the rest of the customers in order to cover costs and maintain their profits. Taken together, companies are simultaneously increasing prices of electricity, while PV companies are decreasing the cost of their electricity. Certainly, this speeds up the differences in prices, which gives PV panels more room to compete, and because prices of conventional energy have increased, a less aggressive cost-lowering program. A case study of Southern California finds that this feedback loop decreases the amount of time it takes for PV panels to supply 15% of peak energy by 4 months.

There are many caveats in arguing solar PV energy is as expensive as traditional power sources. Reichelsten and Yorston (2013) find that large-scale PV installations still cost 35-50% more than comparable generation faculties, even when based on favorable locations and the highest utilization of tax incents. When removing key tax breaks, prices soar to over 75% higher than conventional sources. The implementation of utility-scale solar projects then, is certainly due to state-level policies, such as the California Renewable Energy Portfolio Standards (Reichelsten & Yorston, 2013).

The government's role in creating solar energy profitability must not be underestimated. Reichelsten & Yorston, Cai Et al., Jung & Tyner, and Borenstein compare solar energy markets both by state, across markets and time periods. They all find that given market factors alone, solar PV energy would not be an effective substitute toward conventional fossil fuel energy producers[4].

Each paper reviewed begins in its introduction or motivation with facts and figures about the growth of the solar market, or the steep decline in costs in the last 10-20 years. They also stipulate that this was only made possible through heavy incentivizing through policies and incentives. California, largely has seen success with policy and incentives in growing the size of the market for solar PV and decreasing costs. My research question will attempt to quantify by just how much the policies and incentives have affected the market and price. Other states that do not have a historically strong relationship with solar energy have also benefited from polices incentivizing market increase. An example of this benefit is Indiana, who has implemented similar programs to California with varying degrees of success. My research question studies how the differences in polices affect the overall prices and size of the markets.

International Case Studies

While clearly the United States is different in its energy policy, demands, and history from other countries, studying the implementation of solar PV arrays in other countries is relevant in examining other methods that improve the size and lower the cost of solar PV markets. The tools, struggles, and methodology other governments use to make PV a realistic alternative to conventional energy can be considered in the context of the United States. Ondracezk (2014) analyses Kenya, where a quickly growing population and economy is causing a rise in the demand for energy. With only 14% of the population connected to the grid in 2005, there was a major opportunity for Kenya to increase the

[4] An interesting contour to these studies is the lack of uniformity in their time to break-even price for solar PV. Due to calculation differences as well as other methodological differences, Reichelsten & Yorston, Cai Et al., Jung & Tyner, and Borenstein all find solar energy to be cost effective in the future, however there is a disagreement as to when.

population's electricity rate by using policy to create a competitive marketplace. Ondracezk (2014) uses LCOE methodology to show that costs in Kenya between traditional energy and solar PV energy is narrow, and cost competitive. Costs from local pollution, fossil fuel emissions, and waste disposal certainly add to the costs of conventional power, while making solar PV more competitive. While Ondracezk (2014) finds that solar PV energy is not yet competitive with base energy production, this only factors in base scenarios. Given the growing population, a peak load scenario would could provide more descriptive results[5]. When using the peak load scenario, solar PV in Kenya already could produce electricity at a cheaper rate than conventional methods (Ondracezk 2014). Kenya's link with solar PV energy and its ability to electrify rapidly growing regions can prescribe a way forward for rapidly growing states and regions in the United States. To be sure, a higher base amount of homes are connected to power in the United States, but in the new housing developments and construction projects may want to consider that it will be cost effective at certain levels to choose solar PV.

Zimbabwe, like Kenya, has seen relatively fruitful solar PV implementation, while other countries such as Ghana have been relatively unsuccessful at implementing solar PV. Obeng (2010) catalogues and compares solar energy positions of Kenya, Zimbabwe, and Ghana. He finds that Kenya and Zimbabwe have successfully embraced solar PV, while Ghana has yet to fully develop its markets. Government policy toward electrification, tariffs, and other market approaches are similar in Kenya and Zimbabwe, while different in Ghana (Obeng, 2010). Rural electrification through the traditional production grid in Kenya and Zimbabwe, while a priority, carried with it high structural

[5] Base load and Peak load are two different amounts of energy demanded during a normal day. A base load is the minimum amount of energy required over 24 hours. Examples of this are refrigerators and air condition systems, which work non-stop. Peak load are times of high demand. Examples of this include the toaster oven and hair dryers (SINO Voltaic, 2015).

costs from organizational and political issues. Furthermore, Zimbabwe has extensive coal reserves, but even given this natural energy source, poor policies and slow work meant that in 2003, only 5% of homes in rural Zimbabwe were grid connected to coal powered power plants. These challenges to traditional production, in addition to favorable government policy, created a strong solar PV market. Exceptions to tariffs for solar PV technology and low interest rates for solar panel installations created the right atmosphere for Kenya and Zimbabwe to grow solar PV markets. Although Ghana experiences the same structural and logistical issues in terms of electrification, it pursued conventional electrification only. Ghana did not protect the solar PV market and funded only fossil fuel producing plants. This resulted in not only indefinitely long wait times for Ghanaian resides to be connected to the grid, but resulted in the highest electricity rate between the three countries studied (Obeng, 2010 & World Bank Group, 2017). Given the same structural roadblocks to the growth of energy markets, Kenya and Zimbabwe used policy to incentive solar PV markets. Additionally, policies such as the exemption to tariffs in Zimbabwe, decrease costs of unit prices of solar PV panels. These policies can be applied at the state level in the form of regulations demanding energy sources be developing sustainably, and incentives to pay import and tax fees. While this analysis is important toward determining the outline for a developing countries growth in green energy production, the United States is not a developing nation, and has one of the oldest energy markets. given the dichotomy between the energy demands and problems facing developing countries and developed one, attempting these policies may not be advisable, as growth determinants are far different from the problems faced in electrifying developing countries.

For the most mature international solar energy markets, which are in Germany, Spain, and Italy, government policy has been instrumental in the adoption of solar PV. An aggressive goal, the EU wants to achieve a 20% renewable energy portfolio by 2020 (Susarla & Friedrich, 2013). To achieve this goal, the EU members have enacted mostly state and lower level policies. The most popular policy in the EU, feed-in tariffs (FiT)[6] comprise the core of 13 countries portfolios. Additionally, other more common policies such as capital subsidies, grants and invectives are present in 8 EU countries. The literature suggests these policies, which rely mostly on free-market mechanisms, will overachieve in Germany, Italy, and Spain. Germany has achieved 43.8% of its 2020 target by 2012, while Spain ahead 45% of its 2020 target in 2011.

Internationally, the literature shows that government policy plays a major role in increasing solar PV implementation. In Europe, market pressures created by countries are providing the necessary space for solar PV to compete within the residential energy market. The policies, have actually gone beyond the minimum requirements of the countries and will overachieve in the time frames set. In developing African countries, government policy in solar PV has too at least met the goals set out by policy makers. Kenya and Germany have both proven that government implementation is effective across different counties. For the United States, this provides evidence that government policy has the ability to make a competitive solar PV marketplace.

In context, African countries have experienced many different outcomes with solar PV markets. Kenya and Zimbabwe have done remarkably well in developing its solar markets through effective use of policy and incentives to meet the rising demand as population and modernization grow in these countries. Studying the policies other countries used toward growing their solar PV markets and keeping costs down can be applied to states who wish to reach the same goals.

[6] Feed-in Tariffs (FiT) are another form of government policy that is designed to increase the cost competitiveness of solar PV energy. A basic program has three financial benefits: First, a payment for all the electricity produced, even if it is used by the producer. Second, additional payments for all the energy a panel produces for the grid. Third, a direct cost reduction in your final energy bill (What are FITs?).

European countries combination of policies and incentives to create a nation-by-nation competitive solar PV markets in developed countries. their practice creating solar markets through forcing regulation, while making it alternatives such as solar PV price competitive relates to my study of the determinants of cost per kilowatt hour of solar PV energy. Through incentives, and backed by regulation, European countries have integrated a strong solar PV ethos into their energy structure. The analysis of European countries can directly apply to state level planning within the larger federal structure of the United States. Countries who exist within the European Union, while certainly more layered than the state-federal relationship, find themselves serving two different masters at the same time, often who weave several different mandates into one policy.

While both a study of Europe and Africa are important in developing a well-rounded study of current solar PV market size and cost, their analysis is lacking a true connection to the issues and factors which are present in the United States at state and local levels. To be sure, there are still important lessons to be learned from the study of international counters, but their work must be understood within the right context, so these cases are not directly comparable to the case of the United States.

Summary of Literature

The wide array of solar PV policies provides plenty of space to examine how effective different aspects and policies affect the competitiveness of solar PV energy at the state and local level. The literature shows that given proper government policy, solar PV energy can be cost comparative to conventional sources (Bornstein, 2007, 2012), and that, across countries, significant government intervention is the main perquisite for solar energy (Burns & Kang, 2012; Li & Yi, 2014; Timilsina et al, 2011). These policies increase the size of solar PV markets by increasing the adoption of solar PV panels at the household level. Literature on determining costs of solar PV panels is limited.

While many authors focus on determents of adoption, there is little written n determents of price in relation to government policy in the current literature.

IV. Methodology

<u>Size of Solar Market</u>

(1) $SPVI_\theta = \alpha_0 + \beta_0 FI_\theta + \beta_1 RP_\theta + \beta_2 CTW_\theta + \beta_3 Skw_\theta + \beta_4 \ln(P_\theta) + \beta_5 \ln(IAN_\theta) - \beta_6 Cpvw_\theta + \beta_7 SREC + \epsilon_\theta$

The number of solar energy instillations in a state ($SPVI_\theta$), serves as a proxy for size of the solar PV market. As explained in regression (1), the hypothesis postulates the size of a state's solar PV market will be positively related to the number of financial incentives (FI_θ) and regulatory policies (RP_θ) in each state. Theoretically, a larger number of financial incentives will incentivize households to purchase solar PV panels. Financial incentives such as rebates or grants can decrease costs, or other policies, (as outlined by Bauner & Crago (2015), and Timilsina et. al, (2011)) which allows more households and families the ability to pay for solar PV. Additionally, breaking down barriers and mandating renewable energy portfolios for utility providers, regulatory policy will increase the size of the solar market. These state and local-level incentives and policies are meant only to provide increase the size of the solar PV market. SRECs ($SREC_\theta$), as discussed by Kang & Burns (2012), I hypothesize SRECs will too represent a positive relationship with the size of solar energy markets. SRECs demand of utility companies to diversify their energy portfolio creates demand for solar energy and solar markets, which will be represented by an increase adoption by households. This analysis relies on the same rationale as financial incentives and regulatory policies.

The cost of traditional energy (CTW_θ), as detailed in Bornstein (2008), is the competitors cost of energy that solar PV energy must compete with. Natural resources such as coal and natural gas will be positively correlated to the size of the solar PV market. That is, when the cost of traditional energy sources increases, the relative competitiveness of the price of the alternatives, such as solar PV energy increases as the difference between the two prices narrow. This will increase the number of installations, as more people choose to power their home with solar PV installations, and thus the market increases. Bornstein (2008) derives this relationship, and finds that the prices of solar and traditional energy are important in determining how much of the other is used. Although this work uses this relationship and LOCE methodology in attempting to determine the cost of externalities, the relationship of the two is well defined.

I also hypothesize that a higher amount of sunlight with higher intensity (Skw_{θ}) will increase solar market adoption in the state markets. Solar PV energy is clearly dependent on the sun, as it is the only source of energy for generation in solar PV technology, and states with a higher amount of sunlight I expected to have a larger solar market because there is more solar energy to be captured. As detailed in Kwan (2012), the higher amounts of solar available energy increase the adoption of solar PV panels. If we consider sunlight as in the same vein as other sources of energy creation, like coal or natural gas, then the positive correlation becomes clear. States and regions who are better endowed with the natural rescores, have a larger market for them.

Additionally, a log of population (P_{θ}), and Average State Income (IAN_{θ}), (in order to smooth out the large differences between states, as is commonly done in literature) I theorize will increase the size of solar PV markets. Simply, states with high population have a greater demand for energy. This will result in higher traditional energy costs, as a result of competition. Additionally, higher populations will mean more residential homes, and more rooftops for PV arrays, which can advance the size of the market. Income, will also move simultaneously with the size of the solar PV markets in each state and have a relationship with size. Even with current government subsidies and other programs, the price of solar PV energy is still at least ten times the cost of the traditional alternative[7]. Purchasing solar PV panels and energy is still only available to those who can afford it. Solar PV installations require a large, up-front payment and as the panel is used over its lifetime, the savings on energy will be played out to the user. Those with lower income simply to do not have access to enough capital to make solar PV panels a reality. Thus, Increased income will mean a larger expendable income, to use premium products, like solar PV panels.

The only expected negative relationship is of my independent variables is the cost per Kilowatt of solar PV energy ($Cpvw_\theta$). Simply, a more expensive cost per unit will discourage purchase of solar PV arrays and therefore decrease the size of the market because alternatives are cheaper. Would the price of the alterative rise or the cost of solar PV energy fall by a large degree, the size of the solar PV would certainly react and become larger as a result. This relationship is defined by Whelan & Msefer (1996) discussion of supply and demand, as outlined in earlier sections. Unwilling to pay a higher price for a good that can be consumed at a lower cost, a high cost of solar PV energy is related to a low market size, as customers will purchase traditional energy resources.

The Cost per Kilowatt Hour

(2) $$Cpkw_\theta = \alpha_0 - \left[\beta_0 FI_\theta + \beta_1 RP_\theta + \beta_2 Skw_\theta + \beta_3 (SPVI_\theta)^2 + \beta_6 (CTW_\theta)^2\right] + \beta_4 SPVI_\theta + \beta_5 CTW_\theta + \beta_7 ln\ (\ P_\theta) + \beta_8 ln\ (IAN_\theta) + \beta_9 SREC + \epsilon_\theta$$

I hypothesize costs per Kilowatt of solar PV energy ($Cpvw_\theta$) is dependent on other factors beyond the cost of inputs. I theorize that financial incentives (FI_θ) decrease the cost of solar PV panels, and thus the cost of the PV panel per kilowatt. Financial incentives directly can reduce cost, through net metering, tax credits, and other programs that can generate income for those who

[7] See Section 9 Table 2

purchase solar PV arrays. Regulatory policies (RP_{θ}) are aimed at mandating that power companies adopt renewable energy standards. Additionally, they prevent possible roadblocks to solar PV installations, such as building restrictions on height or size. These roadblocks and mandates are passed by state and local governments to dictate the transition toward solar PV energy. Creating this market, or using these incentives, policy makers want to encourage price competition and prices to fall, as a result, encourage price competition, and this causes prices to fall. A mutation of policy, SRECs ($SREC_{\theta}$), I believe will have a similar effect on the cost per kilowatt of solar PV energy. The existence of SREC markets and credits in states will allow for a more competitive solar PV market, and lower unit prices. Burns & Kang (2012) have determined that for certain states, SREC markets can be strong and even given their drawbacks, there exist a strong rationale for including them as a central policy tenant and possible determinates of cost.

The amount of sunlight (Skw_{θ}) each state receives will decrease the cost of solar PV energy per watt of solar PV installations, as a state that receives more sunlight can extract a larger amount of energy from each solar unit added. Identical in measure to Kwan (2012), Bauner & Crago (2015) and Kwan (2012), these authors also conclude the arrays in states that have a high and low solar PV exposure will produce very different costs per Kilowatt hour. The high exposure states, who have more sunlight per Kilowatt hour, will be able to capture more solar energy, making its cost per unit cheaper when compared to the lower exposure state.

When considering the cost of traditional energy (CTW_{θ}), a steep hike in the price of conventional residential energy sources would increase the attractiveness of substitutes such as solar PV. Initially, the increased demand for solar PV would increase prices, and cost per kilowatt, as high demand would allow producers to raise prices of units. However, as profits and demand remained high, competitors will enter the market, and more innovation would occur, resulting in falling profits with an end result in an overall lower cost. This is certainly is a long-term trend and the current solar PV market is lies somewhere along this trend. An increase in the price of traditional energy would see a rise in price per kilowatt of solar PV energy. Thus, an increase in the price of traditional energy would also see an increase in the price of solar energy units, as demand outstripped supply and eventually a decline. As a result, the regression (2) squares the cost of traditional energy to represent this. When consider the current prices of traditional energy, its low cost indicates the beginning of this route, thus, if the price of traditional energy increases, the cost of solar PV energy will move in the same direction.

Similarly, when considering the size of the solar PV marketplace ($SPVI_{\theta}$), I expect to have a negative, and then positive relationship with the unit cost of solar PV marketing. Demand will initially increase the price per unit. But competition, as well as a decline in logistical and structural costs[8] will result will ultimately result in decrease prices. To represent this, regressions have a squared relationship, as represented in regression (2). Currently, as the demand is still being artificially inflated as a result of incentives and policies, I hypothesize that prices would rise, due to demand, as size of the market rose. Both the cost per kilowatt hour and state-level size of solar markets represent an addition to the literature. While many sources quantify these in relation to supply and consumer action, I attempt to find a demand-related relationship.

Both regression (1) and (2), create a cannon of work which together generates a holistic view of the state-level solar market. Each regression assess how financial incentives and regulatory policy affect solar markets independently by breaking the study into a supply and demand side model. Measuring the size of the market attempts to understand if policies are helping to increase

[8] Structural costs could be training of labor to install and maintain the solar PV technology, and its infrastructure. Additionally, logistical costs such as transporting both the physical technology and the energy represent logistical costs.

proliferation and adoption, while measuring cost per kilowatt hour attempts to understand if policy has any permeant effects on cost and or firms who produce solar PV panels. Together, regressions (1) and (2) will determine if states and local governments should focus on improving financial incentives or regulatory policies, depending on which side of the market they would like to improve.

V. Data

Many metrics surrounding my dataset are derived from the Renewable Energy Laboratory Project (NREP) called the "Open PV Database". The database is an initiative in which the NREP collects information on every solar PV installation in the United States. Updated by installers, this database is the source from which I derived the cost of solar PV panels per kilowatt ($Cpkw_{\theta}$). I derived this form averaging each residential installation. To determine the cost per kilowatt hour, it was necessary to divide the size of each system by its total cost for each separate entry in my dataset. These figures were then averaged across all residential systems, and tallied for each state. The Open PV Database has every solar PV installation, so it also provides the count of every solar instillation by state at the individual level variable.

The cost of energy (CTW_{θ}) in each state is taken from the Energy Information Administration (EIA), which carries information on energy prices by state, time, and region. Since this data set was already calculated in kilowatts per hour, no other data cleaning or manipulation was required before input into my model. SREC ($SREC_{\theta}$) data comes directly from private firms' literature about the wealth of options for solar PV energy. Currently, there is a marketplace for firms to package, distribute and sell bundled SREC policies, their information for crafting the dummy variable was utilized in my dataset.

To determine the number of financial incentives (FI_{θ}) and regulatory policies (RP_{θ}) within each state, I use the Databases of State Incentives for Renewables & Efficiency (DSIRE). Backed by the U.S. Department of Energy and North Carolina State University, this database catalogues the federal, state, and local financial incentives and regulatory policies in many different metrics. The DSIRE dataset also catalogues several different types of renewable energy policies and programs, for several sectors. The database includes information on solar PV programs for utility and businesses, as well as different renewable programs such as geothermal installations. To prepare a state-by-state analysis of residential, solar PV, programs and policies, it was necessary the data was filtered first by state, then by source of renewable energy, then by sector, and finally by type of policy. The DSIRE database has the original documents for every regulatory policy and financial incentives, and categorizes them quantitatively. I capture this information and use it as the basis for regulatory policy and financial incentives data set.

Aside from the descriptive population data, such as the annual income per state and state-level population information, the rest of my data is updated regularly, as the "Open PV Database" and the DSIRE database are updated as policies and PV arrays are added. Data on electrical prices are too updated nearly instantly, and accrued quarterly for download and use. Data regarding income and population are derived from Data Planet, which is a source for every type of descriptive data. Population information in my regression comes from the 2010 Census projections for the most up-to-date year.

VI. Findings

Size of Solar Markets

(2) $SPVI_\theta = \alpha_0 + \beta_0 FI_\theta + \beta_1 RP_\theta + \beta_2 CTW_\theta + \beta_3 Skw_\theta + \beta_4 \ln(P_\theta) + \beta_5 \ln(IAN_\theta) - \beta_6 Cpvw_\theta + \beta_7 SREC_\theta + \epsilon_\theta$

Table (1) represents regression results assessing several determinates of size of solar markets in each state. Logged population ($\ln(P_\theta)$) has a positive correlation with a state's residential solar PV energy market size. This relationship is likely a result of two main causes; first, a greater population will certainly have a larger solar market, simply due to population size. Not only will there be more homes eligible for PV panels, but a larger population also means more homes need energy, driving traditional prices up, making solar PV energy more attractive as an alternative. Second, a close study of state dynamics can provide further explanation for the relationship between size and population. California, with the largest population in the United States, with nearly 40 million people, also has the largest size of the PV market if measured by size, with over 65,000 installations. New York, also has a very large population, near 20 million, and the 6th largest PV market size. States with large populations appear to have large solar PV market size[9]. This relationship is strengthened when considering the bottom ranking states. North Dakota has both the least number of solar PV installations, and is the third least populous, with a population of only 750,000 people. Larger populations increase the demand for energy, meaning utility companies can charge more for traditional energy. The relationship between population and size of solar markets closes the gap between the cost of solar PV energy and conventional production, meaning more homes now are able to purchase solar PV energy for roughly the same price per unit, increasing the number of solar PV installations, and the size of the market.

Financial Incentives (FI_θ), represent the only significant relationship between the size of solar PV markets and any independent variable. This relationship indicates that as the number Financial incentives increases, the number of solar panels in each state is increased by close to 5,000 solar PV panels. This is likely a result of families and homes capitalizing of the increased number of

[9] While this relationship is evident, multicollinearity is below the acceptable levels, see table 3.

rebates, incentives, grants and other policies offered in states with more competitive solar markets. California and New York, offer some of the most financial incentives, and as a result they have a large solar PV market. SRECs, in the same vein as Financial incentives, represent a strongly correlated relationship. The presence of SRECs in a state's policy portfolio increase the number of solar PV installations by over 40,000 installations. A form of financial incentive, SREC's are market-based, and create demand by utilities buoys the solar PV market size. This aligns tightly with the work of Burns and Kang (2012). Their analysis of Massachusetts SREC policy finds a positive correlation between solar PV adoption by households and the existence and permeation of SRECs throughout the state. Their contextual analysis determines that in states like Massachusetts, New Jersey, and Delaware, SRECS represent strong potential as long-term renewable policies.

Regression (1) returned three unexpected results. First, the cost per kilowatt hour (CTW_θ), carries an opposite correlation compared to my hypothesis. A positive correlation indicates that as cost per kilowatt ($Cpvw_\theta$) increases, so does the size of the marketplace. Possible motives for this could exist in data variation when calculations were completed to determine the cost per kilowatt hour. Analysis did not control for size differences for residential systems. A larger system size would certainly have a larger price tag, and the construction of larger solar PV systems in states with lower sunlight would result in a higher cost per kilowatt hour. As dividing by a smaller or larger number generates vastly different results, I believe this could explain the results expressed in the table. This is a possible explanation for my unexplained results. Second, an unexplained relationship between regulations (RP_θ) and the size of the market. In explaining this, there are two discrete and plausible explanations. Chiefly, the data catalogued by the DSIRE database, encompass an extensive array of programs. For example, some regulations could provide incentives by offering exemptions to local building codes, such as height restrictions, which would prevent to solar PV installations from being installed. Moreover, regulatory policies could include setting up public trusts or public benefit funds for the purpose of increasing the number of solar PV panels industry or in the distant future. With so many dissimilar policies, grouping them together might be the reason the regression shows a negative relationship, and a lack of relationship. Moreover, regulation in a new industry could stifle competition and thus development of an industry. Regulatory incentives likely decrease the measured affect regulation has on the size of the market. Regulating solar PV installers, requiring certain safety conditions and size allocations be met may have a negative relationship with the size of solar markets. Mandating number of hours that an installer must train before they are given a license, or that PV arrays have certain apparatuses in case of natural disasters; raises structural costs to firms and solar PV prices. These regulations, while providing safety and necessary regulation to the market, create barriers to entry for firms, which reduces suppliers and thus the size of the market. The third unexpected result is a negative relationship between logged annual income ($\ln (IAN_\theta)$) and the size of the market. Results indicate a negative relationship. This unexpected sign is likely a result of inelasticity of demand. As discussed in the analytical framework, demand for electricity generation is not relative to the cost, or the amount of income available. A certain indelible minimum will be used, and income's affect thus is not relevant. Income also is affected by and affects so many different contours of household's decisions, it is possible that income is dissociated with the decision to purchase solar PV panels. While Kwan (2012) finds a relationship between income categories and increased adoption of solar PV panels. Kwan's splitting up of income can provide additional reasoning as to the unexpected sign of my results. In examining his paper further, it may be the case that the tactic of grouping incomes into brackets may allow for a more detailed and thus significant relationship. My data on size is collected through average income per state only, and do not account for variety in averages, let along population dynamics between income groups.

Cost Per Kilowatt

(1) $Cpkw_{\theta} = \alpha_0 - \left[\beta_0 FI_{\theta} + \beta_1 RP_{\theta} + \beta_2 Skw_{\theta} + \beta_3 (SPVI_{\theta})^2 + \beta_6 (CTW_{\theta})^2\right] + \beta_4 SPVI_{\theta} + \beta_5 CTW_{\theta} + \beta_7 ln\ (\ P_{\theta}) + \beta_8 ln\ (IAN_{\theta}) + \beta_9 SREC + \epsilon_{\theta}$

In regression (2), the relationships between the cost of solar instillations ($Cpvw_{\theta}$), and the independent variables present a variety of results. Represented in Table 1 as regression (2), output indicates none of the variables measured contain any statistical significance. Setting aside the significance of relationships, the direction and coefficient represented in the table still present intriguing findings and warrant a detailed discussion. Largely, academic literature does not quantify the components of cost for solar PV energy as derivatives of markets and my attempt to do so agrees with this lack of relationship.

Logged Annual Income (IAN_{θ}) represents a negative correlation with the unit price of solar PV arrays. This finding is consistent with my hypothesis, as those who are wealthier are more likely to be able to afford to pay a premium on their residential electricity. With the price of a kilowatt hour of solar PV energy still over ten times more expensive than its conventional alternative, according to my analysis, the ability to pay more determines how much the cost of solar PV arrays is sold to consumers. Bornstein (2008) finds this general relationship, although his is through a LOCE methodology. His determines that cost of solar energy is still more expensive that traditional energy even over its lifetime. His work determines that roughly \$0.23 per kilowatt hour,

Size of solar PV markets ($SPVI_{\theta}$), as measured in my study as the number of solar PV panels in each state, has ambiguous results in impacting the cost per unit of solar PV energy. Table 1 suggests that there is no relationship at all with between the size and cost of solar PV energy. In earlier regression, different variations of the relationship were run, all indicating ambiguous results. A justification for this could be, as was state in regression (1), that the cost per kilowatt hour is too variable by the size of installation. The size of installation that residential markets purchase is relative to the consumption, land size and other factors that site specific. This relationship may be the reason that no value is present for the independent variable. The output could also indicate that multicollinearity exists, and size of markets is determined through other independent variables not measured. However, when considering Table 3, we can see that VIF scores are below the accepted maximum of 5.0. Additionally, Park's test indicates that no irregularities exit in the data due to issues captured in the tests. Although the data passed rigorous robustness checks, the lack of significance clearly show that research should be continued in order to determine the true cost of this unexpected output.

The negative relationship between the squared cost of traditional energy (CTW_θ) and solar PV cost per kilowatt, its alternative, coincides with my hypothesis. A negative relationship would indicate that as prices of traditional energy go up, the unit cost of solar PV goes down. When considering my hypothesis, the relationship indicates perplexing results. Although I hypothesize that after demand has peaked a negative relationship will occur, the inflation of demand by government policy is likely inflating demand past the natural peak given natural prices, and is artificially inflating the relationship. This explanation can provide possible analysis for these ambiguous results.

When considering the relationship between policy and the cost of kilowatt hour of solar PV power, the coefficient suggests conflicting, but minute results. Financial incentives and regulations indicate a negative relationship with the cost per kilowatt hour. This means their pressure creates a cheaper cost per kilowatt of solar PV energy, but the coefficient attached to the independent variable suggests that this relationship is slight. Interestingly, coefficients for SRECs suggest a positive, but small relationship between their existence and the cost per kilowatt. When considering my hypothesis, this is unanticipated, as I hypothesize states that have SRECs would decrease the cost of solar panels cost per watt. Literature from Burns & Kang (2012) agree with my hypothesis, and not the results form regression (2). A plausible explanation could be in the fact that in developing SRECs, utility companies are forced to demand renewable energy. Thus, price increases, due to the fact that a certain amount of structural demand exists. This can slightly inflate prices, as there are assurances a certain quantity is demanded.

Summary of Findings

Interpreting the results from regression (1) and (2) indicate that the size of the solar market is determined partly by the depth and breadth of financial incentives in each state. The regulations which are meant to increase the size of the marketplace carry an opposite relationship, indicating that regulation for solar PV diminishes the overall size of state level solar PV market. Other results suggest alternative theoretical relationships exist between traditional costs of energy and the amount of sunlight received.

In determining the costs of solar PV technology, the effect of policy and competition have little effect on the price of solar PV panels. In fact, certain policies may even increase costs per unit, as producers can charge higher prices knowing there exists a base demand from utility companies. Further study is needed to determine the true determinants of cost.

Policy Recommendations

The regression results suggest that financial incentives are the best policy tool for increasing the size of solar PV markets at the state level. While financial incentives fall into many different categories such as net metering, subsidies, and grants, they are proven to be a critical factor in increasing solar PV size and given this relationship there are many ways of using financial incentives can further incentivize markets. Borenstein (2008) finds that stronger taxes and policies are a realistic method to overcome price gaps. His remedy for this is to include taxes and markets that incorporate externalities traditional energy companies do not pay for currently. He finds that policies need to cover at gap of $316 in order to make Solar PV energy cost competitive (Borenstein, 2008).

While the policies such as a carbon tax and other methods Bornstein (2008) considers are plausible, if not wildly expensive, other method of resource management can also inform our policy decisions. Gasoline for example, is taxed heavily and the revenue is used to improve infrastructure such as roads bridges and highways (Yousaf, 2016). A similar tax could be levied on traditional energy. The effect is twofold; first, revenue from tax collection can be used to fund grants and rebate programs, allowing for either larger budgets for the programs or the ability to use the previously allocated funds elsewhere. Second, this would also make traditional energy prices more expensive, decreasing the cost difference in unit price between conventional energy and solar PV power. As regression (2) suggests, the negative correlation will increase size of PV markets, and crease the per kilowatt hour cost.

Considering regulation, standardization and providing clear explanation of solar PV energy can cut down on the confusion in the residential solar PV field. State and federal governments have done a very poor job of accruing and categorizing the standards that must be met. Water standards are an example of how the federal government has taken charge and catalogued and standardized water standards for drinking. The Clean Water Act and Safe Water Drinking Act both mandate standards for water suppliers from the federal level, and apply for state and local levels. Top down standard setting systematizes regulation and cuts down on state level differences. Thus, making compliance easier for firms who operate across state boundaries and cutting down on structural costs, which will result in savings that are passed on to consumers.

Timilsina, Kurdgelashvili, & Narbel (2011) use their study of Germany's solar PV markets and find that a policy mix of financial regulations and regulatory policies are most effective in making a competitive solar PV marketplace for consumers. From this finding, making sure that any further policy is balanced in its regulation and incentive making is an important step to ensuring a competitive and large market. Additionally, my findings suggest the opposite, that regulatory policies are ineffective and detract from the marketplace, while financial incentives feature the only improvement. Additionally, creating nationwide SRECs may be very effective in improving the size and lowering the cost of solar PV panels. Susaral and Friedrich, (2013) identify RPS (the European version SRECs) of in Europe as a big exemplification of effective standards in solar PV markets. In the United States, states with SRECs too have larger markets, and cheaper solar PV prices. SRECs are mainly a financial tool, as they create artificial markets and prices. This is in line with findings from regression (1) and (2), that financial incentives are the most effective in creating prolific PV markets. Kwan (2012) studies socioeconomic factors and their effect on PV markets. The findings form this paper agree largely with the results from my regression. Increased income, both in Kwan (2012) and my regression show an increased likelihood of solar PV purchase. Additionally, he finds a positive relationship with the amount of solar energy each state receives and the size of the solar market, but slightly different form regression (1). Although he calculates the percent chance a solar PV array will exist given the solar energy, regression (1) finds a similar directional relationship, with more sunlight increasing greatly the size, and lowering the cost of solar PV panels.

VII. Conclusion & Extension

Results from analysis of the size and cost of solar PV markets suggest that the presence of regulatory policies and financial incentives are not enough to drive the cost of solar PV energy lower, but can help in growing the size of solar PV markets in states. Literature confirms this relationship, and finds that the presence of financial incentives and regulatory policies increase size of solar markets at the state level.

There are however significant caveats to this analysis, such as the variety of policies and qualification of benefits. In analyzing data on financial incentives and regulatory policies, I came across over 55 different subsections of policies. The lack of continuity may diminish overall relationships, and can in fact counteract one another. The variety of policies and incentives make the market harder to study, and decrease overall clarity of relationships. Additionally, there are many hurdles in qualifying the affect policy and regulation have on solar PV markets. Each specific policy is different and as a result, translating the narrative of policy into a number serves a difficult task for any comprehensive study. In extending this study, circumnavigating these problems will add to the wealth of information regarding public policy and solar PV adoption information. Another angle with which to extend this work is to create a function which accurately suggest the relationship between cost per kilowatt hour of solar PV energy and its determinates. Many policies and academic works focus on the adoption side, while certainly there are important questions to be asked about how to lower prices on the production side in an effort to make solar PV panels more competitive.

The youth of the residential solar industry, and the subsequent youth in incentivizing it also present problems in assessing the effectiveness. When considering for how long the world has been producing power through traditional, post-industrial methods, the solar PV industry is relatively young. The technology is still being developed, and policy is still catching up to the technology. Considering these facts, and conclusions drawn about the adoption and proliferation of solar PV panels and policies must be understood within these contexts.

Given these data limitations, data captured in this study proves very robust, and lacks multicollinearity or homoscedasticity. Using tests for multicollinearity, all independent variables returned a VIF score below the accepted maximum of 5.0 (Table 3). Additionally, using Park's test to further assess the multicollinearity of my data, no independent variables raised any concerns. On a whole, my data passes all robustness checks.

In extended the work, there are plenty of avenues with which to extend this paper's findings and develop further conclusions. Findings from determinates of cost indicate that government policy aimed directly at the solar PV marketplace does not have any effect on the cost per kilowatt hour of solar PV panels. Examination of the costs of solar PV panels and methods to decrease their final retail price will provide law makers with more tools with which to increase the solar PV marketplace. Additionally, forecasting demand, for solar PV energy in the near and distant future represent natural extensions to my work. Finally, implementing further econometric work into the regressions represented in this paper can provide rich results. For example, detailing and capturing the exact impacts of financial incentives and regulatory policies can provide more accurate determinants of the effect of policy in the solar PV field. In addition to this, using LOCE methodology on my dataset can provide another dimension of the effect of government policy on the size and cost of solar PV panels.

The work represented in this paper concludes that a meaningful relationship exists between the size of solar PV markets and the amount of financial incentives offered at the state level. In determining cost per unit of solar PV energy, results indicate that government policy captured in my study does not represent an effective method for reducing the cost per kilowatt hour of solar PV energy.

VIII. Tables

Table 1:

VARIABLES	(1) Number of Installations	(2) Cost per Kilowatt
LN_Income	-32,336	-0.0956
	(92,258)	(2.216)
LN_Population	12,434	-0.0186
	(12,317)	(0.297)
SQ_Size	--	0
		(0)
Cost of Traditional Energy	356,584	--
	(329,996)	
SQ_Cost of Traditional Energy	--	-11.92
		(23.43)
AVG KWH of Sunlight	33,118	0.0613
	(24,390)	(0.596)
Regulations	-2,383	-0.00426
	(4,683)	(0.113)
Incentives	4,191**	-0.0378
	(2,029)	(0.0508)
SREC Dummy	47,278	0.237
	(29,713)	(0.723)
Constant	-72,922	7.654
	(1.082e+06)	(26.17)
Observations	49	49
R-squared	0.422	0.059

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 2:

VARIABLES	Average	Standard Deviation	Mode	Median
Log Average Income	52,653	8304.571899	N/A	54647.5
Log Population	7456093.96	7842332.153	6794422	2085109
Number of Installations	18389.38	87370.38159	5	1185
Cost of traditional energy	0.128054	0.039316856	0.1155	0.11075
AVGKWH of Sunlight	4.292040816	0.530652034	4.14	4.255
cost per kilowatt	6.134694	1.670857592	6.2	6.172
Regulations	6.1	4.450406998	4	4
Incentives	9.42	10.00222424	4	6.5

Table 3:

HO: $\alpha_1 = 0$

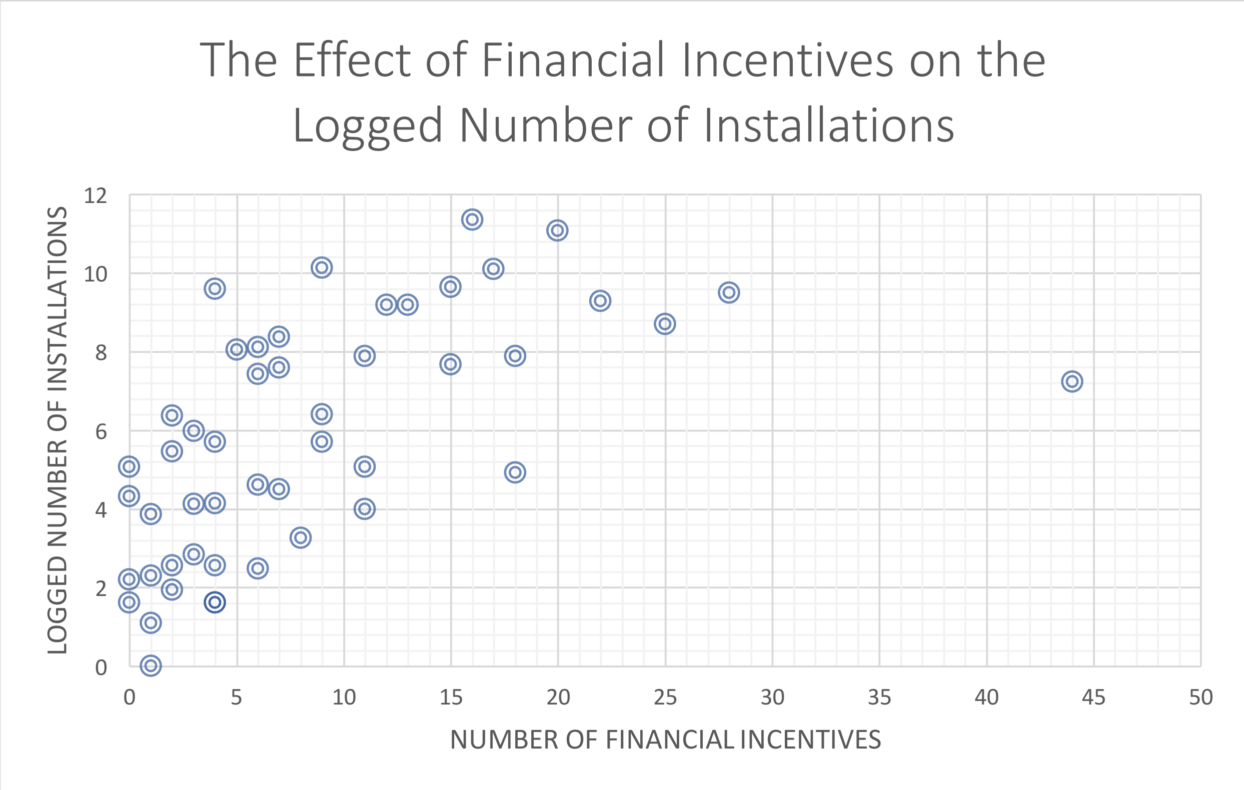
HA: $\alpha_1 \neq 0$

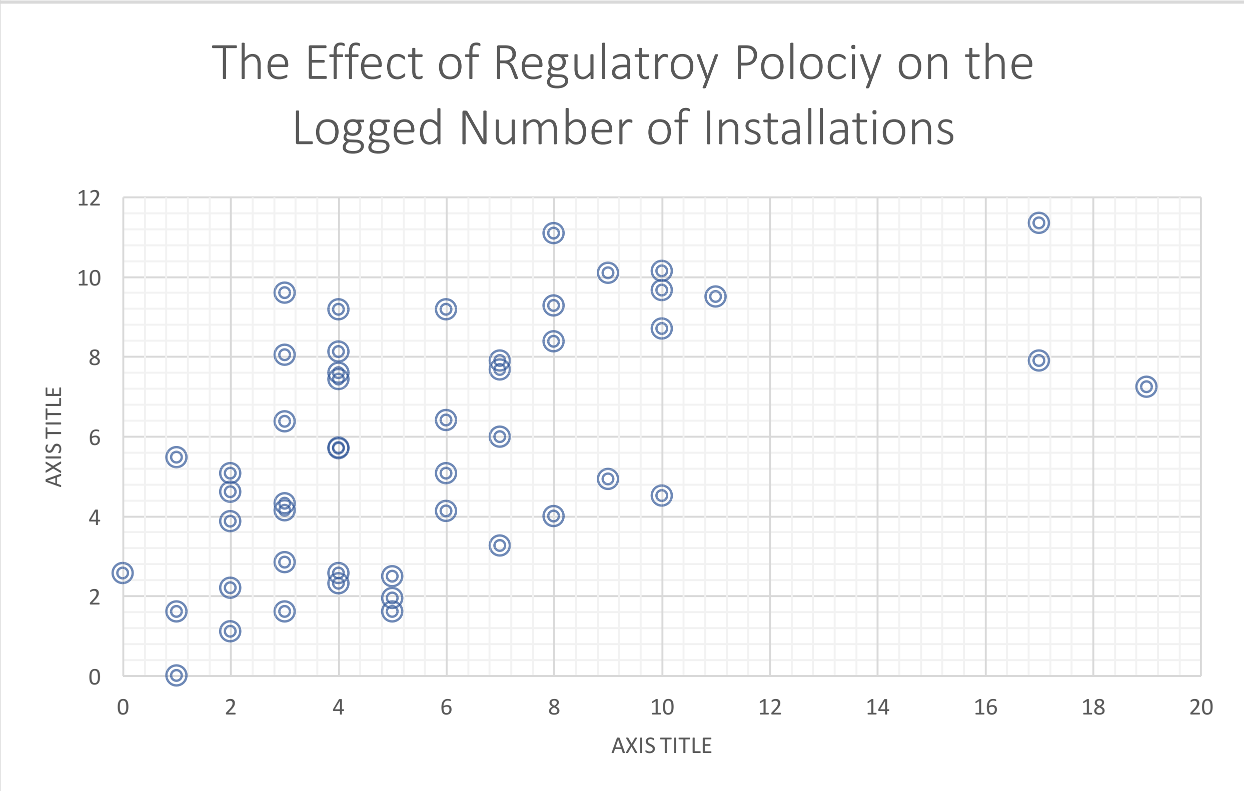
Accept Null Hypothesis

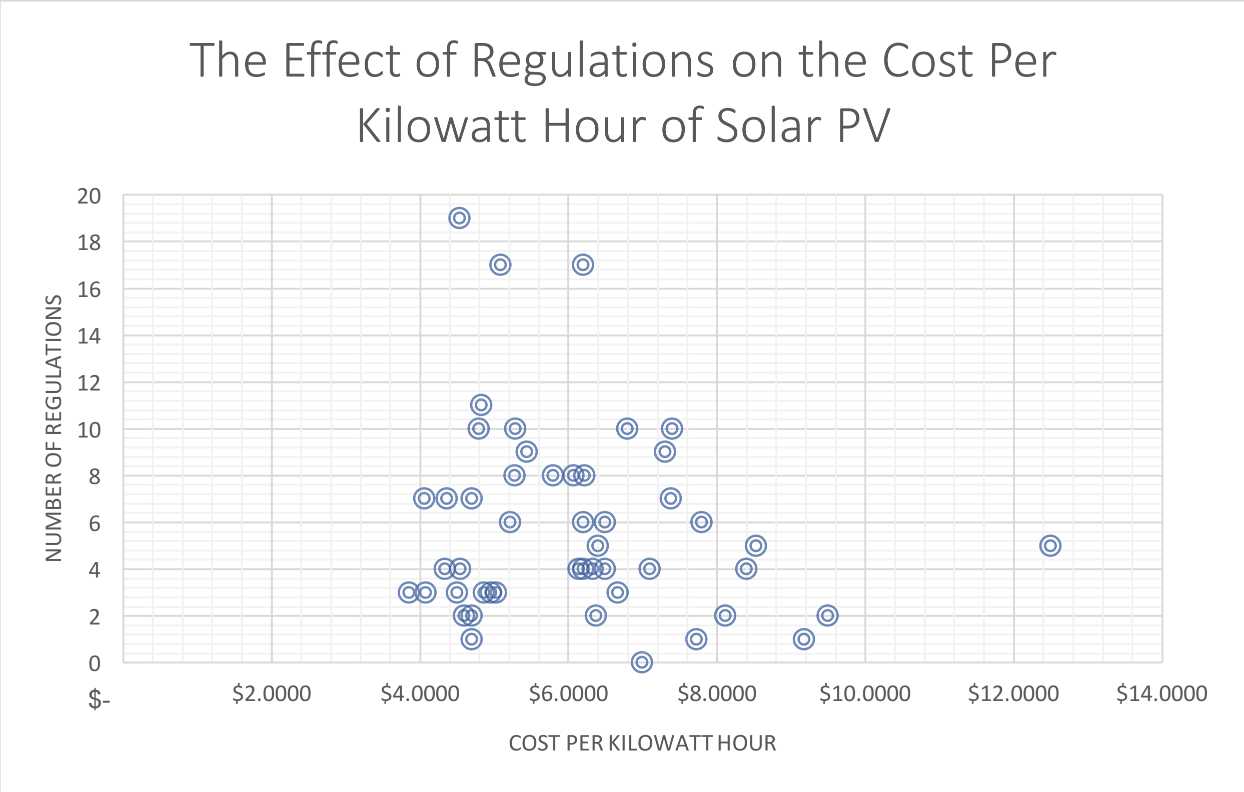
VARIABLES	VIF: Number of Installations	VIF: Cost per Kilowatt
Log Average Income	1.90	1.93
Log Population	2.55	1.36
Number of Installations	--	Squared Number of Installations: 1.56
Cost of traditional energy	1.40	Squared Cost of Traditional Energy: 1.34
AVGKWH of Sunlight	1.49	1.56
cost per kilowatt	1.06	--
Regulations	3.94	4.01
Incentives	3.73	4.10

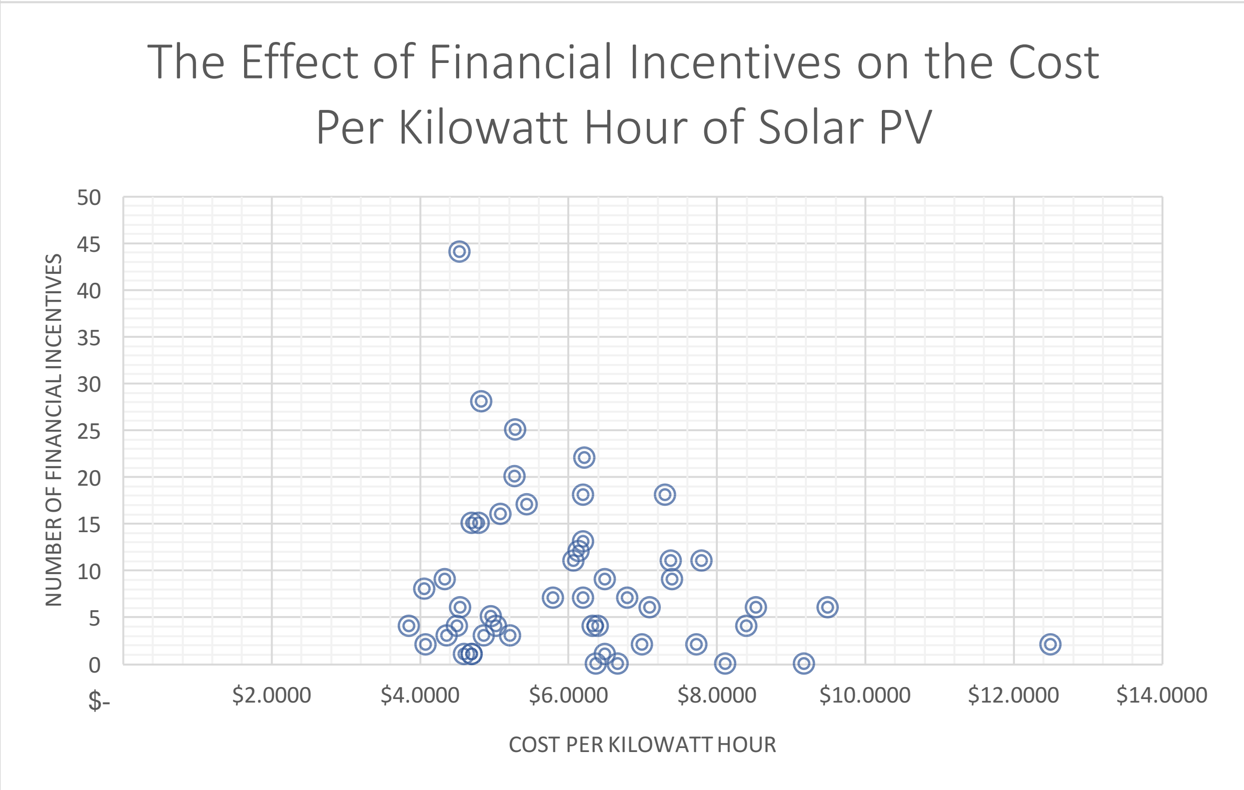
All of the VIF's presented in this table are below the accepted maximum. Additionally, the completion of Park's test across all variables fails to find any multicollinearity or homoscedasticity.

IX. Graphs


The Effect of Financial Incentives on the Logged Number of Installations
LOGGED NUMBER OF INSTALLATIONS
12
10
8
6
4
2
0
0
5
10
15
20
25
30
35
40
45
50
NUMBER OF FINANCIAL INCENTIVES


The Effect of Regulatroy Polociy on the Logged Number of Installations
AXIS TITLE
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
16
18
20
AXIS TITLE


The Effect of Regulations on the Cost Per Kilowatt Hour of Solar PV
NUMBER OF REGULATIONS
0
2
4
6
8
10
12
14
16
18
20
$-
$2.0000
$4.0000
$6.0000
$8.0000
$10.0000
$12.0000
$14.0000
COST PER KILOWATT HOUR


The Effect of Financial Incentives on the Cost Per Kilowatt Hour of Solar PV
NUMBER OF FINANCIAL INCENTIVES
0
5
10
15
20
25
30
35
40
45
50
$-
$2.0000
$4.0000
$6.0000
$8.0000
$10.0000
$12.0000
$14.0000
COST PER KILOWATT HOUR

Isaac LJ Locke
Senior Seminar, Spring 2017
Thesis Draft
5/3/17

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