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The Long-Term Effect of State Renewable Energy Incentive Programs

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Introduction:

According to the United States Energy Information Administration, of the total energy that the US currently produces, 11% is from renewable energy sources (EIA 2017). While on a levels basis this makes the United States one of the renewable energy leaders in the world, this *share* amounts to only 10% of the total energy consumption in the US. Therefore, the country instead is one of the least clean on a share of renewable energy consumption basis (World Bank 2017). This, combined with increasing awareness of negative externalities associated with fossil fuels, has policy makers in the US looking for ways to quickly grow their renewable energy production. Policy makers have two choices, the first being to mandate, and the second being to incentivize. The second option is arguably a more free market approach. This method has been utilized at the both the federal and state level through the implementation of various incentive policies. These renewable energy incentive programs are generally aimed towards the individual and household, and fall under the three categories of 1) financial incentives, 2) technological resources, and 3) regulatory policy (DSIRE 2017).

These incentive programs have increased greatly in popularity, causing the impact of these programs to be studied in depth. Economists Christine Crago and Ilya Chernyakhovskiy examined the effect of financial incentive programs specifically on residential solar photovoltaic capacity. The results showed that rebate programs had the largest effect of photovoltaic growth causing a 50% jump in residential solar output in the Northeast (Crago, 2014). Furthermore, economists Christoph Bauner and Christine Crago in a different study found that without incentive programs at all, median adoption time for household solar photovoltaic is 8 years longer than with the programs (Bauner, 2015). Thus, there is evidence that these policies are effective at the household level, particularly with respect to solar technology.

However, another study, which observed incentive policies' influence on mobilizing households to invest in low carbon technology, was largely inconclusive and discovered that households do not always operate in economically rational manners (Curtin et. al., 2017). Therefore, existing literature studying the effect of renewable energy incentives has lacked in three ways: the first, being that there is mixed evidence regarding their effect at the household level; the second being that there has been little discussion about the effect of these policies beyond households, on a more commercial and national level; and the third being that most studies are focused to a small region of the country, such as California or the Northeast (Kwan, 2012) (Crago, 2014).

Thus, this paper aims to address the question of whether these programs are effective beyond the household, for increased production of all renewable energy at the state and national level. When a policy maker is deciding how to help grow renewable energy production in their state, it is important to have a clear understanding of what greater impact an incentive policy will have in the long run.

This paper analyzes differences in state renewable energy production caused by their specific financial incentives, technological resources, and regulatory policies. Contrary to previous findings, this paper's results suggest that for state wide renewable energy production, technological resources are the most influential incentive category. This insight is tested in an expansion, where different models are utilized to examine technological incentives in depth.

The paper proceeds as follows: Section 1 discusses the data used for analysis and presents basic summary statistics at the state level, Section 2 includes the empirical framework and methodology used to address the research question, Section 3 analyzes the specific results and insight from the findings, and Section 4 concludes the paper.

Data:

In this paper the two main data categories under examination are renewable energy production and state renewable incentive programs. For information concerning energy production and consumption, data was sourced from the US Energy Information Association. For information on state incentive programs, data is sourced from the Database of State Incentives for Renewables and Efficiency. There are 50 states, each with renewable energy production levels from 1960 through 2014, total energy production levels, current number of incentive programs are separated into the three categories (financial incentives, regulatory policy, and technological resources), and basic growth rates and levels on a total and per capita basis. Financial incentives are any program that offers monetary discounts for renewable development. These include corporate tax incentives, feed in tariffs, grant programs, green building incentives, loan programs, performance based incentives, rebate programs, and more (DSIRE, 2017). Regulatory policies are any program that establishes a minimum standard or rule for green consumption and production. These can include building standards, appliance standards, net metering, solar and wind access policies, renewable energy licensing, and more (DSIRE, 2017). Technological resources are programs that provide information or knowledge about renewable energy developments. These programs include energy analysis, training and information, or easier access to renewable experts (DSIRE 2017).

Ultimately, there are roughly 3,350 important observations. Through this data framework, the resolution is on the state level and on an annual basis. Unfortunately, DSIRE does not provide starting and ending dates with overall program data, thus the ideal set of panel data was not collected and the data operates simply as cross sectional data.

To build an argument suggesting causality, more specific panel data regarding starting dates for these programs was collected during a shorter period from 2010 to 2012. DSIRE begins the technological resource incentive category in this period, therefore it offers a good starting point to examine policy effects. Using DSIRE to manually discover a collection of states which implemented policies in this period, a small set of panel data was created for this extension.

Figure 1 shows visually the number of incentive programs that each state has implemented that are currently operating. The first choropleth shows total incentives in each state, and the subsequent choropleths show the breakdown of financial incentives, technological resources, and regulatory policies, as each state has varying ratios of the three types. To highlight the basic research question, Figure 2 shows the positive correlation between number of incentives and the renewable energy output of each state. The fact that states with higher numbers of incentive programs have higher renewable energy production begs the question of if these programs are causing directly and purposefully the increased output.

Lastly, looking at Figure 4, one can observe a sample of five states that highlights the huge difference between states in their evolution of renewable energy production over this time period. The variety of growth and levels between states shows that there are definite factors that cause some states to grow very quickly, while some states do not grow, or even fall off. This paper will look at the extent to which these jumps and lags are caused by renewable incentives and regulatory policy.

Figure 1.

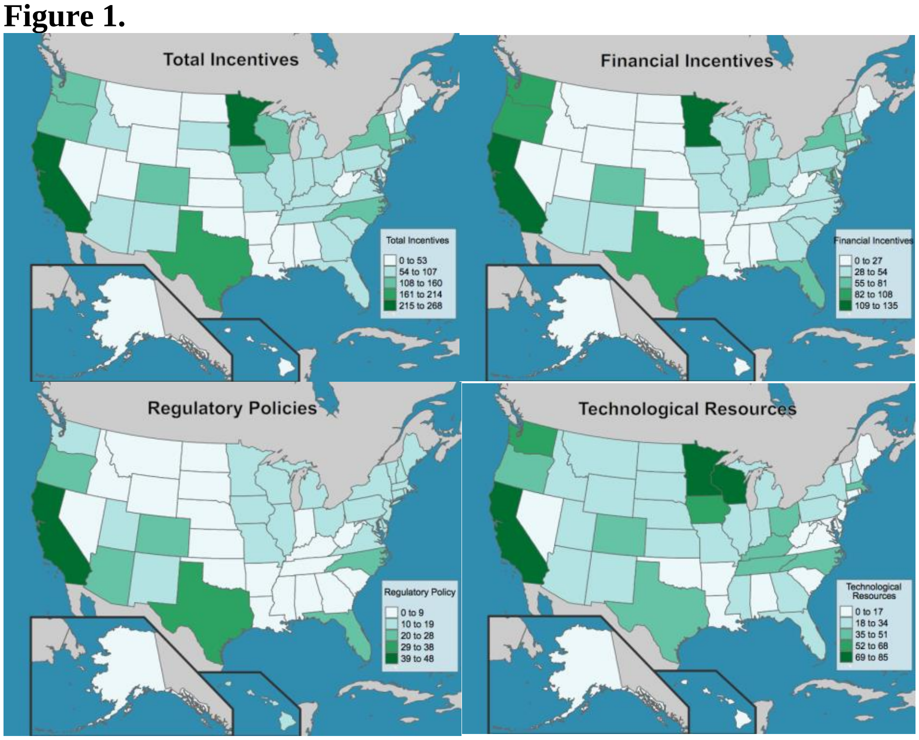


Figure 2.

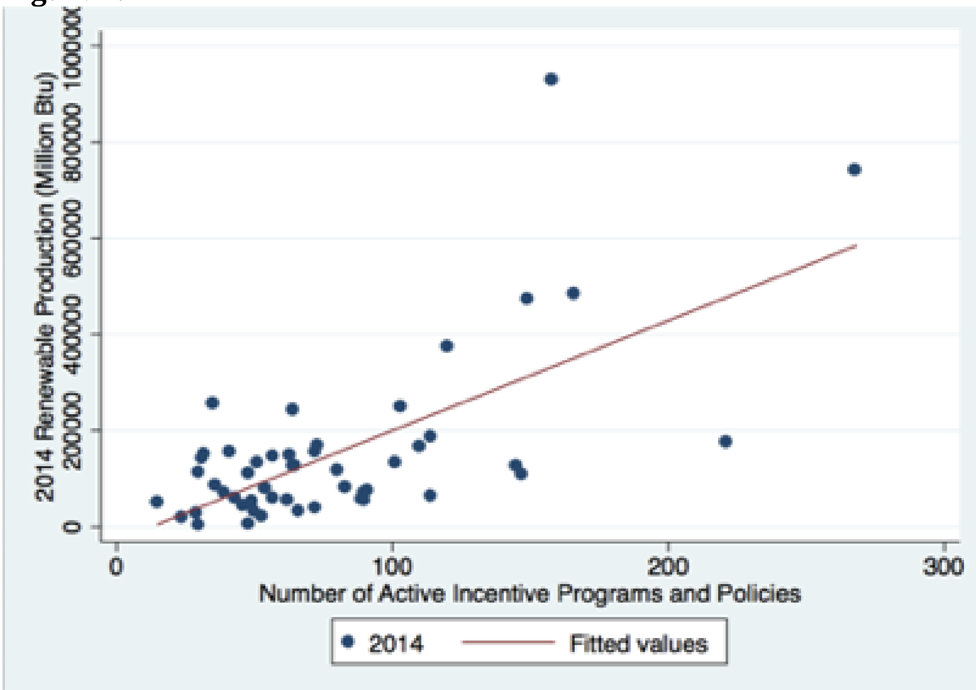
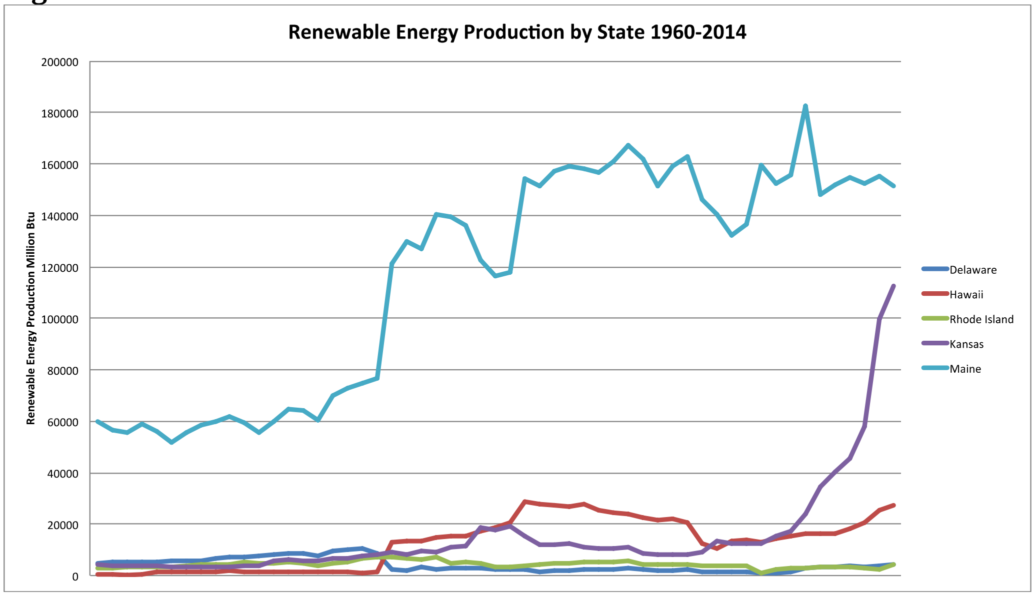


Figure 3. Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Number Incentives	50	78.76	50.82726	15	268
Renewable Production ‘14	50	151476.2	175310.4	4189	928071
Average Growth	50	2.085299	1.616173	-.3205396	8.756782
No. Financial Incentives	50	39.22	28.48006	3	135
No. Regulatory Policies	50	12.24	8.338649	3	48
No. Technological Res	50	26.84	18.63983	1	85
Total Consumption/Cap.	50	358.2	176.0347	190	921
Renewable Prod/Cap	50	49.06742	57.77247	4.070821	260.3472
Population	50	6414932	7228713	586107	3.91e+07

*(All energy production and consumption values in Million Btu)

Figure 4.



Empirical Strategy:

The first part of this paper will examine the strength of the three different incentive programs. The hypothesized linear model for renewable energy production is given by the following equation:

$$P_i = \beta_0 + \beta_1 F_i + \beta_2 R_i + \beta_3 T_i + \beta_4 S_i + \beta_5 L_i + \beta_6 E + \varepsilon_i \quad (1)$$

Here, P_i represents per capita renewable energy production in 2014. β_0 represents a constant. β_1 , β_2, and β_3 all represent the influence of a one program increase in financial incentives, technological resources, and regulatory policies respectively on renewable energy production. L_i represents population, and S_i represents the renewable output level from the initial 1960 starting point in the data. Including each state's starting point allows the difference in *levels* of each state to be largely accounted for, to allow the specific effect of the incentives to be more accurate. E represents energy expenditure per capita for each state to control for budget differences. Due to the fact that Equation 1 is only observing changes between states, this equation is not time sensitive.

The lack of time sensitivity in equation 1 makes it difficult to test for causality. As the paper will later discuss, technological resources seem to be the most important category of incentive to drive state renewable production. In an extension of this first test, this paper employs three unique models to check for the specific effect of technological resources. The below equation represents the methodology behind the thinking:

$$\beta^* = (P_{I1}-P_{I0}) - (P_{N1}-P_{N0}) \tag{2}$$

Equation 2 aims to calculate an "incentive effect," β^*, by finding the change in renewable energy production over a period of time in a state that just started an incentive program and subtracting the change in renewable production from a state that did not implement a policy during this time period. Thus, $(P_{I1}-P_{I0})$ is the change in a state's renewable energy output during a new policy and $(P_{N1}-P_{N0})$ represents the renewable production change in a state that did not implement any new incentives. This broadly will indicate whether these policies and incentives specifically are driving renewable energy production changes. For the distinct three different models, starting in 2010, each one represents a variation of quantifying technological resource incentives. One models observes simply if there was any technological sources at all, the other looks at how many technological resources there was in 2010, and the third represents how many technological resources there was enacted for non-residential use.

Results:

Beginning with the first linear regression model we can observe that not all renewable energy incentive programs are created equal. Both financial incentives and regulatory policies are statistically insignificant, meaning that they have no influence on the state renewable energy output on the whole. While this may seem contrary to previous literature and research, there are a few explanations. The first explanation is that these policies may not be aimed at larger commercial renewable energy production. Previous literature has shown the effect of financial incentives on household renewable investment, but no studies have examined their impact at a larger scale. It is possible that these two types of incentives are more focused on changing household level energy behavior, in which case the production of renewable energy at the state level would look largely unchanged. Furthermore, regulatory policies are not incentives at all; they are forced changes. In other words, regulation may force households and businesses to comply with the new regulation, offering no incentive or benefit to go any further. Regulatory policies may certainly be causing change, but do not encourage continuous and significant development of energy at the larger level.

Moving to technological resources, Table 1 shows a statistically significant and positive relationship between these incentives and per capita renewable energy production. An increase in one technological resource in a state is associated with an increase in per capita renewable energy production of 1.24 million Btu per year. This is statistically significant at 95% confidence interval, thus, we must reject the null hypothesis that technological resources have no influence over state renewable energy production in favor of the alternative hypothesis, that these resources are positively related to renewable production. One explanation for why this incentive type is more effective than the others is that they increase the overall accessibility of renewable energy. If we remember the specific resources that they provide, they are energy analysis, training, and information programs. These policies are education and access focused, so it is logical that they would help boost renewable energy production as people learn more about the energy, and are given easier access to its technology.

This regression also includes population. Population is statistically significant at the 95% confidence interval, indicating that for every additional 1 million people in a state, there is a reduction in per capita renewable energy production of 3.93 million Btu. Part of this may be explained by the fact that the dependent variable is on a per capita basis. However, there may also be other factors behind this. One explanation would be that renewable energy developments are large projects that take up large sections of often very rural areas. In other words, the more dense a population, the less likely a developer would be able to insert a renewable energy source such as a wind farm, solar array, or hydro-electric dam. For an extreme example, in New York City, it would be near impossible to construct a substantial wind farm. In northern Maine, however, it would be quite easy, cheap, and inoffensive.

From this, we also interpret the significant coefficient on energy expenditure suggesting that an increase in per capital energy spending of 1 dollar is related to a 12,900 Btu increase in per capita renewable energy production.

Lastly, this regression includes the initial 1960's level of renewable energy production. While at first one would expect this to be closely related to the current level of renewable energy production, the variable is statistically insignificant. This could be a positive sign that a state's starting point may not be such a defining factor of its future renewable energy production. It could indicate that some states have been more successful in their policy choices, and have been able to drastically change their renewable output.

Table 1.

VARIABLES	Model 1
Financial Incentives	-0.329 (0.487)
Regulatory Policy	0.964 (1.547)
Technological Resource	1.246** (0.581)
Population	-3.93e-06** (1.67e-06)
Initial Level 1960	0.000188 (0.000114)
Expenditure per Capita	0.0129*** (0.00461)
Constant	-32.71 (30.63)
Observations	50
R-squared	0.362

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Now that it has been established that technological resources are most effective for state renewable energy production, this paper builds three models around those specific policies. As discussed in Section 2, Empirical Strategies, the states that implemented a technological resource policy in 2010 are categorized in binary form (Model 1), numerical form (Model 2), and non-residential form (Model 3). In Table 2, we can examine these results.

Ultimately the goal of model 1, is to establish a relationship between states which started these programs and their energy output. There exists a positive relationship significant to the 95% confidence level, which allows us to reject the null hypothesis in favor of the alternative hypothesis that technological resources are important for renewable energy production. The same is true in model 2, where a 1 technological resource increase is associated with a 73.99 billion Btu increase in renewable energy production.

Model 3 seeks to explore the differences between household and commercial scale incentives. As traditional research has shown, the households have been a favorite for policy incentive makers. However, one could hypothesize that commercial and business level energy production is likely a bigger influencer for state wide renewable production, so by looking at non-residential policies, it should indicate if the target audience for these incentives is important. The value in this model is statistically insignificant unfortunately, so we cannot interpret it.

Table 2.

TREATMENT VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3
2010 Resource (0/1)	126,448**		
	(52,890)		
2010 Resource (No.)		73,985*	
		(42,365)	
2010 Non Residential Resource (0/1)			90,567
			(73,447)
Constant	99,597***	107,131***	115,830***
	(23,653)	(23,965)	(23,226)
Observations	50	50	50
R-squared	0.106	0.060	0.031

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

This exercise can be extended one step further to evaluate the longer term effects of such policies. Using lags, we can estimate if there is a lasting effect from technological resource incentives. In Table 3, there are a series of lags. The first, Lag 0, represents the coefficient from Model 1 of Table 2. From this point forward, the horizon is extended in 1 year intervals to see if these 2010 policies are effecting renewable energy production in the long run.

Table 3.

VARIABLES	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
2010 Policy Resource	126,448**	134,135**	125,849**	141,888**	144,058**
	(52,890)	(66,068)	(61,236)	(58,269)	(59,071)
Constant	99,597***	115,686***	112,516***	118,594***	122,665***
	(23,653)	(29,547)	(27,386)	(26,058)	(26,417)
Observations	50	50	50	50	50
R-squared	0.106	0.079	0.081	0.110	0.110

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

In every one of the lags, there exists a positive and statistically significant value. In short, this suggests that states which were the first to begin the implementation of technological resources for renewable energy development experienced larger output of renewable energy 4 years into the future. While this does not prove causality directly, it certainly shows the strong relationship between the two variables of interest.

Conclusion:

This paper addresses the broader effect of state renewable energy incentive programs. Ultimately, the results suggest that for state wide renewable energy production, technological incentives are the strongest type of program. Previous research has shown the success of financial incentives, with a particular attention given to rebate programs at the household level. This paper breaks away from the concentration of research on financial incentives, and household level analysis, to examine the effect of all types of state renewable energy incentive policies on state production of renewables. The contribution of this paper is showing the break between household adoption of renewable technology and state and national adoption of renewable energy. Policy makers can make the most difference at the state level through technological resources, rather than financial incentives, which may be more suited for household adoption.

With that said, the methodology of this paper can be much stronger. While intuitive in its approach, shear number of policies is not the best way to categorize the strength of a state's renewable energy incentives. Future research in this area will be challenged to find a different numerical strategy to gauge the strength of a state's technological resources and regulatory policies.

However, for the interim, the results are quite positive: rather than financial incentives being the largest driver for growth, technological resources are. It is not money that causes increased production of renewable energy. It is *education*.

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