The Influence of Renewable Energy's Changing Cost on Its Capacity Growth

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Abstract

This paper explores whether the changing cost of renewable energy influences renewable electricity capacity growth. Using Levelized Cost of Electricity (LCOE) as the standard to measure cost, the study finds that as the cost decreases by 1%, 0.85% more renewable capacity would be added to the grid. Furthermore, appropriate policy incentives can further accelerate the growth of renewables.

JEL codes: Q41, Q42, Q48

Keywords: Renewable Energy Development, LCOE, RPS,

Introduction

With more and more attention paid to climate change every year, people have long regarded renewable energy as one of the necessary solutions to avert this global crisis. In recent years, the cost of renewable energy has declined significantly and is now lower than conventional energies such as coal and oil at certain locations. Nonetheless, as Simon Larsson (2013) points out, the cost of renewables are very site-specific, even though two locations may only be miles apart. Economic theory suggests that when the price of a normal good decreases, demand should increase. Therefore, despite the fact that clean energy projects may face different cost curves, the ever-lowering industry average should, at least in theory, encourage more renewable energy capacity to be developed.

Existing literature has identified three aspects to have significant correlations with the capacity of renewable energies. The first aspect includes policy incentives such as tax credits and clean energy mandate (L. Alagappan 2011), and the second covers external factors such as carbon emission per capita (Mehmet Efe Biresselioglu 2016), income (António Cardoso Marques 2010), and political lobbying (Antonio C. Marques n 2010) from traditional energy firms. The third one focuses on financial factors such as the cost of renewables, cost of electricity, etc.

Researchers have examined the first two aspects fairly extensively, but the last aspect, the one that seems to be the most straightforward, remains surprisingly unexplored. Therefore, this paper first quickly explores how policy and external factors can influence clean energy development and interact with financial factors. Then, it is dedicated to analyze how financial factors specifically influence clean energy development and the magnitude of such relationship. As the prices of renewables continue to drop, understanding such a relationship can help investors, policy makers, and the energy sector to better react and even prepare for future energy trends.

Key Energy Concepts

Levelized Cost of Energy (LCOE):

The metrics this study uses to measure the cost of different energy projects is Levelized Cost of Energy (LCOE). As the standard measure in the electricity industry, LCOE measures the average cost per either kilowatt or

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megawatt hour of electricity over the lifetime of an energy project. It is a tool to compare the costs of producing electricity across different projects, regardless of the type of energy sources.

In order to do so, LCOE discounts costs including construction, financing, fuel, operations, maintenance, taxes, insurance, and incentives to the present value. Then, the cost is averaged out over the lifespan of the project ("What Is Lcoe, Renewable Energy Advisors" 2017). Such calculation is particular useful when renewable energies are compared to conventional energies because they have very different cost structures.

Specifically, renewable projects often have a bigger upfront cost compared to traditional sources because the fluctuations in generation put more requirements on the transmission system for renewables. However, since the sources for clean energy (sunlight, wind, hydro, etc) are free, the operating cost of renewables is much lower than that of conventional energies. In addition to different cost structures, traditional energy costs tend to vary more over time. Using fossil fuel as the main sources of energy, conventionally-produced electricity cost is very much subject to highly volatile oil and gas prices.

LCOE is designed to avoid precisely both of these two problems. First, it takes future risks into consideration by adjusting discount rates. Second, it looks at the cost of projects over their lifetime. These two features make LCOE a reliable way to compare costs across projects.

Renewable Portfolio Standards (RPS):

While this paper focuses on the impact of financial factors, it controls for the impact of policy incentives by including a dummy variable representing whether a state has a renewable portfolio standard (RPS) in one year. RPS is a government rule that requires a certain percentage of the energy supplied by utility companies in a state to come from renewable sources. For the electricity market, energy companies often act as the producers and utility companies are the distributors.

Because producers and distributors are often seperately entities, many state governments have set up the Renewable Energy Certificate (REC) system to facilitate the compliance of RPS. For every megawatt of renewable energy produced, energy companies are credited with one Renewable Energy Certificate (REC). Utility companies then purchase these RECs to show that some of their electricity is renewable to meet the state RPS.

RPS policy incentives are particularly popular for two reasons. One, it provides renewable energy firms an additional revenue channel compared to conventional energy companies. Second, staggered RPS goals gradually steer a state's energy production to be more renewable heavy without causing major disruptions to the market.

Despite the seemingly clear definition of RPS, the strength of different RPSs can vary greatly. Haitao Yin (2009) conduct a comparative study on all states currently with RPSs and find that RPSs can vary on several grounds. One, RPSs do not cover the same group of energy producers in each state. Six states (Maryland, Iowa, Texas, Minnesota, Hawaii, and Wisconsin) require all projects to comply. However, some states give exemptions to either an entire class of projects or even specific companies. In Montana, for example, only investor-owned projects are required to comply. RPSs in many states (Connecticut, Pennsylvania, Arizona, Illinois, and Colorado) only cover 60% of all electricities produced. Second, different states also vary on whether they allow generations from existing clean sources to be counted toward RPSs. When only new capacities are eligible, there is a stronger incentive to build new facilities. New capacities refer to the capacities built after RPS policies are in policy. Thus, generations from existing projects would not qualify for RPS. Third, states also differ on if they allow out-of-state RECs to be counted toward RPS. Some (California, Iowa, Illinois, and Hawaii) prohibit any out-of-state RECs. Some allows out-of-state RECs but heavily incentivizes in-state RECs. A small group of states allows free trading of RECs.

Due to limits in time, this study is unable to dive into the laws of all 50 states on RPS and REC. Therefore, a simple dummy variable is included to control for whether a state has any kind of RPS.

Feed-in-Tariff (FIT):

In addition to RPS, another popular mechanism often used by the government to stimulate clean energy is Feed-in-Tariff (FIT). FIT often has three key components. First, it offers guarantees access to the grid. Second, FIT provides developers with long-term purchasing agreement for clean electricity. Third, FIT stipulates that clean electricity need to be paid for at the price level that properly reflects its cost. Since clean power is still more expensive than traditional in most cases, this allows renewables to be sold at a premium.

While RPS essentially creates a market based trading mechanism very much to the cap-and-trade system for carbon dioxide, the government plays a much more active role in the FIT system.

Literature Review

As stated earlier, three key aspects have been identified as drivers of renewable energy development. They are: policy initiatives, external environmental and political factors, and financial factors. The following section examines existing literature and justifies some of the variables included in the model.

Policy Incentives:

Two of the most popular policy incentives are RPS and FIT, both of which are discussed above. Literatures generally agree that they are helpful to the development of renewables but sometimes disagree on the level of helpfulness.

To examine whether RPS is indeed effective, Haitao Yin (2009) looks at how variations in RPS could impact its effectiveness. Despite the fact that RPS can vary greatly across states, they find that RPS policies overall have significant positive impact on renewables. While this result is not very surprising, their finding on how allowing "free trade" of RECs could significantly reduce the effectiveness of RPS shows that RPS is best used under appropriate complementary conditions. For example, A. Mahone a (2009) looks at California specifically to examine the relationship between RPS and the cost-effective level of clean energy investment. Their results suggest that if renewable energy remains more expensive than conventional energy, increasing the RPS target is an effective way to stimulate clean energy. This is important because it highlights policy incentives and financial factors do not work independently.

As for whether FITs are effectives, L. Alagappan (2011) looks at fourteen energy markets and examines whether feed-in-tariff, along with market structure and transmission planning, are effective ways of promoting clean energy development. They find that market structure has very little impact on renewable energy development. However, in markets with FITs and employing anticipatory transmission planning, in contrast to reactive transmission planning, renewable energy development has been very active and successful. Their finding affirms that FIT, along with RPS, are effective measures of boosting renewables. Moreover, it is feasible to compare renewable energy capacity development across different states although their market structures may be slightly different.

Lastly, Shahrouz Abolhosseini (2014) compares the effectiveness of feed-in-tariff and RPS. The analysis shows that the former helps to reduce the risks for investors whereas the latter helps the energy industry to take a market approach. Depending on the strength of RPS and premium level of FITs, either one can be more effective than the other. Nonetheless, both policies spur renewable energy developments.

External Factors:

In addition to policy factors, many previous papers have identified some other external factors to be relevant. Some of the factors include political lobbying, CO2 emission level, income level, and public-private sector relationship.

Antonio C. Marques n (2010) talks about how political lobbying efforts from traditional energy sources and objectives to reduce energy dependency all can impact renewable energy development. By looking at a group of European countries, he finds that the efforts of traditional energy companies can slow down the pace of clean power development. On the other hand, countries with CO2 emission reduction goals see a faster growth of renewables than those that do not. Moreover, by looking at wind only, Mehmet Efe Biresselioglu (2016) argues that higher carbon dioxide per capita has a positive relationship with more capacity in the European countries they observed. Similarly, using data from G7 countries, Sadorsky (2009) finds that increases in real GDP per capita, as well as CO2 emission per capita, drive renewable energy up. However, neither studies controlled for RPS or FIT. It is possible, as a result, that higher CO2 emission in the observed countries lead to these RPS or FIT. These policies subsequently help increase renewable capacity.

In addition, Dent (2015) looks at empirical evidences from China, as it has seen a dramatic increase in its renewable energy capacity. The author argue that the strategic goals put forward by the Chinese government, enabled by the competition between State-Owned-Enterprises (SOE) and private companies, are key drivers of this capacity hike. However, the paper admits that this formula's main advantage is in the equipment manufacturing stage rather than the entire energy value chain.

Irene Henriques (2007) analyzes alternative energy stocks, technology stocks, oil prices, and interest rates. They find that shocks to technology stocks have a greater impact to renewable energies than oil. To many's surprise, clean energy stocks aren't very much subject to oil price changes. The authors attribute this to the high volatility of the traditional energy sector.

In short, while both policy incentives (RPS and FIT) turned out to be significant, it is only the case for some social and political factors. More importantly, even for those are significant, the link between them and new capacity seem to need more careful explorations because it is unclear whether they indeed describe the effects of some lurking variables. Importantly, the last two studies mentioned above do suggest that private sectors play a great role in increasing renewable capacity.

Financial Factors:

In addition to policy and external factors, financial factor is the third aspect that could potentially affect renewable energy development. Specifically, how could the cost changes of building renewable projects affect the capacity? After examining the literature, this question, despite seemingly straightforward, remains unanswered. Existing studies, nonetheless, does provide relevant useful insights.

One of the most relevant pieces on this topic is from Xiaoling Ouyang (2014). Their work focuses on how cost factors influence renewable energy development in China and what policy makers could implement to further speed up its development. Specifically, they look at fourteen variables included in LCOE and changed these metrics to see how LCOE would be affected. By testing variables like import levies, project development cost, auxiliary equipment cost, cost of decommissioning, etc under 3 discount rates, the study indicates that high cost is a restriction for development of renewable energy, especially for large scale projects. This makes sense because large renewable energy projects are often capital-intensive and therefore a small LCOE change can have material impact on the whole project.

Other scholars further identify what variables have the most impact on LCOE. Focusing on wave and tidal energy in the UK, Grant Allan (2010) conducts sensitivity tests on different variables. They find that construction costs, fuel costs, and discount rates are key factors affecting the LCOE of various kind of renewable energies. Similarly, Simon Larsson (2013) conducts a meta-analysis of twenty recent journal articles regarding the cost of renewables. They find that LCOEs are most sensitive to discount rates and fuel cost. Note that this is somewhat contrary to the findings of Irene Henriques (2007) because oil and gas prices are insignificant there.

Lastly, by looking at the LCOEs of different projects, both conventional and renewable, Falko Ueckerdta (2013) find that LCOEs are highly time and location specific. LCOEs for project geologically adjacent could be vastly different depending on technologies used, incentives received, etc. Therefore, when aggregating cost information to state or yearly levels, it is inappropriate to simply use the industry LCOE mean times total capacity. Instead, the total cost should should be the sum of each individual project.

In summary, existing literature has touched on the sensitivity of LCOE to its various components and provided the method on how to aggregating LCOE data. However, the link between renewable energy development and LCOE remains unexamined.

Methodology

To examine this relationship, this paper uses the amount of new clean electricity capacity in a state in a given year as the y-variable. On the right side, it includes variables such as the cost of developing renewable energy, the average electricity cost price, median income, and policy incentives.

Note the dependent variable here is the new capacity added rather than new clean electricity generated. This is a deliberate choice for two reasons. One, capacity increase does not necessarily lead to generation increase. Second, the time period between the investment of a project to that project becoming operational, mainly the construction and test time, can be significant and vary greatly. It would be hard and unreliable to find and use any industry-level data for project construction and testing.

With a set of panel data, this paper uses the following models to explore the relationship between renewable energy capacity and LCOE. Each variable varies across different states and different years.

Panel Model 1 (Fixed Effect):

$$\begin{aligned} ln(RenewableEnergyGeneration)_{it} &= \alpha_i + \beta_1 ln(WeightedAverageLCOE)_{it} + \beta_2 ln(StateMedianIncome)_{it} \\ &+ \beta_3 ln(ElectricSectorEnergyAvg.Price)_t + \beta_4 ln(RPS)_{it} \end{aligned}$$

Panel Model 2 (Random Effect):

$$\begin{aligned} ln(RenewableEnergyGeneration)_{it} &= \alpha_i + \beta_1 ln(WeightedAverageLCOE)_{it} + \beta_2 ln(StateMedianIncome)_{it} \\ &+ \beta_3 ln(ElectricSectorEnergyAvg.Price)_t + \beta_4 ln(RPS)_{it} \\ &+ \beta_4 Year \end{aligned}$$

This model includes variables from each of the three aspects discussed above. Specifically, RPS controls for some of the policy impacts. Median income in each state each year tests is added in the model in case income has any influence. For the financial factor category, LCOE and Electricity Energy Price are included.

As Grant Allan (2010) and Simon Larsson (2013) note, discount rates and fuel costs are the two most important variables influencing the cost of renewables. LCOE and Electricity Energy Price account for both. Specifically, according to OpenEI.Org (2017), a part of LCOE is the Capital Recovery Factor (CRF), which is made of the discount rate (D) and the lifetime of the investment (N). CRF is then used to calculate the capital cost of the LCOE. In rare cases that D = 0, there still is a CRF, which would then become 1/N. Fuel cost is included in the electricity energy price. A great percentage of electricity still comes from conventional fossil fuel sources such as oil and gas. Thus, fluctuations in the price of fuel is captured by changes in electricity energy price.

When running regression models, four variations of Model 1 are also tested. Three tests independently add a variable of LCOE lagged by one, two, and three years respectively. Doing so can potentially reveal any relationship between LCOE from previous years and capacity growth. The fourth variation of Model 1 is to add a "Year" variable and "Year^2" variable. The first variable measures how capacity changes over time and the second variable measures the growth rate trend as time progresses.

Data

A total of four datasets were used to construct this model, and below is a summary of the variables.

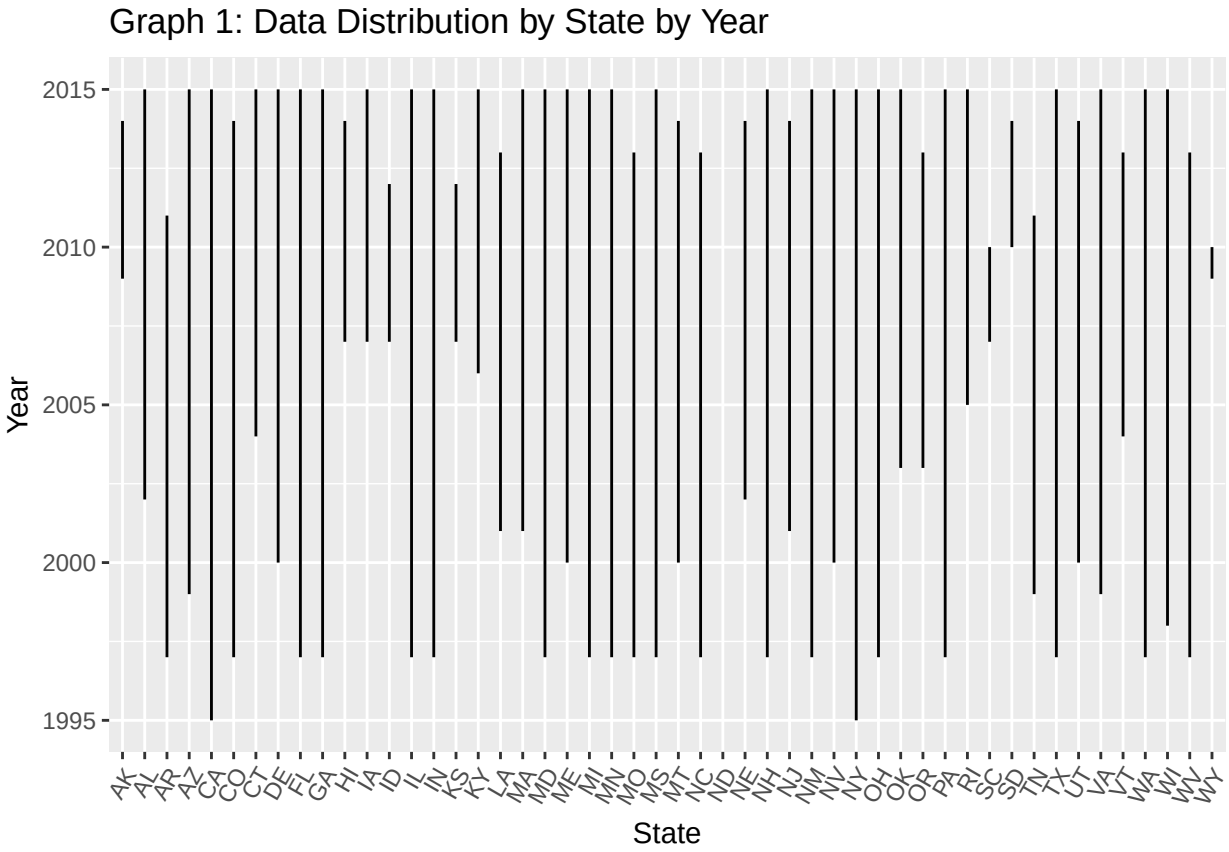
Statistic	N	Mean	St. Dev.	Min	Max
Year	525	2,007.996	4.804	1,995	2,015
Total_New_Capacity_LCOE	525	58,821.760	230,871.500	0.900	2,368,236.000
Total_New_Capacity_KW	525	11,236.390	46,722.920	0.064	436,159.300
RPS	525	0.602	0.490	0	1
ElecCost	496	2.849	1.836	0.590	18.380
Median_Income	525	49,993.720	8,978.131	26,162	76,165
Weighted_Avg_LCOE	525	6.786	2.809	1.550	21.110
Logged_New_Capacity	525	5.308	3.231	−2.749	12.986
Logged_Avg_LCOE	525	1.833	0.410	0.438	3.050
Logged_ElecCost	496	0.908	0.509	−0.528	2.911
Logged_Income	525	10.804	0.181	10.172	11.241

The y-variable here is the total new capacity from renewable energy, measured in KwHrs, in each state each year. Our main interested variable is the weighted average LCOE of a state in a given year. Both of these variables are calcuated based on a dataset from the U.S. Department of Energy. The original dataset includes over 500,000 renewable energy projects and their cost information from 1995 to 2015. These data points were aggregated to calculate the weighted average LCOE in each state and each year using the following formula.

$$WeightedAverage.LCOE = \frac{Project_1TotalCost + Project_2TotalCostOf \cdots + Project_nTotalCost}{Project_1Capacity + Project_2Capacity \cdots + Project_nCapacity}$$

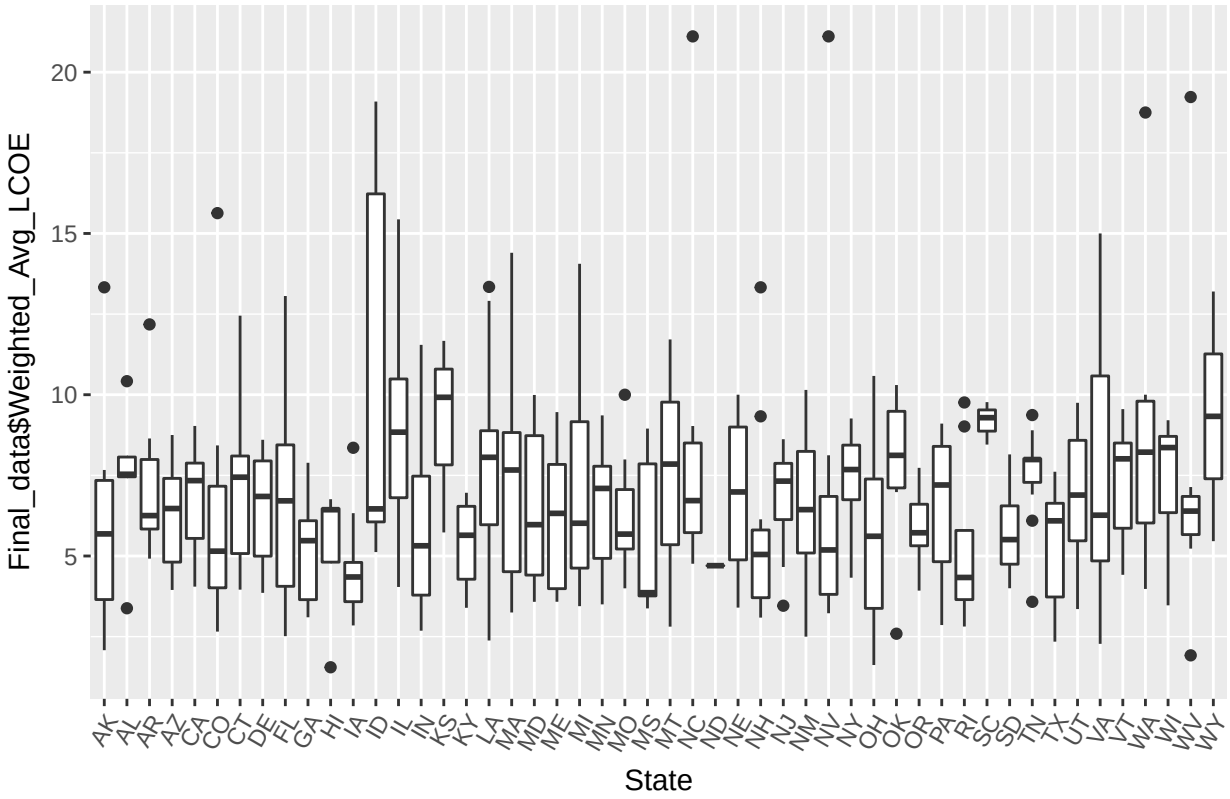
The aggregated capacity (in Kw) and LCOE (Measured in Dollar per Watt) data is then merged with RPS, Electricity Energy Cost (Measured in Dollar per Watt), and Median Income (Household value measured in 2015 Dollars) to construct the final dataset.

Graph 1 shows the years in which we have data for each state. As the graph suggests, our panel is quite unbalanced. This is important to keep in mind as we later run panel regressions.

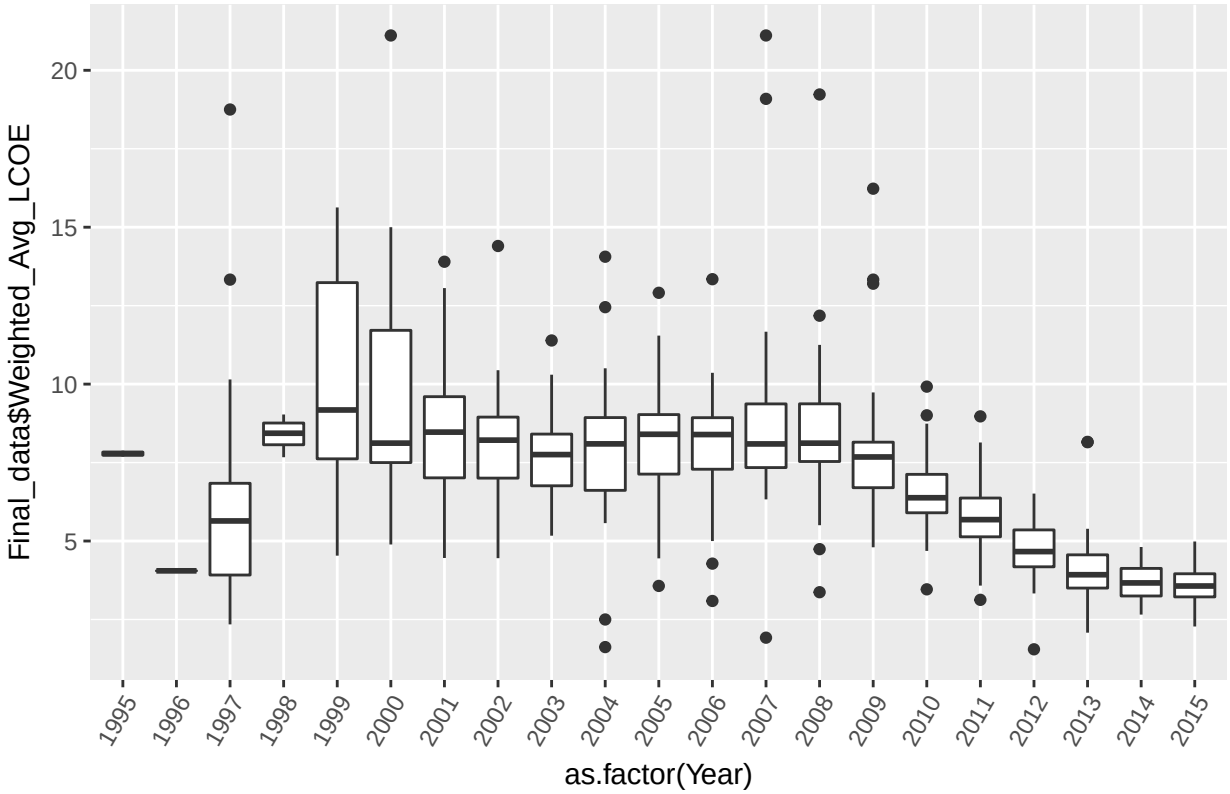


As Falko Ueckerdta (2013) suggests, the aggregated LCOEs should vary across state and time. Graph 2 shows that LCOE in different states can vary significantly. Moreover, Graph 3 shows that LCOE decreases over time, especially after 2009.

Graph 2:LCOE Distribution by State

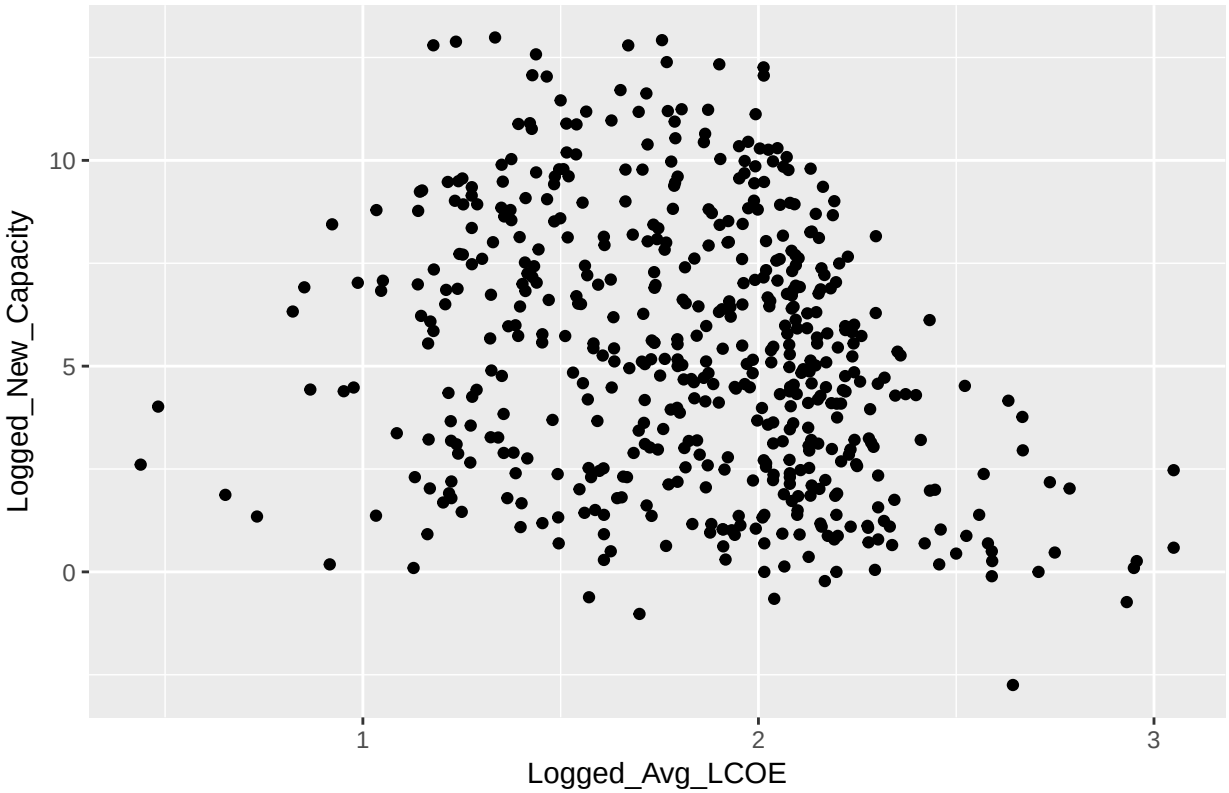


Graph 3:LCOE Distribution by Year

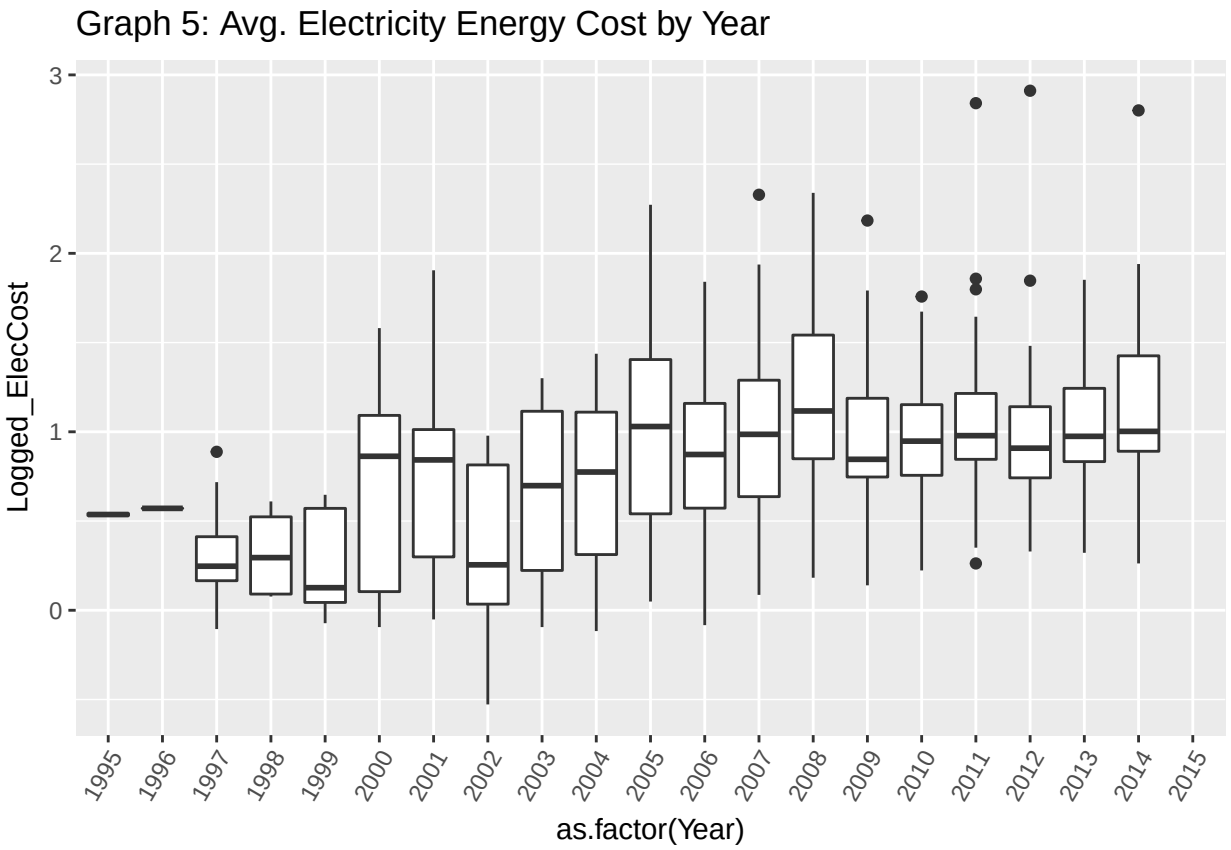


Without controlling for anything, a scatter plot of the logged total capacity from renewable sources and logged weighted average LCOE suggests that there may be a linear relationship between the two. Nonetheless, other variables need to be controlled to verify this linear correlation.

Graph 4: Logged Capacity (Kw) v. Logged Weighted Avg. LCOE

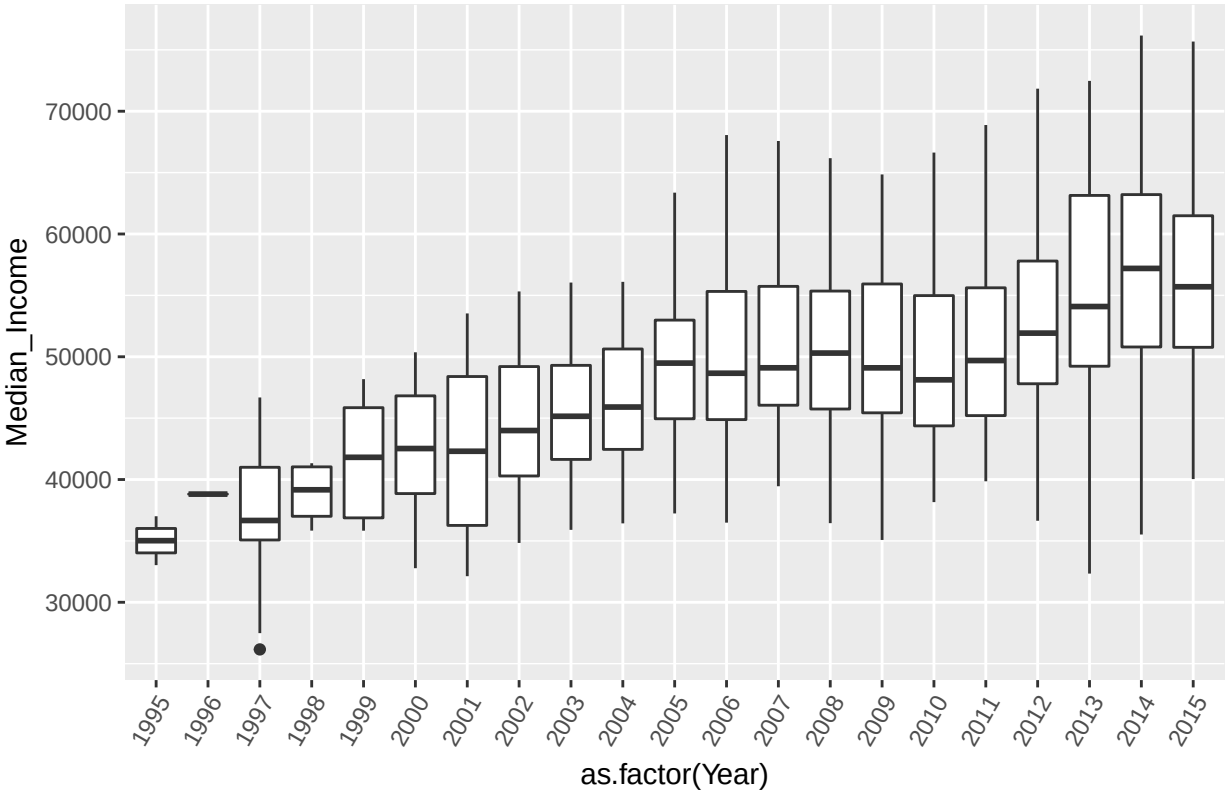


The first control variable is the primary energy average price in the electricity sector from the U.S. Energy Information Administration (EIA). It measures the average energy price a state pays for producing its electricity each year. Graph 5 below shows that electricity energy costs, despite having some slight variations, exhibit a stably upward trend.



The second control variable is the median income of each state in each year from the Census Bureau. This is important because previous studies such as António Cardoso Marques (2010) indicate that income may influence renewable energy capacity development. Intuitively, having income as a control also makes sense because people's income may influence whether they are willing and capable or investing in renewables, which often demand a large upfront investment. The graph shows that similar to electricity cost, income has also been increasing steadily. However, there are almost no outliers in the distribution of income across different years.

Graph 6: Income by Year



Lastly, as for policy incentives, this paper uses a dummy variable to indicate whether a state has RPS in a given year. Such data is from the Database of State Incentive for Renewables & Efficiency (DSIRE). The graph below shows how states at different times have changed RPS requirements. A red dot means a state does not have a RPS in one year, while a blue dot indicates the presence of a RPS. Twenty states instituted some kind of RPS during the time this dataset covers.

Graph 7: RPS by State by Year

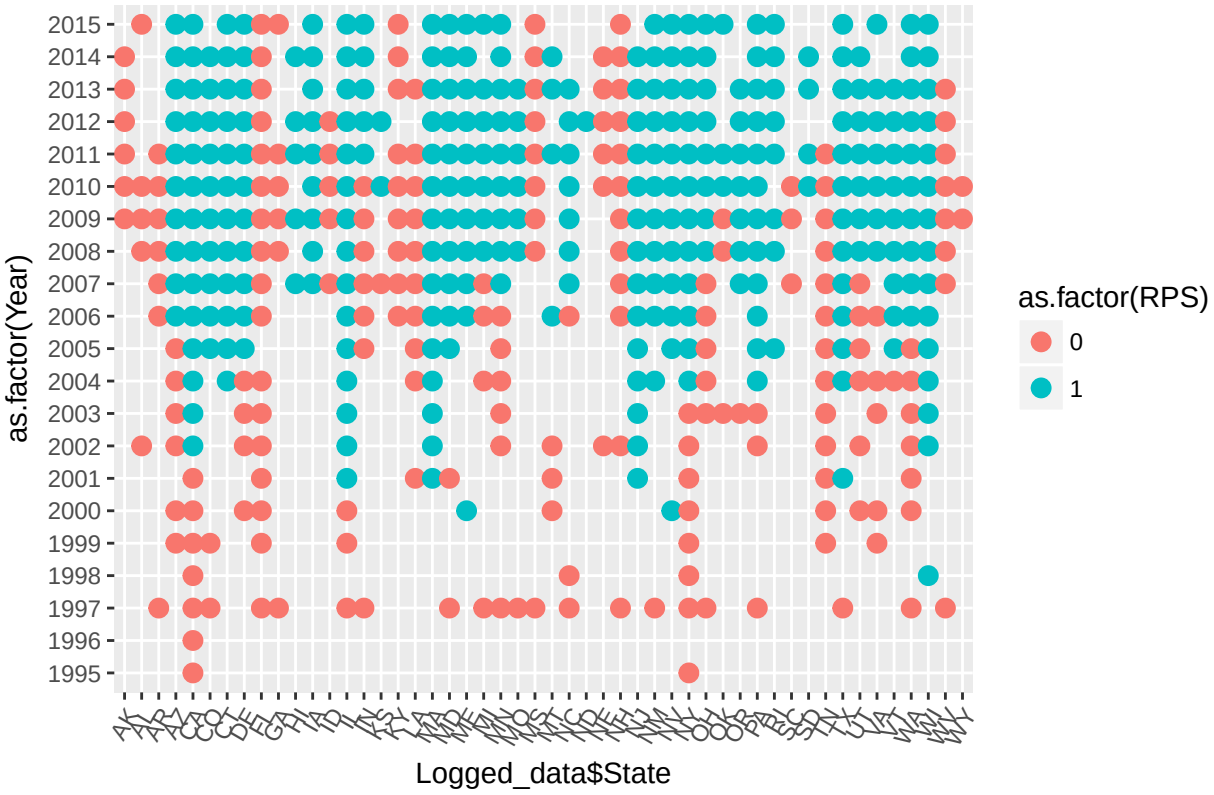


Table 1: Model 1, 2, 3, 4, 5 Summary (All Fixed Effects Model)

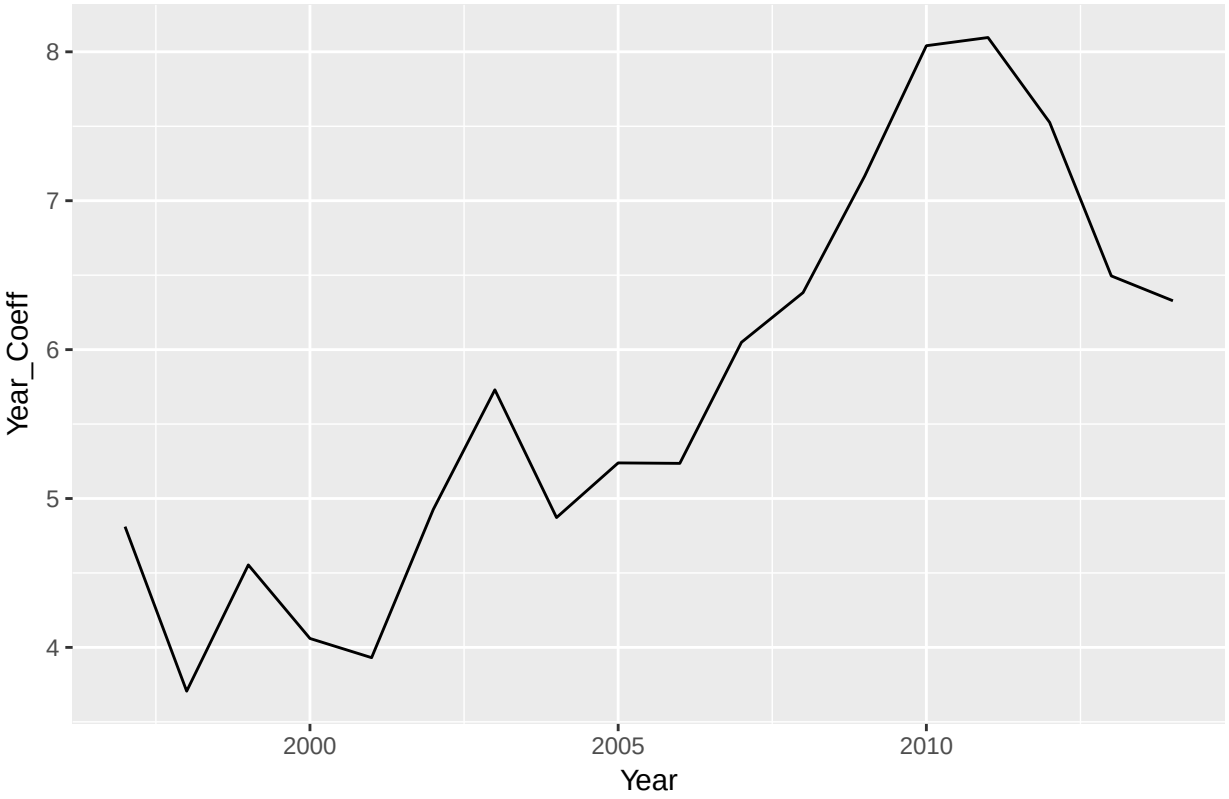
	Dependent variable:				
	Logged_New_Capacity				
	(1)	(2)	(3)	(4)	(5)
Logged_Avg_LCOE	−0.856***	−1.579***	−2.202***	−2.275***	−0.709**
	(0.288)	(0.416)	(0.511)	(0.591)	(0.299)
Logged_ElecCost	0.502	0.098	0.232	0.734	0.138
	(0.477)	(0.541)	(0.578)	(0.641)	(0.443)
Logged_Income	1.624	3.063	5.081**	4.431**	−2.095
	(1.693)	(1.885)	(1.960)	(2.080)	(1.706)
RPS	0.256	0.210	0.289	−0.105	0.570*
	(0.297)	(0.363)	(0.400)	(0.466)	(0.324)
lag(Logged_Avg_LCOE, k = 1)		0.068			
		(0.348)			
lag(Logged_Avg_LCOE, k = 2)			−0.031		
			(0.371)		
lag(Logged_Avg_LCOE, k = 3)				0.140	
				(0.382)	
as.numeric(Year)					0.664***
					(0.126)
I(as.numeric(Year)^2)					−0.012**
					(0.005)
Observations	496	389	332	287	496
R^2	0.028	0.057	0.097	0.094	0.522
Adjusted R^2	−0.137	−0.151	−0.123	−0.157	0.463
F Statistic	3.053** (df = 4; 423)	3.818*** (df = 5; 318)	5.733*** (df = 5; 266)	4.640*** (df = 5; 224)	80.177*** (df = 6; 440)

Note: *p<0.1; **p<0.05; ***p<0.01

Results

	Dependent variable:
	Logged_New_Capacity
Logged_Avg_LCOE	-0.977^{***}
	(0.305)
Logged_ElecCost	0.418
	(0.359)
Logged_Income	3.216^{***}
	(1.202)
RPS	0.930^{***}
	(0.283)
Year1996	-1.385
	(2.157)
Year1997	4.811^{***}
	(1.328)
Year1998	3.706^{**}
	(1.533)
Year1999	4.554^{***}
	(1.420)
Year2000	4.060^{***}
	(1.381)
Year2001	3.931^{***}
	(1.391)
Year2002	4.926^{***}
	(1.361)
Year2003	5.730^{***}
	(1.375)
Year2004	4.872^{***}
	(1.371)
Year2005	5.239^{***}
	(1.399)
Year2006	5.236^{***}
	(1.393)
Year2007	6.049^{***}
	(1.408)
Year2008	6.383^{***}
	(1.421)
Year2009	7.166^{***}
	(1.396)
Year2010	8.041^{***}
	(1.399)
Year2011	8.096^{***}
	(1.410)
Year2012	7.526^{***}
	(1.421)
Year2013	6.495^{***}
	(1.447)
Year2014	6.328^{***}
	(1.466)
Constant	-35.557^{***}
	(12.648)
Observations	496
R^2	0.547
Adjusted R^2	0.524
F Statistic	24.363^{***} (df = 23; 472)
Note:	*p<0.1; **p<0.05; ***p<0.01

Graph 8: Random Effects Model Capacity Growth Rate by Year



A total of six regressions were performed. Five of these models are fixed effects models, and the sixth is a random effects model. Summaries of these models are attached, with the coefficients shown and their standard errors in parentheses. In addition, Graph 8 plots the year coefficients, which reflect the percentage increase in renewable capacity from one year to the year, in the random effects model.

All six models suggest that there is a statistically significant negative relationship between logged average LCOE and logged new capacity. In Model 1, for instance, the coefficient is -0.85. This means with every 1% increase in the cost, the amount of new capacity developed that year decreases by 0.85%. This negative correlation fits the intuitive expectation because demand generally goes up as price drops. The magnitude of such correlation, which measures elasticity, indicates that capacity growth is very much subject to price changes.

Interestingly, models with lagged LCOE did not find the cost from previous one, two, or three years to have an direct impact on the capacity today. Nonetheless, as the number of years lagged increases, the coefficient of the current LCOE increases. This is likely a result of people who waited in previous years for cheaper renewables decided to invest once they see current year's cost goes up. The basic model without any lagged LCOE has a lower LCOE coefficient compared to lagged models because the effects of these waited-for-years clients building new projects cancels out some of the capacity drop caused by price increase in the current year.

Moreover, income does not seem to have any correlation with renewable energy capacity. In Models 3 and 4, where lagged LCOE of two and three years are included, income is statistically significant. Nonetheless, it is not significant in Models 1, 2, and 5. Since income increases every year, it is possible that income here may be capturing the effects of some variables not included in the dataset that are changing from year to year. This hypothesis is reinforced by the fact when a "year" variable is added in Model 5, the effect of income disappears. The insignificance of income here is consistent with other studies such as António Cardoso Marques (2010).

Furthermore, the average electricity energy cost is not significant either. This is not very surprising because fossil fuel, which makes up the majority of the energy sources, can change quickly over a short period of time. On the contrary, adding renewable capacity often requires long term planning, so it is hard to add or drop capacities quickly. An investment decision never relies too much on average electricity energy cost because of its high

volatility. However, if generation rather than capacity is the dependent variable, it is very possible that average electricity energy cost would be significant because generations can be adjusted quickly.

RPS also appears to be insignificant in most of the fixed effects models, but its insignificance here does not mean it actually has no influence over capacity growth. The random effects model does indeed demonstrate that RPS is significant to the development of renewables. The magnitude of the coefficient, however, require a more careful interpretation. Since the random effects model measures variations across states and time, many differences across states, such as political leaning, are captured in the RPS model. As a result, the real impact of RPS is smaller than the random effects model suggests.

Furthermore, as Haitao Yin (2009) states, the strength and effectiveness of various RPS can vary greatly. Because the RPS variable in the models in this study is simply a dummy variable, it does not fully capture the variations in different state RPSs. It's possible that a more sophisticated RPS variable is necessary. Moreover, only about 20 states changed from no-RPS to RPS in the dataset. This is a relatively small sample size so more data points can also help to further examine the impacts of RPS.

Model 5, where variables "Year" and "Yearˆ2" are added, tells us about the trend of renewable capacity change. Specifically, both new variables are statistically significant, and Year has a positive coefficient while Yearˆ2 has a negative coefficient. These coefficients suggest that renewable energy capacity continues to grow over time. Nonetheless, holding everything else constant, the growth rate gradually slows down.

Model 6, the random effects variable, tells us the capacity increase rate each year. Graph 8 plots these rate and demonstrates a noticeable jump in 2005. While this may seem surprising, it can actually be attributed to the federal government implementing a ten-year Residential Renewable Energy Tax Credit Program in 2005 (gov, n.d.). Moreover, the drop of the growth rate starting around 2010 suggests that macroeconomic performance may have an influence over renewable energy capacity increase.

Discussion

Overall, all models suggest that as the cost of renewable energy decreases, more clean capacity is added to the grid. This relationship, regardless of adding lagged variables, year variables, or changing regression effects, is very robust. The magnitude of LCOE coefficients indicates that new renewable capacity has a very elastic relationship with cost. Furthermore, this study electricity energy price and income have little impact on people's decision to invest in renewables. Consistent with the findings of other studies, policy incentives such as RPS are very helpful to renewable energy development.

The results also suggest that renewable energy growth tends to slow down over time, unless new stimulators kick in. Policy incentives are often very effective ways to jumpstart or second-jumpstart renewable growth. For policy makers, adding incentives when the economy growth is slow is important to sustain the high rate of clean energy capacity growth.

Lastly, if possible, a more sophisticated RPS variable can be used in future studies. Also, since many of the studies discussed above have talked about the importance of Feed-In-Tariffs, a new variable on FIT is also worth considering.

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