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The Relationship Between State Economic Growth and Renewable Portfolio Standards in the United States: A Panel Causality Analysis

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I. Introduction

In his 2009 inaugural address, President Obama called upon the nation to expand its usage of renewable energy to confront the impending challenges of energy security and climate change. The first president to mention renewable energy use in an inaugural speech, those words foreshadowed the significant shift in energy policy that would take place in the years thereafter. Questions surrounding energy security and climate change are highly political in nature, but questions regarding the impact of clean energy policies are much more tangible, especially as states have increasingly committed to renewable portfolio standards. As of January 2016, 37 states throughout the nation have adopted policies or regulations intended to expand the use of clean energy. Chief among state energy policies are renewable portfolio standards (RPS), regulatory mandates intended to increase the production of energy from renewable or alternative sources. Though exact standards differ by state, broadly, RPS polices set a time line for a state to generate a predetermined fraction of their electricity from renewable energy sources.

The widespread adoption of RPS policies begs questions regarding both their effectiveness and impact. Unfortunately, much of the existing literature on the topic has been limited to two areas of focus: (1) how RPS standards have altered renewable energy consumption; and (2) how political, economic, and social factors have acted as drivers of clean energy policies in states. There are a few studies that analyze the green businesses and job growth as a result of RPS; however, literature that aims to evaluate the causal relationships between economic growth and renewable portfolio standards remains, to the best of the authors knowledge, nonexistent. This paper fills that gap in the existing literature by evaluating the causal relationship between RPS policies and economic growth in the fifty states.

II. Literature Review

The state legislatures that enact RPS policies often herald promises of economic vitality and sustainable job growth. This rhetoric plays a role in the political process, though a number of studies that have sought to better understand the driving forces behind RPS adoption note that there are many other factors influencing their adoption. Common reasons include promised economic growth, the states potential for renewable energy development, the presence of a restructured electricity market, strong Democratic presence in the state legislature, and organized renewable energy interests (Lyons and Yin, 2010; Yi, 2014). State policy goals associated with the standards often emphasize bolstering the prevalence of green jobs and businesses; however, research attempting to measure the outcome of the policies has often been limited by absence of uniformly accepted definitions of “green jobs” or “green businesses” (Bowen, Park, and Elvery, 2013; Yi, 2013).

Nonetheless, a comparative analysis of some of the more recent studies that estimate RPS impacts can shed light on the true policy implications. The studies reviewed (see Appendix A1) are sorted into two categories: ‘evaluating studies’ and ‘aggregating studies.’ ‘Evaluating studies’ are those that employ a model to predict or analyze the economic effects of RPS policies, while ‘aggregating studies’ review independent studies and normalize their findings. Four of the five ‘evaluating studies’ included in Appendix A1 report the gross impacts of clean energy policies, showing a statistically significant and positive relationship between RPS and green job and/or green business growth. Barbose et. al (2016), the most detailed of the ‘evaluating studies,’ concluded that RPS policies developed 170,000 jobs in construction and 30,000 jobs in operation related to renewable energy facilities in 2013. The findings of these studies should not come as a shock. Certainly, any policy mandating the use of new energy sources will create jobs in that sector; since, by sheer virtue of the mandate jobs in in the construction and operational infrastructure will be demanded by the necessitated increase in supply.

In attempt to better grasp the economic realities of RPS, the ‘evaluating studies’ consider the net impacts of the policies. The ‘evaluating studies’ include calculations of job losses in other sectors that ensue from RPS adoption. Unfortunately, such studies are not as common as those estimating gross impacts. Boampong et. al (2016) recently attempted to fill this gap in existing literature by conducting an ex-post evaluation of RPS net employment impacts in states. Using both OLS and IV estimation techniques, they conclude that RPS policies had no statistically significant effect on state net employment. Though many studies estimate positive gross impacts, the notion of RPS having little net impact is not new. Barbose et. al (2015) perhaps said it best when they postulated, “economic benefits [of RPS] may be viewed better as wealth transfers.”

The ‘aggregating studies’ provide a more detailed look at RPS job creation but also fall short of considering the economy wide impacts. Both ‘aggregating studies’ reviewed in Appendix A1 model various scenarios of policy stringency and parameters, concluding that in each scenario the clean energy policies lead to more jobs per unit of energy delivered than the competing fossil fuel sector. Interestingly, however, both emphasize the importance of ‘parameters, that is, the nominal generation requirements and energy sources specified by the policy. They caution that even a slight change the amount of energy required for various sources can lead to wildly different employment outcomes (Kammen, Kapadia, and Fripp, 2004; Wei, Patadia, and Kammen, 2009).

The importance of policy ‘parameters should not be understated, Fowler and Breen (2013) argue that since RPS is implemented at the state level, the individual enacting state plays a large role in determining policy outcomes. They further suggest that the effectiveness of RPS is highly dependent on the availability of renewable resources in the state, the structure of the state’s renewable energy market, and the preexisting state regulations. Barbose et. al (2015) quantified the differences in state-wide outcomes when they compiled and compared state-level outcome studies. They find that total economic benefit from the policies can vary widely. For example, in Maine the estimated impact was $4.5 million in 2010, while in Illinois the estimated impact was $177 million in 2011.

Given the prevalence of RPS policies and the lack of clear understanding of the true economic impacts surrounding their enactment, this paper intends to explore the causal relationship between state economic growth and RPS policies. The parameters of each states policy will be considered and the direction of causality will be tested to give insight into how state legislatures can craft renewable energy regulations in an economically optimal way.

III. Methodology

4.A. Research Goal

Previous studies have estimated the positive employment and business growth associated with the enactment of RPS policies. This study seeks to understand the relationship between renewable portfolio standards and percent change in gross state product per capita from 2005-2015. It is analyzed using cointegration, a Dynamic Ordinary Leader Squares estimate, and a Vector Error Correction model to determine long-run causality for the cointegrated panel data set of the fifty states.

Based on the findings of the studies reviewed in Appendix A1, in the long-run this study hypothesizes a positive causal relationship running from RPS Stringency and percent change in per capita GSP, though no long-run causal relationship running from percent change in per capita GSP and RPS Stringency.

4.B. Data Collection

This study investigates the relationship between RPS policies and economic growth, thus variables are constructed to represent both the stringency of the policies and the economic impact they have in states. As a result, two variables are created: Percent change in per capita GSP and RPS Stringency.

Percent Change in Per Capita GSP

Data to measure the percent change in percent change in per capita GSP was gathered from the Bureau of Economic Analysis annual reporting on Gross Domestic Product by state from the period of 2005-2015. The percent change in GSP is employed to account for the varying levels of percent change in per capita GSP in every state. This variable will be referred to simply as "% per capita GSP."

RPS Stringency

As Barbose et. al (2015), Kammen, Kapadia, and Fripp (2004), and Wei, Patadia, and Kammen (2009) all note, different RPS policy constructions can lead to wildly different economic outcomes. Thus, any variable that attempts to capture the nature of RPS policies should be a metric not solely of their nominal requirement, but one that takes into account the way in which the policies differ by state. The variable that considers RPS policies will be called 'RPS Stringency. RPS Stringency is constructed based o↵of the Incremental Share Indicator (ISI) as developed in Yin and Power's (2010) oft cited paper on the impact of RPS on in-state renewable energy generation. RPS Stringency for this study is calculated as follows:

$$RPS\ Stringency_{it} \equiv \frac{Nominal_{it} * Coverage_{it} * Sales_{it}}{Sales_{it}}$$

Where $Nominal_{it}$ reports the nominal generation requirement in state i in year t, $Coverage_{it}$ details the percentage of load serving entities eligible to meet the nominal requirement, and $Sales_{it}$ represents the total retail electricity sales in state i in year t. This method allows the true stringency of the policy to be considered because it accounts for the scope of the mandate to the state's load-serving entities.

The U.S. Energy Information Administration's (EIA) Electric Power Annual Data was used to gather data on electric sales and generation. North Carolina State University's Database of State Incentives for Renewables and Efficiency was used to record policy parameters.

Table 1: Descriptive statistics

	GSP	RPS Stringency
Mean	.5671	.0187
Median	.8	0
Maximum	18.8	.1849
Minimum	-10.1	0
Std. dev	2.4823	.0355

IV. Empirical Framework

In this study, panel unit roots tests are first applied for the fifty states, then Pedroni Panel Cointegration Tests are preformed (Pedroni, 1999). Panel DOLS models are then performed and, finally, causality is considered within a vector error correction model for cointegrated panel data.

V.A. Unit Roots Testing

The stationarity of the panel must be determined before any sort of causality testing as the presence of unit roots can strongly influence the panels behavior and properties. Testing for unit roots in each individual state series is not practical, so a panel unit roots test is conducted. Levin, Lin and Chu (2002), Im, Pesaran and Shin (2003), and Fisher-type tests using Augemented Dickey-Fuller (ADF) and Phillips-Perron (PP) Tests (Maddala and Wu (1999) and Choi (2001)), are all multiple-series unit root tests that can be applied to panel datasets. The null hypothesis of these tests is that the variable contains a unit root.

Panel unit roots tests were applied for the 50 cross-sections. The Levin, Lin and Chu (2002), Im, Pesaran and Shin (2003), and Fisher-type tests using ADF and PP Tests (Maddala and Wu (1999) and Choi (2001)) were applied at both level and first difference. Per all of the unit roots tests, all series are stationary and have statistically significant results at the level of first difference. More specifically, % per capita GSP is stationary at level and first difference while RPS Stringency is non-stationary at level but is stationary when transformed to first difference.

Table 2: Panel Unit Roots Tests

	%Δ per capita GSP		RPS Stringency	
	Level	First Difference	Level	First Difference
LLC	-8.8859***	-12.5550***	-3.8636***	1.1123
IPS	-4.6404***	-6.6352***	2.2323	-2.6141***
ADF-Fisher Chi-Square	174.801***	226.874***	47.3519	64.0437***
ADF-PP Fisher Chi-Square	342.824***	628.224***	30.1248	130.785***

Notes: The lag length was selected using Schwartz Information Criterion.
*** Indicates statistical significance at the 1% level.

V.B. Panel Cointegration Tests

Cointegration analysis will then be applied to improve estimations for data potentially excluded in the unit roots process. Cointegration analysis considers the long-run relationship between integrating variables, that is if there is a time series process x_t and it has d unit roots, then x_t is integration of the order d.

Pedroni (1999) panel cointegration tests will be used to investigate if cointegration is present within the panel data set. The tests measure seven separate panel cointegration statistics based on the absence of cointegration. The null hypothesis is of no cointegration. This Residual-Based Test tests for the existence of a unit root in the residuals of a cointegrating regression equation of the following form:

$$\%\Delta\ per\ capita\ GSP_{it} = \beta_{0it} + \beta_{1it} * Stringency_{it} + \varepsilon_{it} \quad (1)$$

$$\text{for } i = 1, \ldots, N \text{ and } t = 1, \ldots, T$$

The Pedroni Panel Cointegration (1999) tests with individual intercept trend and no deterministic intercept or trend explore the long-run relationship between % per capita GSP and RPS Stringency. These results are provided in Table 2. An overall evaluation of the six tests results (both panel and group statistics) indicate that there in a cointegrated relationship between the series. In context, this implies that % per capita GSP and RPS Stringency act together in the long-term and that they share a long-run relationship.

Table 3: Pedroni Panel Cointegration Test

	Without Trend	With Trend
Panel v-Statistic	-1.7877	-6.2854
Panel rho-Statistic	-3.0271***	1.5215
Panel PP-Statistic	-10.1805***	-12.7568***
Panel ADF-Statistic	-10.0989***	-10.1029***
Group rho-Statistic	-0.1836	3.2352
Group PP-Statistic	-14.6455***	-18.3888***
Group ADF-Statistic	-11.4397***	-11.4581***

Notes: Null hypothesis is that variables are not cointegrated.
*** indicates statistical significance at 1% level.

1. Panel DOLS Estimates

Since the variables have been determined to be cointegrated, the next step in the analysis is to estimate the long-run relationship that they share. The long-run relationship between the variables will then be estimated using Dynamic Ordinary Least Square (DOLS) methods. Though an Ordinary Least Squares (OLS) estimator would lead to biased and inconsistent results when applied to a cointegrated panel, the DOLS method allows for the presence of heterogeneity in cointegrated panels (Pedroni, 1999). If the results of this test are statistically significant, the coefficients will provide some explanation to the direction of causality, if present, in the long-run relationship between GSP and RPS Stringency.

The DOLS regression estimate revealed variables are statistically significant at the 5% level with a positive coefficient, indicating that as RPS standards become more stringent, the overall impact of state economic growth is positive. Notably, the model also suggests a that as % per capita GSP increases, RPS Stringency increases.

Table 4: Panel Cointegrated Regression Estimates

Independent Variable	DOLS Model
%Δ per capita GSP	0.0073** (0.0035)
RPS Stringency	10.9168** (4.812236)

Notes: Standard errors are given in parentheses.
** indicates statistical significance at 5% level.

2. Panel Causality Tests

The presence of causality, the question at the heart of this study, will be determined through the Vector Error Correction Model (VECM) of long-run cointegrating vectors. A VECM were designed for use with nonstationary series that are known to be cointegrated, such as the series analyzed throughout this study. A VECM can be applied after the series is proven to be cointegrated in the long term since the test attempts to determine the presences causality between the variables. In the VECM if the error correction term is negative and statistically significant, there is said to be long-run causality running from the independent variable to the dependent variable. If the error correction term is neither negative nor statistically significant, then there is no indication of long-run causality.

The results suggest that at a 1% confidence level there is a long-run relationship running from RPS Stringency to % per capita GSP, implying greater economic growth under more stringent policies.

Table 5: Panel Cointegrated Regression Estimates

Test	Dependent Variable	
	%Δ Per capita GSP	%Δ Stringency
VECM	-.8407***	-.0019
(Long-Run Estimate)	(.0700)	(.0026)

Notes: Standard errors are given in parentheses.
*** indicates statistical significant at 1% level.

V. Conclusion

This study used panel data gathered from the Bureau of Economic Analysis reporting of annual Gross Domestic Product by state, EIA Electric Power Annual Data, and North Carolina State University's Database of State Incentives for Renewables and Efficiency to estimate the causal relationship between per capita Gross State Product and Renewable Portfolio Standard policies. This relationship was estimated using both Dynamic Ordinary Least Squares methods and Panel Vector Error Correction Models. The estimates from the Dynamic Ordinarily Least Squares methods suggest that % per capita GSP has a statistically significant, positive impact on RPS stringency and that RPS Stringency has a statistically significant, positive impact on % per capita GSP. The Panel VECM results suggest that there is long-run causality running from RPS Stringency to % per capita GSP and short-run causality (at the 10% confidence level) from % per capita GSP to RPS Stringency.

Analyzed together, these results are consistent with previous literature. All the studies reviewed, with the exceptions on Boampong et. al (2016), concluded that RPS policies would cause green job and business development, two factors that would contribute to state eco- nomic growth. Furthermore, these results emphasize the importance of policy 'parameters as stressed by Kammen, Kapadia, and Fripp (2004) and Wei, Patadia, and Kammen (2009), who indicate that more stringent RPS policies lead to more economic growth.

With more than half of the fifty states having enacted these policies, developing an understanding of the way in which they interplay with state economics caries many policy implications. The results suggest that enacting more stringent RPS policies, that is policies with a higher nominal requirement or those that mandate electricity generation come from a high proportion of the load-serving entities in the state, are more beneficial to state economies. State legislatures should consider ambitious RPS policies to maximize economic growth and mitigate carbon emissions.

Though to the best of the authors knowledge this work is the first to analyze the causal relationship between % per capita GSP and RPS Stringency, there is still more work to be done. The stringency of the policies was considered; however, the true complexity of the policies was not captured in this analysis. Future studies may factor in the other aspects of RPS policies such as renewable energy credits to both better analyze the impacts of policy design and economic results.

VI. Appendix: Literature Review Table

Study	Year	Author	Method	Results
Aggregating Studies				
Putting renewable and energy efficiency to work: How many jobs can the clean energy industry generate in the US?	2009	Max Wei, Shana Patadia, Daniel M. Kammen	Created an analytical job creation model for the US power section from 2009 to 2030 that synthesized data from 15 studies. Then normalized job data to show average employment per unit of energy produced.	Modeled various scenarios of energy supply composition (varying RPS levels, varying energy sources, etc.). In every case, the clean energy sector created more jobs than the fossil fuel sector per unit of energy delivered.
Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?	2004	Daniel M. Kammen, Kamal Kapadia, Matthias Fripp	Reviewed the assumptions and methodologies of 13 independent studies predicting the economics and employment impacts of clean energy policies to develop a job creation model. This model normalized employment numbers to determine jobs per MWa in various sectors based on different scenarios.	Though the model assumes energy production to remain the same as 2002 levels and did not account for "learning effects" that may make production of clean energies less costly, in all cases RPS policies led to more jobs in manufacturing, construction, installation, operation and management, fuel production, and processing then fossil-fuel scenarios.
Evaluating Studies				
Green businesses in a clean energy economy: Analyzing drivers of green business growth in the U.S. states	2013	Hongtao Yi	Study analyzing the policy, economic, political and labor market factors contributing green business growth. Fixed-effect regression model is used to preform analysis.	Over time, RPS adoption leads to a 2% average increase in green businesses (also reports the factors that other independent variables have on green business development).
A retrospective analysis of benefits and impacts of U.S. renewable portfolio standards	2016	Galen Barbose et. al	Gross job and economic development impact was estimated using National Renewable Energy Laboratory's Jobs and Economic Development Impacts (JEDI).	RPS policies developed 170,000 jobs associated with building RE facilities and 30,000 in operation of RE projects in 2013

Clean energy policies and green job: An evaluation of green jobs in U.S. metropolitan areas	2011	Hongtao Yi	Ran OLS regression model and 2SPLS to study determinants of green jobs in U.S. metropolitan areas.	The state clean energy policies index which was composed of 21 policy tools and rated states based on the number they adopted (with RPS being among the most common) was associated with increases in green jobs.
Empirical Estimates of the Influence of Renewable Energy Portfolio Standards on the Green Economies of States	2013	William M. Bowen, Sunjoo Park, Joel A. Elvery	Sought to determine if the presence of RPS can predict future growth of green firms and jobs in a state. Developed a cross-sectional time series model after testing and controlling for other variables that could cause green economic development.-	RPS is not directly related to green business growth, but the duration of the standards is a predictor of business growth in the state. RPS policies is not a statistically significant predictor of green jobs.
The Effect of Renewable Portfolio Standards on State-level Employment: An Ex Post Analysis	2016	Richard Boampong, Colin Knapp, Michelle Phillips	Explored the impact of RPS policies on state level employed using both OLS estimation and IV estimation techniques.	Both models found no statistically significant effects of RPS policies on net employment in states.

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VIII. End Notes

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