The Evaluation of the Effective Determinants of Renewable Energy Generation in Developed Countries

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Economics

Abstract

In the last two decades renewable energy (RE) generation has been an increased topic of discussion among legislators. The purpose of this thesis is to gain an understanding of how political, socioeconomical, country-specific factors and policies interact to drive a country to invest in RE generation. Using a panel dataset from 2001-2014 this paper looks at variables that fall in all four of these categories to determine which variables are the most important and effective and influencing RE output. This paper finds that CO_2 emissions, land area and energy imports are all significant influencers of RE generation. This paper, interestingly, finds that quota policies actually impede RE production.

KEYWORDS: (Renewable Energy, Renewable Energy Policy, Feed-in-Tariffs, Renewable Portfolio Standards, Panel data)
JEL CODES: Q20, Q28, Q48

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John Ammons

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Introduction

The global appetite for renewable energy over the last two decades has increased exponentially. Countries across the world are starting to spend more and develop policies to increase renewable energy (RE) generation. Governments have become more willing to create policies in support of RE because of climate and pollution concerns, national security risk over energy autonomy, increased energy demand and the appeal of new and innovative sources of energy, among other factors (Alagappan et al., 2011; Schmalensee, 2012; Jenner et al., 2013). With the increased focus on RE, a few questions arise. Are the policies that have emerged to help stimulate RE growth effective? How do country specific attributes, policy instruments and policy design interact to make for effective RE generation growth? This paper seeks to account for these variables to help determine what drives these developed markets to successfully grow RE production.

Governments around the world have recently been setting lofty and ambitious goals to increase their generation of renewables significantly in the coming years. This is a relatively new agenda for these governments. The first global summit on the issue was the Kyoto Protocol in 1997, a treaty amongst countries aimed at combating harmful greenhouse gas emissions. Confrontation of these challenges have sped up drastically more recently though. In 2015, the Paris Agreement was signed by 194 countries to build off of the expiration of the Kyoto Protocol. Just last year, California signed a bill aimed to make the state rely fully on zero-emission energy by 2045, which includes RE generation to be 50% of total electricity usage as soon as 2025. In order to stay true to these ambitions goals, governments have created various policies to incentivize the production of RE.

Two policy instruments have emerged as the most popular and widely used in the last two decades, the Feed-in Tariff (FIT) and the Renewable Portfolio Standard (RPS). A FIT is essentially a subsidy to energy producers for the production of RE. A FIT typically gives producers a long-term contract that gives them a premium for generating renewables to help encourage RE investment and innovation. FIT mechanisms are the most common policy instrument found in the EU. An RPS is type of quota. Renewable portfolio standards require a load servicing entity to have a certain percentage of their energy production being generated by renewables (Alagappan et al., 2011). RPS policies are the main policies implemented at the state level in the United States. Jenner et al. (2013) notes that the design of RPS tends to encourage low cost forms of renewables. Conversely, they note that load servicing entities in a market employing a FIT are motivated by production of additional kilowatt-hours, therefore there is still appeal to invest in more expensive forms of RE.

It is imperative to develop an understanding of what variables in a market, both country-specific and policy mechanisms, are effective in promoting RE. The findings can help policy makers make more informed decisions to help governments across the world reach their ambitious emission reduction targets.

This paper employs a panel dataset from 2001-2014, with data from 23 different countries in order to determine what variables are the most effective at increasing the percent of renewable energy production in a market in a given year. The model places the variables into four different categories: political, socioeconomical, country-specific elements and policy.

With the boosted interest and developments in RE, there has been increased studies looking into the various attributes of RE production. In the last 15 years there has been more and more literature on the topic, this paper looks to build off the findings of these papers by creating a more robust approach while using more recent data.

Literature Review

Over the last decade, research on both the drivers of renewable energy and the effectiveness of policies on renewable energy have increased significantly. Three main focus areas for papers on the subject have developed. There have been several studies that address how country characteristics drive renewable energy development, how differences in certain policy types impact RE generation and how heterogeneity of a certain policy effects the development of RE capacity. There, however, has been relatively little research that looks at how all of these factors interact together to show a more wholistic answer to what the determinants of renewable energy generation are. These studies often look at state level policies in the US or country wide policies (mainly in the EU), with a few that compare both state-level US policies with the national policies in the EU.

2.1 Country specific variables

Two recent papers (Marques et al., 2010; Aguirre and Ibikunle, 2014) aim to find the determinants of what drives RE development by just looking at country specific characteristics. Marques et al. (2010) employs a panel dataset from 1990-2006 using a fixed effects vector composition (FEVC) to assess the drivers of RE in 24 European countries. They use variables that measure the percentages of traditional energy consumption (coal, oil, nuclear, etc.), total energy consumption, income level, and country specific factors like geographic area to find what determines these countries RE deployment. They find that more traditional energy uses, and CO_2 emissions are negatively correlated with RE generation and on the contrary if the country is trying to reduce energy dependency, they are more likely to have higher RE deployment.

Aguirre and Ibikunle (2014), build off of Marques et al. (2010) framework but use a panel corrected standard error model that utilizes an updated time frame of data from 1990-2010 and a large sample size of 38 countries, now including countries that are outside of the EU. They present their independent variables in three separate categories: political, socioeconomic and country-specific factors. Aguirre and Ibikunle (2014) introduce new variables not used in Marquez et al. (2010), for example the Kyoto protocol ratification dummy variable and a continuous commitment to RE dummy variable. They confirm that CO_2 emission levels have a significant impact on RE development and that energy use is negatively correlated to RE generation. This makes sense, as a country is more dependent on energy, they are more likely to stick with the more conventional ways of producing energy to ensure energy security and cost effectiveness.

2.2 Different policy instruments

As mentioned earlier, since the need for more renewable options and better renewable efficiency has increased, there has been two main policy instruments that have emerged, the Feed-in Tariff (FIT) and the renewable portfolio standard (RPS). Since these policies have emerged, there have been increased research papers on which policy instrument is the most effective. Alagappan et al. (2011) and Kilinc-Ata (2016) have addressed this question in varying ways but have come to similar conclusions.

Alagappan et al. (2011) examines 14 markets that differ in four main ways: market structure (restructured vs. not), the use of FITs (yes vs. no), transmission planning (reactive vs. anticipatory) and transmission interconnection cost allocated to RE generator (high vs. low). They find that RE development is most successful in markets that use a FIT, use anticipatory transmission planning (transmission development occurs before the a RE developer requests it) and have end-users paying the majority of cost of transmission interconnection. Unsurprisingly, the exact opposite of above made for the least successful RE development in a market. It is interesting to note that the policies that made for successful RE development are common practices in European markets. The least successful practices are more commonly found in US markets. An important note is that even though FIT was a dummy variable, the markets that did not employ FITs had a form of RPS enacted instead.

Kilinc-Ata (2016) examines the effectiveness of renewable energy specific policies by taking a panel dataset from 1990-2008, with data from all 50 US states and 27 EU countries. They find similar results to Alagappan et al. (2011). The results suggest that RE policies are effective at increasing RE capacity, but some policy instruments are much more effective than others. The study finds the policies that generate the best returns for RE capacity are FITs, tenders and tax incentives. The study does not find RPS to be a significant factor in stimulating the growth of RE capacity. There are several studies that look into the difference in effectiveness of the certain implementation of a single policy instrument.

2.3 Differences in policy implementation

It is clear that most studies have found FIT policies to be more effective instruments in the promotion of RE development than RPS, but some argue that categorizing all FIT and RPS policies into one group is grossly overgeneralizing them. It is true that the specifics of each policy and how they are implemented can vary widely across markets. Characterizing similar policies as identical can potentially lead to misleading conclusions. Jenner et al. (2013) looks at differing FIT policies across Europe. Carley (2009) and Yin and Powers (2010) take an in-depth look at how differing RPS policies across US states can impact RE generation.

Jenner et al. (2013) noticed that the few papers being published on the effectiveness of FITs failed to take into account market structure and policy design in their studies. The authors had observed that from 1990-2011, 23 EU countries had implemented some sort of FIT, but RE development in these countries was quick and uneven. This prompted them to study the policy structures thoroughly. They utilize panel data from 1992-2008 in 26 EU countries. Their study only looked at solar and onshore wind renewables and not the share of renewables as a whole. In order to determine the effectiveness of each FIT policy, Jenner et al. (2013) created a new indicator that took into account tariff size, contract duration, digression rate, electricity wholesale price and electricity generation cost to make a new measure of the return on investment (ROI) for RE development in a respective market each year. They found that for every 10-percentage point increase in ROI, countries were installing 3.8% more solar capacity and 2.8% more onshore wind capacity annually. Important findings for policy makers because it shows that it's not just about enacting a policy aimed at promoting RE generation, it's more important to focus on the actual details of the policy in order to make it effective.

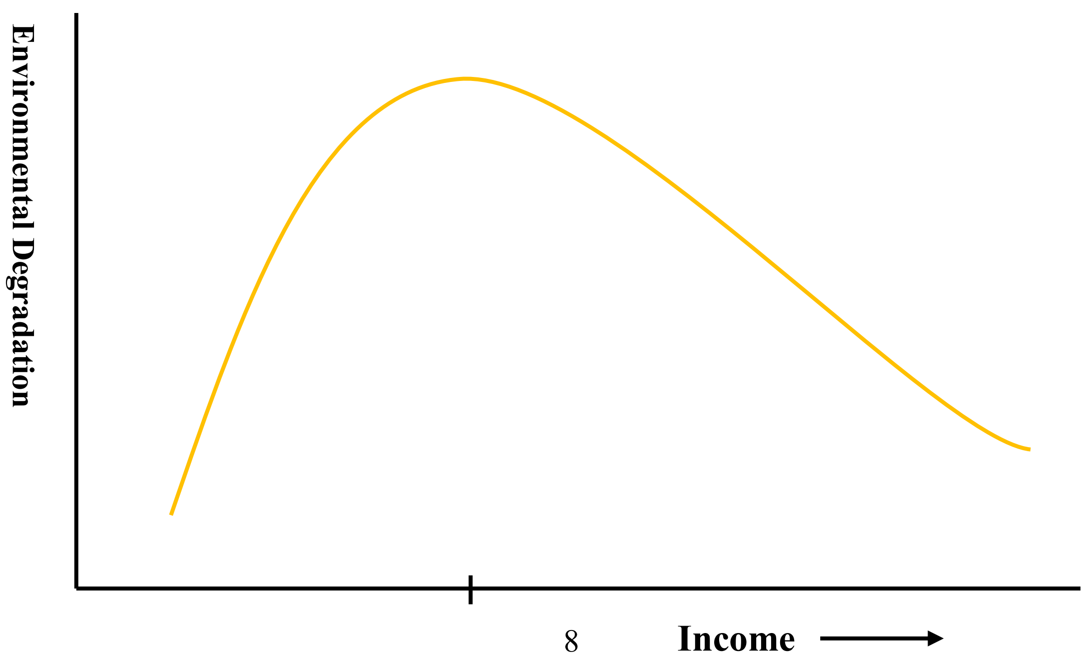
Carley (2009) and Yin and Powers (2010) were the first studies to look into how the nuances of RPS policies in the US states drive policy effectiveness. Carley (2009) runs a fixed effects vector decomposition that uses data from 1998-2006 to evaluate the effectiveness of RPS policies at the state level. Carley (2009) finds, similarly to other studies, that RPS is not a significant predictor of percentage production of RE out of total energy production. She does, however, find that for every year with an RPS policy enacted, the RE percentage generation out of total generation increases. The study does also find various significant variables like natural resource endowment, electricity use per person and electricity price.

Yin and Powers (2010) employ panel data in order to examine the impact that RPS has on state level RE development. The authors looked to build off the past research done on RPS policies in the US but failed to address the heterogeneity amongst state policies. In order to address the heterogeneity problem of past papers, Yin and Powers (2010) developed a new measure of RPS stringency. They argue that their new measure for policy stringency is a much-improved indicator of the magnitude of RPS incentive. This new measure shows that some aggressive RPS policies are actually less effective at incentivizing RE development than more moderate approaches. Contrary to other studies, this paper finds that RPS has a significant impact on in-state generation percentages, but this impact is not seen when policy design is not controlled for.

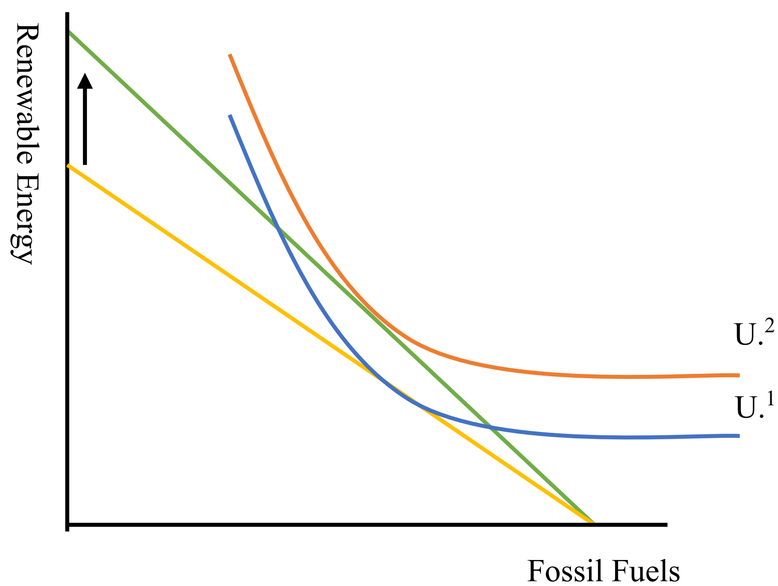
Theory

In order to understand why the variables used in this study would influence RE generation we look to the Environmental Kuznets Curve (EKC) hypothesis (Dinda, 2004). The EKC builds off of the original Kuznets curve but instead of mapping economic inequality across income we map *environmental* inequality across income.

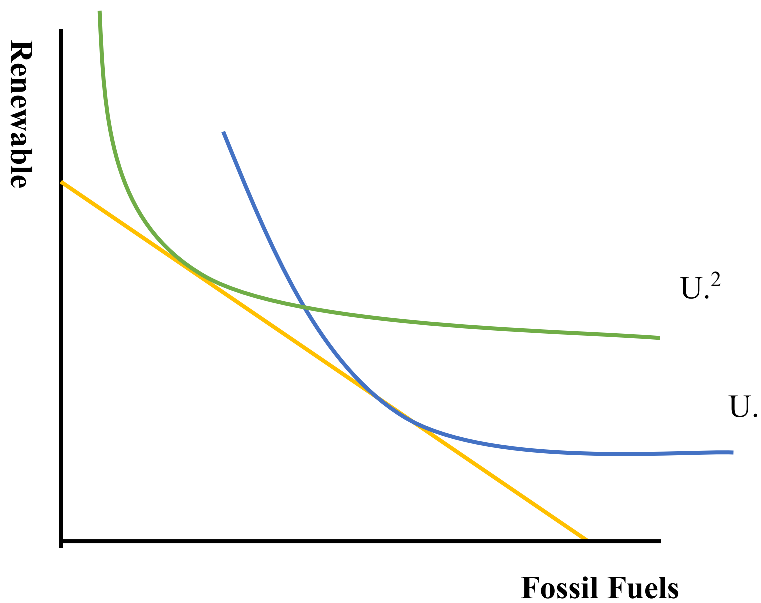
The relationship between increased income and environmental degradation can be seen through an inverted-U. The theory is that before an economy is industrialized it has little to no pollutant emissions. As the economy advances and starts to industrialize the amount of pollutants being emitted will start to increase significantly. The economy's income and environmental degradation will increase with the industrialization process. At this stage in the economy, people care more about production output and jobs over clean air and pollution. There then hits a point in the income per capita, where people begin to care more about the environment. As industrialization advances and the wealth of an economy increases people typically become more educated, regulatory systems become more effective and people will start to care more about the environment they live in (Dinda, 2004). This will result in the environmental degradation to start to decrease overtime.



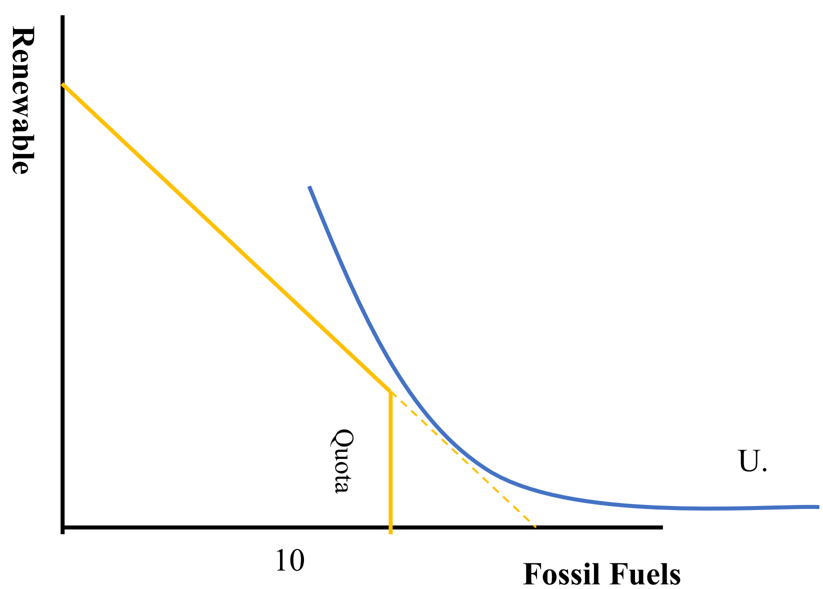
This curve will not look the same for all economies. Depending on the country's characteristics and societal attitudes this graph can look much different. Consider an individual country's budget constraint, with the consumption choice being between renewable energy and more traditional sources of energy like fossil fuels. Where the tangency of this line to the country's indifference curve is the ratio of which kinds of energy generation the country will consume.



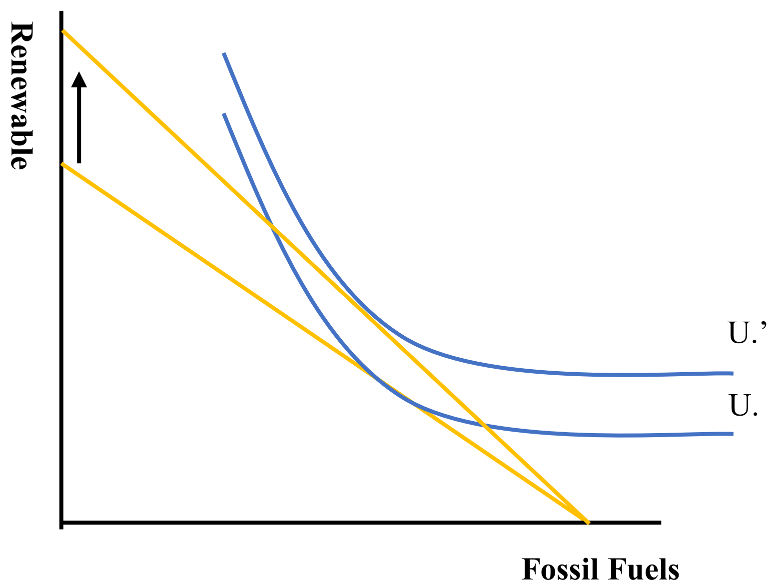
The attributes of an economy can change their budget constraints and also their indifference curves. Modeled above are two countries. Country 2 has a substantially larger land area in a sunny and windy climate. While the other does not. They have the same preferences and therefore the same indifference curves. The country specific attributes of country 2 (modeled orange) raise the amount of RE generation in the budget constraint because it is more economical to invest in solar and wind power in this environment. The relative cost of RE generation is lower in country 2. This would kick up the budget constraint on the y-axis allowing for consumption to take place on a higher indifference curve that consumes more renewables.



Next, consider the attitudes of two different countries that have the same budget constraint between RE consumption and fossil Fuel consumption. Country number two, however, has a higher level of education and their citizens care more about the environment than country one does. Country 2 has an indifference curve (denoted in green above) that is oriented more toward renewable consumption than country 1 (denoted in blue). Country 2 will consume more RE than country 1.

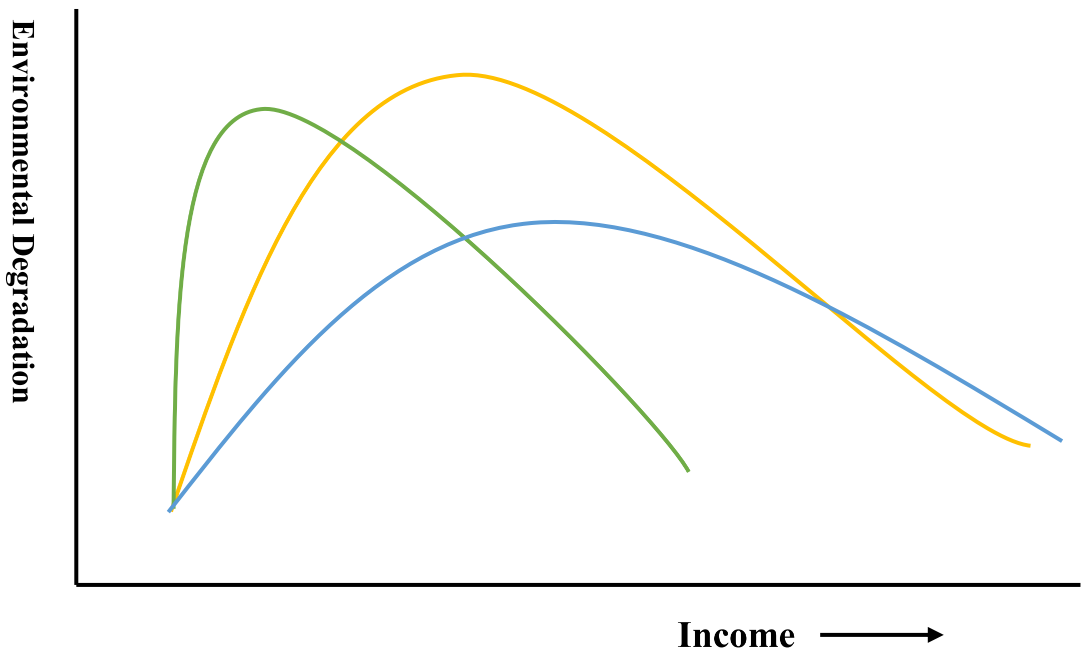


Now consider a country that has been progressing and has become much more effective at implementing policies. This country has recently installed a renewable quota or an RPS policy and now utility providers must have a certain percentage of their energy production come from renewables. The quota makes it so this country cannot consume entirely fossil fuel. Their consumption of RE is below the quota currently, and therefore the country will have to increase their RE generation.



Finally, consider another country that has recently become more effective at implementing policies. This country, however, decided to install a Feed-in Tariff instead of an RPS. This has a different effect than the quota system but will still theoretically increase the RE consumption. This policy implementation will make the relative cost of RE cheaper which will push the budget constraint upward on the y-axis. This will allow the country to consume at a different indifference curve that utilizes more RE than before.

These various differences in political, socioeconomic, country-specific and policy variables can make for countries to have varying Environmental Kuznets Curves. The goal of this paper is to figure out how these variables interact with each other and determine which are the most significant and effective at driving developed nations to generate more renewable energy annually.



Data and Methodology

In this study, the majority of the data is gathered from the World Bank. The data is on 23 different countries that are mainly in the EU. The rest of the countries are there to help capture the difference in structure and policy types along with representing different regions around the globe. The data for the dependent variable, percentage of RE production as a percentage of total energy, is from the World Bank, along with all of the other population, land, GDP and trade variables. The information regarding the policy type dummy variables are found from the International Energy Agency and the United States Energy Agency.

This model puts the data into a panel dataset because cross-sectional and time series fail to account for the differences in individual countries which will bias the end results. The panel data model also allows to control for unobservable variables and to control for variables that change across time within a specific country. This model is set to estimate the percent energy consumption out of total energy consumption in a particular market as a function of four different vectors containing various variables. This builds off of Aguirre and Ibikunle (2014) who broke up the determinates in their model into three groups: political, socioeconomical and country-specific factors. In this model we will use these three and add in a fourth category of RE specific policy.

4.1 Model

The model can be summarized for each country as follows:

$$RE_{it} = A + \delta_1 \mathbf{x}_{it} + \delta_2 \mathbf{y}_{it} + \beta_1 \mathbf{z}_{it} + \delta_3 \mathbf{w}_{it} + \varepsilon$$

Where *i*=1,…,23 represents an individual country and t=2001,…, 2014 denotes the time period. RE_{it} is the dependent variable, the percent of renewable energy output out of the total output in country *i* at time *t*. X_{it} is a vector containing political variables, which includes: Kyoto protocol dummy, trade as a percentage of GDP as a measure of trade openness and energy imports. δ_1 is the vector that contains the coefficients for the variables that are mentioned above.

Y_{it} is a vector containing socioeconomic explanatory variables for country *i* at time *t*. The variables included in this vector are CO_2 Emissions, Brent crude oil prices, GDP per capita, GDP per capita squared, annual population growth, population density and percent of students enrolled in secondary school. δ_2 is the vector that contains the coefficients for the above socioeconomic variables. It is important to note that Brent crude oil is a commonly used benchmark for worldwide oil prices and therefore serves as a good indicator for a widely used fossil fuel price.

Z_{it} is a vector containing country specific factors that impact RE generation of country *i* at time *t*. The country specific variables include measures of a country's renewable endowment such as land area. β_1 is the coefficient for the variable of land area.

W_{it} is a vector that takes into account the different RE specific policies enacted in a country *i* at time *t*. This vector includes two dummy variables. There is a FIT dummy variable, where a "1" represents and FIT policy that is being enforced before July in a given year and a "0" represents the absence of a policy. The second dummy is for a RE quota policy like an RPS. A "1" represents an established policy, while a "0" represents the absence of one.

4.2 Data Analysis

Table 1: Descriptive statistics of variables across all countries

Variable	Observation	Mean	Std. Dev.	Min	Max
RE output (% of total electricity output)	**345**	**30.40**	**26.50**	**1.37**	**99.58**
CO_2 Emissions (metric tons per capita)	322	9.533	4.28	3.71	24.82
Crude Oil Price, Brent ($/bbl)	345	66.84	28.89	24.35	105.01
GDP Per Capita (current USD)	345	37,580.81	22,199.33	2,100.36	119,225.4
GDP Per Capita (squared)	345	1.90e+9	2.35e+9	4,411,522	1.42e+10
Population Growth (annual %)	344	.499	.709	-2.26	2.89
Population Density (people/ sq. km.)	345	124.18	118.78	3.42	502.82
School Enrollment, Secondary (% gross)	335	109.75	15.60	82.74	163.93
Land Area (square kilometers)	345	1,684,954	4,021,306	2,430	16,376,870
Trade (% of GDP)	345	94.95	60.69	22.15	410.17
Energy Imports, Net (% of energy use)	342	7.49	149.60	-843.48	98.077

There are a few important things to note from the descriptive statistics. There is a wide range of CO_2 Emissions by country, with Luxembourg totaling the most in 2005 with 24.82 metric tons per capita. Although there is a wide range of carbon emissions, all of the countries besides Lithuania and Russia decreased their output. The reason for Lithuania's increase is most likely because for the majority of the time panel they were still an emerging economy. This puts them on the front end of the EKC. Russia had a slight increase, but they have yet to enact a policy to incentivize the use of RE. The only country in the data that hasn't enacted such policy.

There is a large wealth gap between the countries in the dataset, with Luxembourg holding the highest GDP per capita in 2014. All of the countries are fairly developed nations. This can be seen with the high percentages of secondary school attendance across every country in the data. There is fairly constant population growth across all countries and years.

Land area and consequently population density have a significant difference across countries. This could have some serious implications for my model. RE typically requires a lot of space to generate. Additionally, areas were RE generation is the most efficient is typically in areas where there is low population density (Alagappan et. al., 2011).

Finally, there is a significant difference between the amount of energy the countries in this dataset import. Norway imports the least, exporting roughly 843% of their net energy use in 2002. Conversely, Luxembourg imported roughly 98% of their net energy use in 2002. This variable is important because it is a good indicator of energy security. A country that imports a majority of their energy is theoretically more inclined to increase their domestic energy production for national security concerns.

Table 2: Average annual percent increase in RE production out of total energy production

Country	Average Annual Increase
Austria	0.90%
Belgium	22.14%
Canada	0.60%
Croatia	0.60%
Czech Republic	10.88%
Denmark	11.98%
Finland	4.27%
France	1.50%
Germany	11.55%
Ireland	15.90%
Italy	5.65%
Spain	6.33%
Sweden	1.74%
Lithuania	33.40%
Luxembourg	10.76%
Netherlands	10.27%
New Zealand	1.85%
Norway	-0.13%
Poland	16.25%
Portugal	8.28%
Russia	-1.27%
UK	18.54%
USA	5.30%

Table 2 above shows that for the most part, every country in the data set has increased their RE production on a yearly basis. There are, however, some countries that have increased only slightly. Norway and Russia both decreased annually. As explained above though, Norway has produced almost all their energy production from RE from the start of the time interval and Russia has shown little interest in enacting any policies meant to incentivize renewable production.

Results and Analysis

Table 3: Regression Results

Dependent Variable: % of RE Production (out of total energy production)

Variable	Coefficient	P>|t|
CO_2 Emissions (metric tons per capita)	-3.65	.001*
Crude Oil Price, Brent ($/bbl)	.0299	.336
GDP Per Capita (current USD)	.0003	.117**
GDP Per Capita Squared	-2.95e-09	.056**
Population Growth (annual %)	-.403	.817
Population Density (people/ sq. km.)	-.309	.071**
School Enrollment, Secondary (% gross)	.070	.458
Land Area (square kilometers)	.0004	.008*
Kyoto Protocol	-1.29	.082**
Trade (as % of GDP)	.181	.078**
Energy Imports, net (% of energy use)	.052	.047*
FIT	1.266	.390
Quota	-2.06	.014*

Observations: 311
***Significant at the 95% Confidence level**
****Significant at the 85% Confidence Level**

My initial panel data regression resulted in 311 observations and all 23 countries were included in the regression. When running a panel dataset, it is imperative to check to see whether a fixed effects model or a random effects model is more efficient. After storing the fixed and random effects results from a regular regression, a Hausman test was implemented in order to determine which model would be the best. The test statistic led me to reject the null hypothesis that the difference in coefficients is not systematic. The chi-squared value for the Hausman test was .0000. Therefore, the fixed effects model was the most efficient model moving forward. After running both a Breush-Pagan test and a White's test, it was clear the model suffered from heteroskedasticity. In order to correct for the heteroskedasticity in my model, the panel dataset uses robust standard errors. A variance inflation factor (VIF) test was employed next in order to check my variables for multicollinearity. None of the resulting values were above 5, leading me to believe the model is not impacted by multicollinearity. Next, a Ramsay RESET test was used in order to check for omitted variables. The test statistic showed that my model does indeed suffer from omitted variable bias. I next transformed my significant coefficients into standardized coefficients in order to make direct comparisons between variables and to determine which X variable was the most important in influencing RE output. This step was needed because most of my variables use different measurements. In order to do this, the beta coefficient was multiplied by the same X variables standard deviation, then divided by the standard deviation of the dependent variable, RE output (appendix A). These standardized coefficients are interpreted by an increase in one standard deviation of the X variable leads to the standardized coefficients change in the dependent variable.

5.1 Discussion

Table 4: Detailed Results of Variables Significant at the 95% Confidence Level

Independent Variable	Coefficient	Standardized Coefficient	P>|t|	(95% Confidence interval)	
CO_2 Emissions (metric tons per capita)	-3.65	-.587	.001	-5.55	-1.75
Land Area (square kilometers)	.0004	N/A	.008	.0001	.0007
Energy Imports, net (% of energy use)	.052	.292	.047	.0007	.102
Quota	-2.05	-.077	.014	-3.65	-.465

The panel data gives us four variables that are significant at the 95% confidence level, and another five more that are significant at the 85% level. The first and most significant variable was *CO_2 emissions* (metric tons per capita). On average, a one metric ton per person increase in CO_2 emissions leads to a decrease of 3.65% RE production out of total energy production. Past papers have had similar finding of fossil fuels (Marquez et al., 2010). This conclusion is logical and speaks to the effect of RE on climate degradation as well as to the attitudes of people in a given country. The negative correlation shows that the less a country emits greenhouse gases, the more likely they are to produce more energy from renewables.

Land area is another strong predicator of RE generation. With every additional square kilometer of land area, a country will on average increase their RE production by .00041%. This is seemingly a small increase, but as noted earlier the countries in the data vary greatly in size.

The standard deviation of the land area amongst countries is over four million. A country with 10,000 additional square kilometers of land will on average produce 4.1% more RE out of total production. This effect is most likely due to the fact that renewables typically require a lot of land in order be efficient. Although this has an influence on RE generation, this variable has little importance on policy decisions because land area isn't something that changes.

Energy Imports was a significant predictor of RE output. If a country increases their imports by 1% of total energy use, their mean RE production will on average increase by .052%. This correlation is also logical. If a country does not have the means to produce traditional sources of energy on their own like oil or coal, they are forced to import their energy. A country in this situation is more inclined to invest in RE in order to establish energy security and to move away from the volatility of the worldwide energy market.

The last variable that is significant at the 95% confidence level is the dummy variable of a quota system. This was the only policy variable, of the two (FIT and quota), found to be significant in the model. The majority of the past studies have only found FITs to be a significant variable and not a quota system like the RPS. The correlation of the quota variable, however, is the opposite of what policy makers intended of it. The model finds that if a country implements a quota policy, on average their mean RE production will decrease by 2.05%. A lot of past studies have found that quota policies are ineffective (Kilinc-Ata, 2016; Carley, 2009). Aguirre and Ibikunle (2014) is the only other study that found that some policies aimed at incentivizing RE production, actually impede it.

Table 5: Detailed Results of Variables Significant at the 85% Confidence Level

Independent Variable	Coefficient	Standardized coefficient	P>|t|	(95% Confidence interval)	
GDP Per Capita (current USD)	.0003	.250	.117	-5.553	-1.75
GDP Per Capita (squared)	-2.95e-9	-.260	.056	-5.098e-9	7.87 e-11
Population Density (people/ sq. km.)	-.309	-1.38	.071	-.646	.029
Kyoto Protocol	-1.28	-.048	.082	-2.75	.178
Trade (as % of GDP)	.181	.413	.078	-.022	.385

The five variables that were significant at least at the 85% confidence level were GDP per capita, GDP per capita (squared), population density, Kyoto protocol dummy and trade (as a % of GDP). Although both GDP per capita and GDP per capita (squared) were both significant at this level, the analysis will focus on GDP per capita (squared) because it is the more accurate variable, because the income distribution is not linear. GDP per capita (squared) had a negative correlation with RE output. Meaning that as GDP per capita increase, RE production decreases. This correlation could suggest that the majority of the countries in this study have yet to reach the peak of the EKC. If the Environmental Kuznets Curve Theory holds true, these countries still have to make an adjustment, through policy or societal attitude, to decrease their environmental degradation as they become wealthier. This can be seen in the scatter graph in appendix B.

The Kyoto protocol dummy is significant at this alpha. The negative correlation coefficient means that it is not an effective driver of RE output. This, however, is not a direct policy to incentivize RE development but rather just an indicator of a country's attitude towards climate change and pollution. Studies in the future could try and use a Paris agreement dummy to see if that global pact has an influence on RE production.

Population Density is significant at the 90% level and has a negative correlation with RE production. This suggest that the denser a country's population, the less likely they are to produce RE. This could be related to land area, because smaller countries are more likely to have higher population density. As mentioned before RE generation typically takes up a lot of space and therefore land area is crucial to production (Alagappan et. al., 2011).

Trade (as a % of GDP) was the last variable significant at this level. If a country increases their trade by 1 percent of their GDP, they will on average produce .181% more RE out of their total energy production. This variable is a good indicator of trade openness. These results confirm the theory that if a country is more open, they are more likely to invest in energy from renewables because of the increased access to technologies from other countries.

There is at least one variable from all 4 of the variable categories in the model that is significant at least at the 90% confidence level. This shows that all of these categories are important factors in RE generation. It is crucial that all of these factors are taken into account by policy makers.

5.2 Model Inefficiencies

It is important to note that although there are significant findings in this paper, the model has several shortcomings. As mentioned earlier, the model suffers from omitted variable bias, but this is often a problem in models that deal with population statistics and attempt to draw conclusions on a broad subject such as this. There are several country specific factors that have no data that focus on aspects like traditional energy endowment and RE endowments. That's why the model includes variables like land area which contributes to what makes up a country's energy endowment to attempt to account for these unmeasurable variables. These stand in variables, however, do not account for all of the variability.

One of the most significant inefficiencies in the model is that it does not control for the nuances in-between policies. The paper generalizes all FITs and RPS as the same policy. Past studies have shown that these policies can actually prove to be effective when controlling for the differences between them (Jenner et al., 2013; Yin and Powers, 2010). Making these policies into simple dummy variables does drastically oversimplify them, and similar policies are often implemented in very different ways. It, however, is difficult to control for these differences in like policies while looking at different policy instruments around the world. It is much easier to control for these differences when examining one policy instrument, like solely an FIT across the EU or solely an RPS across the US.

A similar shortcoming in the model is the generalization of all renewables. Types of renewables differ drastically in everything from installation, price, technology and access. A few of the previous studies on the subject look at RE generation as a whole (Carley, 2009), but a lot of the literature tends to look at a select few types of renewables. They often focus in on either solar, wind or hydro (Jenner et al., 2013). This generalization of all renewables as one, most likely adds a bias on the results and again adds to the simplification of policies. This is because often times certain policies target a certain type of RE.

Conclusion

The goal of this study was to build off of prior literature on the subject in order to help determine what are the determinants that make developed countries around the world invest in renewable energy. This study and previous literature are crucial to understanding how different government approaches combined with their characteristics effect RE generation. They come at a transitional time in our world's history where issues like increased energy demand, pollution, climate change and energy security are coming to the forefront of national and world agendas (Alagappan et al., 2011; Schmalensee, 2012; Jenner et al., 2013). This paper finds empirical evidence that four variables significantly influence the amount of RE a country will produce, like *CO_2 emissions*, *land area, energy imports* and a *quota* policy.

Using the standardized coefficient estimates, CO_2 Emissions was the most significant variable in the model that influenced a country's RE production with a standardized coefficient of -.0587 and a P-value of .001. *Energy imports* was the next most significant variable with a standardized coefficient of .292 and a P-value of .047. *Land Area* was also significant variable. As mentioned earlier though, this is interesting to see but, land area should not be considered too much because it is a variable that doesn't change for an individual country. The most interesting finding of the study was the results for the two policy variables though.

The *Quota* dummy variable had a significant impact, but in the opposite direction of its intention. The model also found that the *FIT* dummy variable was not a significant influencer on the RE generation of a country. This varies from past literature in a couple of ways. Only one paper has found quotas to actually hinder production, and FIT policies are typically found to have a significantly positive effect on RE production. The reason for this could be that as renewables become cheaper, technologies improve, and economies of scale is reached, these policies aimed at stimulating RE in their infancy become less effective over time. It will be interesting to see if governments start to peel back on these early staged policies and work to make different policies that are directed at a more current state of RE.

Future studies on the subject are crucial to finding out if these policies are actually becoming less effective as economies of scale in renewables is slowly being met. These studies should include a worldwide approach with several policies and also some should have a more localized approaches that examine the intricacies in-between certain policy instruments and between different types of renewable technology.

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Appendix

Appendix A: Standardized Coefficient Equation

$$b'_k = b_k * \frac{s_{x_k}}{s_y}$$

Appendix B: EKC Scatter Graph