Does Extensive Fossil Fuel Wealth Affect Renewable Energy Consumption in Developed Organization of Economic Development Countries?

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**Statement of Research Question with Motivation**

The topic of fossil fuel dependence and the development of new renewable energy industries is an interesting topic to study, because it is important to look at whether competitive industries are hindering the development of clean energy sources. Research reviewed by Time Magazine shows that the influence of global warming on economic growth is very apparent in developing countries and identifying barriers to this clean energy source can allow for renewable energy to develop more (Worland, 2016).[[1]](#endnote-1) According to data from Bloomberg, fossil fuels serve as the greatest competitor to renewable energy and the wealth that fossil fuels retain can be used to preserve that wealth. Renewable energy would hinder the preservation of that wealth and thus it is important to explore the reality of these theoretical and practical issues. This is relevant due to the fact that the recent crash in the price of fossil fuels have created downsizing within the renewable energy sector (Randall, 2016).[[2]](#endnote-2) Additionally, 2015 financial support for fossil industries from policymakers was higher than spending dedicated towards meeting international climate goals within OECD countries, which means that the industry is much more established compared to clean energy sources (OECD, 2015).[[3]](#endnote-3) Therefore, this paper will explore whether a country’s greater economic dependence on fossil fuel wealth has a negative impact on the domestic consumption of renewable energy.

**Literature Review and Economic Theory**

The relevant theory that will be explored in this paper is resource curse. Roy, Sarker, and Mandal 2013 explains that resource curse is where a country focuses, on one industry within either a specific or broad range of different natural resource categories, which is often due to political support for the established industry that invests a lot of energy in the political system. What results from this trend is that when the price of a resource that a country relies upon increases, the economy will grow because natural resource producers can get a large premium for producing that resource in large quantities. However, when the price of that resource decreases, the economy will contract, because the country’s main economic actors that rely on high commodity prices will lose wealth from selling at a lower price (Roy, Sarker, and Mandal, 2013).[[4]](#endnote-4) Gylfason 2006 found that the literature on resource curse consistently demonstrates that resource curse countries tend to have anticompetitive tendencies and are often resistant to the development of new industries (Gylfason, 2006).[[5]](#endnote-5) Ding and Field 2005 also found that the endowment received from natural resource wealth can also be harmful to GDP growth, particularly when human capital is omitted from the empirical model (Ding and Field 2005).[[6]](#endnote-6)

The implications from these findings is that because fossil fuel industries are now seeing greater competition from innovative renewable energy technologies (World Watch Institute 2017)[[7]](#endnote-7), many stakeholders have identified political and knowledge barriers as one the most pressing challenges for the growth of renewable energy industries (Richards, Noble, and Belcher 2012).[[8]](#endnote-8) Thus, the resource curse phenomenon could be negatively renewable energy through the political economy, because Bayulgen and Ladewig 2017 asserted that the greater a country country’s political constraints, which are measured by the number of political actors within a country that can veto policy, the less statistically likely that renewable energy industries will experience strong economic growth (Bayulgen and Ladewig 2017).[[9]](#endnote-9)However, Sathaye, Nyboer, and Nilsson 2009 found that issues of market failure were the primary issues in the development of renewable energy, which can arise from a private energy market’s inability to make costly long-term investments in energy efficient technologies (Sathaye, Nyboer, and Nilsson 2009).[[10]](#endnote-10) So, the literature on the issue of renewable energy barriers is not universally conclusive, which means that it is an open question as to whether the resource curse phenomenon applies to the renewable energy industry. Therefore, the economic model that will be used for this paper will build off the literature by identifying specific market, knowledge, and political variables that will allow for an answer to arise to the question of whether a country’s dependence on fossil fuel wealth degrades renewable energy consumption.

**Economic Model**

*The Independent Variable of Interest and the Dependent Variable*

The dependent variable of interest will be the consumption of renewable energy and the main independent variable will be the total natural resource rents as a percentage of GDP. Renewable energy includes geothermal, hydroelectric, wind, solar, and biofuels within the World Bank data set. It is expected that the natural resource wealth variable will have a negative parameter estimate, since the resource curse phenomenon could apply to industries that would represent a threat to natural resource wealth and the rents that can be extracted from the industry by the host government.

*Formulating the Model*

Other variables will be used to account for factors that could influence the domestic consumption of renewable energy. The equation for the model will be based off the Ding and Field 2005 model on the influence of natural resource wealth on GDP (Ding and Field 2005).[[11]](#endnote-11) The Ding and Field model is different in that it is a model for measuring GDP, while its independent variables are used as potential components of GDP. The new model can retain some of the variables from the Ding and Field model, which include those variables relating to trade and investment, because the global flow of capital across borders and domestically is crucial to the development of new energy systems and reducing the cost of energy technology (OECD 2016).[[12]](#endnote-12) Such a model will look as follows:

*Model with North America and Western Europe Dummy Variables*

*Model with North America and Asia Pacific Dummy Variables*

*Model with Western European and Asia Pacific Dummy Variables*

*Economic Theory Behind the Variables*

Net Energy Imports

The net energy imports variable is a measure of domestic consumption of fossil fuels minus the production and exports of fossil fuels. The implication that energy imports have for the renewable energy industry is that Bhattacharya and Jana 2009 concluded from empirical work in India that if a country is relying on fossil fuel imports for power production then it could push the government and investors to quickly come up with new ways to diversify the energy industry so that the market can become more stable for consumers to quickly access electricity (Bhattacharya and Jana 2009).[[13]](#endnote-13) Thus, the parameter estimate for net energy imports is likely to be positive.

Energy Research, Development, and Demonstration

The parameter estimate for energy research, development, and demonstration will likely be positive. The investment in new energy technology can play an important role in consumption of energy products. From the perspective of the mainstream macroeconomics, a country’s investment in human capital within its industries is crucial to maintaining the functionality of those industries over the long term. This energy RD&D can be very important for the development of new renewable energy technologies and thus can influence the consumption of renewable energy.

Foreign Direct Investment

Foreign direct investment can play an important role in the development of emerging industries and the consumption of products from those industries. The principle of comparative advantage dictates that when countries open trade barriers they can commit to greater specialization of labor. Since foreign direct investment is traditionally associated with greater uses of more efficient and cleaner energy technologies (Mert, M., & Bölük, G. 2016)[[14]](#endnote-14), the parameter for foreign direct investment is hypothesized to be positive. Theoretically, this is because the greater a country is open to trade, the more likely they can innovate based off the resurgence in energy technology from other countries.

The Education Rate

For a country to consume more renewable energy, it must have enough highly skilled workers to produce the energy for consumption. These new energy processes require engineers and quantitative experts to make sure that renewable energy infrastructure is built to withstand climate conditions and to make sure that the software and technology that goes into continuing renewable energy systems is working correctly (Prospects 2015).[[15]](#endnote-15) The production possibilities curve can be used to explain this phenomenon as the inputs of education can increase the ability of the population to take these high skilled jobs and increase the productive capacity of the energy economy. Thus, the parameter estimate will most likely be positive.

Corruption

Corruption can often be corrosive to economic growth and can stifle technological progress. In the context of energy economics Van der Ploeg 2011 showed empirically that natural resource wealth is linked to corruption, because natural resource wealth can shift government accountability away from the average citizens through disproportionate taxation of natural resource wealth (Van der Ploeg 2011).[[16]](#endnote-16) From a public choice standpoint, often interest groups can act solely for their own economic interests and not for the overall economy. The domination of these groups in political decision-making could prevent the development of new industries through political favors, which can indeed be quid pro quo. In fact, political barriers have been shown earlier to be a credible explanation for the difficulty of renewables becoming fully competitive.[[17]](#endnote-17) Thus, corruption will most likely be harmful to renewable energy consumption, because the interests of fossil fuel industries will likely conflict with renewable energy industries. So, the parameter estimate for corruption will probably be negative.

Regional Dummy Variables

In three separate regressions, three regional dummy variables will be used to determine differences in the data among separate regions of the developed countries that will be examined. These regional dummy variables will be Western Europe, North America, and the Asia Pacific region. Since Western Europe has very well developed renewable energy industries and ambitious goals, it can be expected that Western Europe will have the highest parameter estimates when the dummy variable is compared to the other 2 dummy variables (Vaughn 2016).[[18]](#endnote-18) Most likely the North American region will have more renewable energy consumption than the Asia pacific region since the Asia Pacific region is still developing its renewable energy industry (Cronshaw and Grafton 2014).[[19]](#endnote-19)

**Data Sources and Description**

The following sources below detail the data used for this study. The data was organized into a panel dataset of 106 observations from 18 developed OECD countries during the years 2008 to 2013. Two of the countries within specific regions only had data available from 2008 to 2012. The Asia pacific region included Australia, and Japan, while the North American region contained the United States and Canada. The western European region contained Austria, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

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| **Table 1.1: Data Table** | | |
| **Fossil Fuel Wealth and Renewable Energy Consumption** | | |
| *Variable Definitions and Data Sources* | | |
| **Variable** | **Definition** | **Source** |
| Total natural resources rents (% of GDP) | Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents. | [Source: World Bank, World Development Indicators, http://data.worldbank.org/indicator/NY.GDP.TOTL.RT.ZS] |
| Energy Imports Measured in Oil Equivalents | Net energy imports are estimated as energy use less production, both measured in oil equivalents. A negative value indicates that the country is a net exporter. | [Source: World Bank, World Development Indicators, http://data.worldbank.org/topic/energy-and-mining |
| Energy RD and D | Total energy research, development, and demonstration in millions of US Dollars | [Source : OECD, http://stats.oecd.org/BrandedView.aspx?oecd\_bv\_id=enetech-data-en&doi=data-00488-en] |
| Foreign Direct Investment | Trade as a Percent of GDP in US Dollars | [Source: World Bank, http://data.worldbank.org/indicator/NE.TRD.GNFS.ZS] |
| Tertiary Adult Education Rate | The tertiary education percentage rate within a country | [Source: OECD (2017), Population with tertiary education (indicator). doi: 10.1787/0b8f90e9-en |
| Perception of Corruption | Transparency International comes out with a measure of corruption per country based on the strength of the country's institutions 1 to 10 indicates most corrupt to least corrupt | [Source: Transparency International, http://www.transparency.org/research/cpi/overview] |
| Renewable Energy Consumption (% of total energy consumption) | Renewable energy consumption is the share of renewable energy in total final energy consumption | [Source: World Bank, http://data.worldbank.org/indicator/EG.FEC.RNEW.ZS] |
| Regional Dummy Variables | Three regions will include Asia Pacific, Western Europe, and North America. Their renewable energy consumption will be analyzed. | [Source: Data Sets for the other variables] |

**Model Estimation and Hypothesis Testing**

The model estimation for the economic model involved a close look at the shape of the data to determine if controls for nonlinear data could be introduced into the model. After a close inspection of the data, it was determined that quadratic components could be introduced to produced regression models that best fit the size and shape of the data set. As scatterplot 1, 2, and 3 show, there is a clearly nonlinear relationship between renewable energy consumption and the variables Energy RD&D, Natural Resource Rents, as well as the Corruption variable. Please note that to get an increasing scale of corruption from 1 being least corrupt to 10 being most corrupt the data had to be multiplied by negative 1 to do the regression models.

*Analysis of the Scatterplots*

Additionally, the presence of regional dummy variables meant that separate analyses had to be conducted for each of the regression techniques in combination with different pairs of regional dummy variables, which is because the different combinations will yield different results for the test statistics of the variables being analyzed. Below are tables detailing the results of the 4 models that were compared and narrowed down to one model for hypothesis testing.

*Analysis of the Regression Models*

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| **Table 1.2: Regression Models**  **Fossil Fuel Wealth and Renewable Energy Consumption**  *Dependent Variable: Renewable Energy Consumption*  *Controls: The White Test for Heteroscedasticity, Regional Dummy Variables, and Quadratic Components for Nonlinear Data* | | | | |
|  | 1.Simple Linear Regression Model | 2.Regression with a quadratic component for ER\_DD | 3.Regression with quadratic components for ER\_DD and NRRENTS | 4.Regression with quadratic components for ER\_DD, NRRENTS, and CORRUPTION1 |
| **Natural Resource Rents as a Percentage of GDP [NRRENTS]** | -0.38846  (-6.26)\*\* | -0.46872  (-8.53)\*\* | -0.75714  (-4.59)\*\* | -1.04177  (-6.42)\*\* |
| **Quadratic Component for NRRENTS** | N/A | N/A | 0.00845^  (1.90) | 0.01276  (3.28)\*\* |
| **Energy Research, Development, and Demonstration [ER&DD]** | 0.00476  (1.47) | 0.03802  (4.47)\*\* | 0.03559  (4.15)\*\* | 0.03255  (4.14)\*\* |
| **Quadratic Component for ER&DD** | N/A | -0.00001564  (-4.14)\*\* | -0.00001461  (-3.86)\*\* | -0.00001394  (-3.87)\*\* |
| **Foreign Direct Investment in millions of US Dollars [FDI]** | -0.00000571  (-0.47) | -0.00004032  (-2.72)\*\* | -0.00003568  (-2.42)\* | -0.00003878  (-2.86)\*\* |
| **Net Energy Imports Measured in Oil Equivalents [ENERGYIMPORTS]** | -0.04920  (-15.81)\*\* | -0.05274  (-15.58)\*\* | -0.05245  (-15.65)\*\* | -0.05324  (-16.97)\*\* |
| **Adult Tertiary Education Rate [EDUCATION]** | 0.72963  (3.76)\*\* | 0.52216  (3.02)\*\* | 0.52978  (3.12)\*\* | 0.33433  (2.38)\* |
| **Perception of Corruption [CORRUPTION1]** | -0.69724  (-0.76) | -1.34984^  (-1.65) | -1.43471^  (-1.73) | -28.86501  (-4.27)\*\* |
| **Quadratic Component for the Corruption Variable** | N/A | N/A | N/A | -1.86657  (-3.92)\*\* |
| **Difference Between the Asia Pacific Region and the North American Region for Renewable Energy Consumption** | -9.50599  (-5.77)\*\* | -12.23568  (-5.99)\*\* | -28.21132  (-12.20)\*\* | -18.22117  (-8.69)\*\* |
| **Difference Between the Western Europe Region and the North American Region for Renewable Energy Consumption** | 18.62045  (5.14)\*\* | 16.11848  (4.79)\*\* | -14.59596  (-4.35)\*\* | 10.18162  (3.59)\*\* |
|  |  |  |  |  |
| **R Squared** | 0.7107 | 0.7433 | 0.7460 | 0.7786 |
| **Adjusted, R Squared** | 0.6868 | 0.7192 | 0.7192 | 0.7527 |
| **Root Mean Squared Error** | 8.37994 | 7.93461 | 7.93506 | 7.44650 |
| **Number of Observations** | 106 | 106 | 106 | 106 |
| The following in parentheses are t values and ^ indicates statistical significance at the 10% level, \* indicates statistical significance at the 5% level, and \*\* indicates statistical significance at the 1% level. The values above the t values are parameter estimates for the variables being analyzed. | | | | |

Based on the t values for these models, model 2, 3, and 4 have similar levels of statistical significance for the parameter estimates. Model 1 cannot be used because it is a simple linear regression that does not fit with the shape of the data, which is for the most part nonlinear. Model 4 cannot be used because it has an extremely high parameter estimate for the corruption variable to the point where a 1 unit increase in the perception of corruption on a 1 to 10 scale within a country would decrease renewable energy consumption by over 28%. This does not make any theoretical sense, so model 4 cannot be used. Models are 2 and 3 are very similar in terms of the adjusted r squared value, but model 2 has a slightly lower root mean squared error of 7.93461 compared to a value of 7.93506 for model 3. Additionally, the T values for Natural Resource Rents, Energy RD&D, FDI, and Energy Imports are higher under model 2, which means that for these combinations of dummy variables, model 2 is the best approach for hypothesis testing.

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| **Table 1.3: Regression Models with Regional Dummy Variables**  **Fossil Fuel Wealth and Renewable Energy Consumption**  *Dependent Variable: Renewable Energy Consumption*  *Controls: The White Test for Heteroscedasticity, Regional Dummy Variables, and Quadratic Components for Nonlinear Data* | | | | |
|  | 1.Simple Linear Regression Model | 2.Regression with a quadratic component for ER\_DD | 3.Regression with quadratic components for ER\_DD and NRRENTS | 4.Regression with quadratic components for ER\_DD, NRRENTS, and CORRUPTION1 |
| **Natural Resource Rents as a Percentage of GDP [NRRENTS]** | -0.38846  (-6.26)\*\* | -0.46872  (-8.53)\*\* | -0.75714  (-4.59)\*\* | -1.04177  (-6.42)\*\* |
| **Quadratic Component for NRRENTS** | N/A | N/A | 0.00845^  (1.90) | 0.01276  (3.28)\*\* |
| **Energy Research, Development, and Demonstration [ER&DD]** | 0.00476  (1.47) | 0.03802  (4.47) \*\* | 0.03559  (4.15)\*\* | 0.03255  (4.14)\*\* |
| **Quadratic Component for the ER&DD Variable** | N/A | -0.00001564  (-4.14)\*\* | -0.00001461  (-3.86)\*\* | -0.00001394  (-3.87)\*\* |
| **Foreign Direct Investment in millions of US Dollars [FDI]** | -0.00000571  (-0.47) | -0.00004032  ( -2.72)\*\* | -0.00003568  (-2.42)\* | -0.00003878  (-2.86)\*\* |
| **Net Energy Imports Measured in Oil Equivalents [ENERGYIMPORTS]** | -0.04920  (-15.81)\*\* | -0.05274  (-15.58)\*\* | -0.05245  (-15.65)\*\* | -0.05324  (-16.97)\*\* |
| **Adult Tertiary Education Rate [EDUCATION]** | 0.72963  (3.76)\*\* | 0.52216  (3.02)\*\* | 0.52978  (3.12)\*\* | -0.22397  (2.38)\* |
| **Perception of Corruption [CORRUPTION1]** | -0.69724  (-0.76) | -1.34984^  (-1.65) | -1.43471^  (-1.73) | -28.86501  (-4.27)\*\* |
| **Quadratic Component for the Corruption Variable** | N/A | N/A | N/A | -1.86657  (-3.92) |
| **Difference Between the North American Region and the Asia Pacific Region for Renewable Energy Consumption** | 9.50599  (5.77)\*\* | 12.23568  (5.99)\*\* | 13.61536  (6.62)\*\* | 18.22117  (8.69)\*\* |
| **Difference Between the Western European Region and the Asia Pacific Region for Renewable Energy Consumption** | 28.12644  (11.01)\*\* | 28.35416  (12.15)\*\* | 28.21132  (12.20)\*\* | 28.40279  (12.48)\*\* |
|  |  |  |  |  |
| **R Squared** | 0.7107 | 0.7433 | 0.7460 | 0.7786 |
| **Adjusted, R Squared** | 0.6868 | 0.7192 | 0.7192 | 0.7527 |
| **Root Mean Squared Error** | 8.37994 | 7.93461 | 7.93506 | 7.44650 |
| **Number of Observations** | 106 | 106 | 106 | 106 |
| The following in parentheses are t values and ^ indicates statistical significance at the 10% level, \* indicates statistical significance at the 5% level, and \*\* indicates statistical significance at the 1% level. The values above the t values are parameter estimates for the variables being analyzed. | | | | |

These models are very like the previous ones in terms of overall trends, the adjusted r squared values were the same for model 2 and 3. Model 4 and 1 cannot be used because model 4 has too high a corruption parameter and model 1 is a simple linear regression, which is not representative of the shape of the data. Model 2 will be preferred since the root mean squared error is lower than model 3 at 7.93461 as opposed to 7.93506. Since the T values are stronger for the Natural Resource Rents, FDI, and energy RD&DD variables, Model 2 will be preferred because the Natural Resource Rents variable is the most important independent variable of interest in this study.

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| **Table 1.4: Regression Models with Regional Dummy Variables**  **Fossil Fuel Wealth and Renewable Energy Consumption**  *Dependent Variable: Renewable Energy Consumption*  *Controls: The White Test for Heteroscedasticity, Regional Dummy Variables, and Quadratic Components for Nonlinear Data* | | | | |
|  | 1.Simple Linear Regression Model | 2.Regression with a quadratic component for ER\_DD | 3.Regression with quadratic components for ER\_DD and NRRENTS | 4.Regression with quadratic components for ER\_DD, NRRENTS, and CORRUPTION1 |
| **Natural Resource Rents as a Percentage of GDP [NRRENTS]** | -0.38846  (-6.26)\*\* | -0.46872  (-8.53)\*\* | -0.75714  (-4.59)\*\* | -1.04177  (-6.42)\*\* |
| **Quadratic Component for NRRENTS** | N/A | N/A | 0.00845^  (1.90) | 0.01276  (3.28)\*\* |
| **Energy Research, Development, and Demonstration [ER\_DD]** | 0.00476  (1.47) | 0.03802  (2.75)\*\* | 0.03559  (4.15)\*\* | 0.03255  (4.14)\*\* |
| **Quadratic Component for the ER&DD Variable** | N/A | -0.00001564  (-4.14)\*\* | -0.00001461  (-3.86)\*\* | -0.00001394  (-3.87)\*\* |
| **Foreign Direct Investment in millions of US Dollars [FDI]** | -0.00000571  (-0.47) | -0.00004032  (-2.72)\*\* | -0.00003568  (-2.42)\* | -0.00003878  (-2.86)\*\* |
| **Net Energy Imports Measured in Oil Equivalents [ENERGYIMPORTS]** | -0.04920  (-15.81)\*\* | -0.05274  (-15.58)\*\* | -0.05245  (-15.65)\*\* | -0.05324  (-16.97)\*\* |
| **Adult Tertiary Education Rate [EDUCATION]** | 0.72963  (3.76)\*\* | 0.52216  (3.02)\*\* | 0.52978  (3.12)\*\* | 0.33433  (2.38)\* |
| **Perception of Corruption [CORRUPTION1]** | -0.69724  (-0.76) | -1.34984^  (-1.65) | -1.43471^  (-1.73) | -28.86501  (-4.27)\*\* |
| **Quadratic Component for the Corruption Variable** | N/A | N/A | N/A | -1.86657  (-3.92)\*\* |
| **Difference Between the Asia Pacific Region and the Western European Region for Renewable Energy Consumption** | 28.12644  (-11.01)\*\* | -28.35416  (-12.15)\*\* | -28.21132  (-12.20)\*\* | -28.40279  (-12.48)\*\* |
| **Difference Between the North American Region and the Western European Region for Renewable Energy Consumption** | -18.62045  (-5.14)\*\* | -16.11848  (-4.79)\*\* | -14.59596  (4.35)\*\* | -10.18162  (-3.59)\*\* |
|  |  |  |  |  |
| **R Squared** | 0.7107 | 0.7433 | 0.7460 | 0.7786 |
| **Adjusted, R Squared** | 0.6868 | 0.7192 | 0.7192 | 0.7527 |
| **Root Mean Squared Error** | 8.37994 | 7.93461 | 7.93506 | 7.44650 |
| **Number of Observations** | 106 | 106 | 106 | 106 |
| The following in parentheses are t values and ^ indicates statistical significance at the 10% level, \* indicates statistical significance at the 5% level, and \*\* indicates statistical significance at the 1% level. The values above the t values are parameter estimates for the variables being analyzed. | | | | |

For the following models, the 2nd model has more pronounced t values for the FDI variable, Natural Resource Rents variable, and the quadratic component of energy RD&D than the 3rd model. The root mean squared error is lower for model 2 at 7.93461, in comparison to 7.93506 for the 3rd model. Since the improvements in T values are marginal at best for the other variables it does not justify the adding of another component into the model. The 1st model cannot be used since it is a simple linear regression and the 4th model has too large a parameter value for the corruption variable. Therefore, the 2nd model should be used in this study.

**Interpretation of the Results**

Based on the 2nd model that was chosen for all the combinations of regional dummy variables, the T value for the natural resource rent variable allows for the rejection of the null hypothesis that natural resource rents do not affect renewable energy consumption and the negative parameter estimate can be confirmed at the 1% significance level. This means that when you multiply the parameter estimate by the standard deviation, from table 1.5 below, for natural resource rents it can be shown that under the conditions of the model, a 1 standard deviation increase in the natural resource rents as a percentage of GDP parameter is associated with a 5.27971542% decrease in renewable energy consumption, with similar estimates coming from the models that had different combinations of regional dummy variables. This could be a significant finding because it can provide some evidence to demonstrate that significant negative economic ramifications could occur for the renewable energy industry from an economy that relies more on fossil fuels. This is a salient finding because the corruption parameter estimate was found to also be negative, but was found to nearly reach statistical significance at the 10% level. However, one reason why the relationship might not be as strong as was predicted would be the fact that only developed countries were used in the panel data set, which could naturally mean that corruption is less present overall and as a result does not have that much of an effect on microeconomic trends within those countries. So, the underlying economic explanation for this could be that those economies that receive the greatest shock to the renewable energy industry from natural resource wealth are those countries that have slightly weaker institutions and could be plagued with greater political barriers to the emergence of new renewable energy industries.

One way to verify this claim empirically is to examine the parameter estimates for the adult tertiary education rate among the adult population, and the parameter estimates for Energy Research, Development, and Demonstration. The parameter estimate for the tertiary education rate was positive showing that a 1 standard deviation increase in the tertiary educational attainment parameter is associated with a roughly 12% increase in renewable energy consumption. This was consistent with the hypothesis made for the preliminary economic model. The t value for this parameter of 3.02 for the different combinations of dummy variables is confirmed to make this statistically significant at the 1% level. What this could mean is that since research has demonstrated in the past that educational spending often represents a shift in a government’s priorities away from corruption,[[20]](#endnote-20) then the increase in education could also help to create an institutional environment where the citizens are actively participating in the political process and are preventing corruption from harming the integrity of government institutions. Some evidence to demonstrate this trend came from regressing the corruption variable against the other variables in the model, which yielded a negative parameter estimate for education in relationship to corruption with statistical significance confirmed at the 1% significance level using a T value of -3.96.

However, turning to the Energy RD&D parameter, the parameter estimate was positive with statistical significance being confirmed at the 1% significance level. The interpretation from this finding from the parameter estimate is that a 1 standard deviation increase in the Energy Research, Development, and Demonstration parameter is associated with a 10.41% increase in renewable energy consumption with similar conclusions emerging from models and considering the influence of the quadratic term. This is consistent with the hypothesis in the preliminary economic model. The finding is of relevance because it shows some evidence to demonstrate that when countries invest more in the development of new energy technology, then the technological benefits of innovation can spillover into the emerging renewable energy industry.

Two more interesting findings were that the parameter estimates for foreign direct investment and net energy imports were both negative and confirmed to be statistically significant at the 1% significance level. Utilizing the standard deviation, this means that a 1 standard deviation increase in the parameter for FDI is associated with a 2.561352192% decrease in renewable energy consumption. The reason why this could be happening is because foreign direct investment can finance a broad variety of investment projects beyond renewable energy, which could explain the negative relationship if foreign direct investment was also financing fossil fuel investments. For net energy imports, the negative parameter estimate was surprising considering the previous literature that was cited earlier about how countries are being encouraged to move away from energy imports and invest in renewable energy. One possible explanation could be that countries do not change their energy policies overnight. So, policy paralysis could be an explanation for why energy imports are associated with lower renewable energy consumption from the empirical model.

Turning now to some of the aggregate trends in the model, the regional dummy variables functioned as they were predicted to do. The statistically significant parameters for these dummy variables showed that that if one lived in the Western European region, then that was associated with 28.12644% more renewable energy consumption in comparison to the Asia Pacific region. The North American region also saw less renewable energy consumption in relationship to the Western European region, which was consistent with the hypothesis made before in the preliminary model. The status of Western Europe as the dominant consumer of renewable energy is consistent with the previous research showing the rapid development of the renewable energy industry. Furthermore, the adjusted r squared for the models was 0.7192, which means that 71.92% of the variation in the data can be explained by the current model. This is relatively strong for a panel data set like this and can serve as positive evidence for the reliability of the model. This is in addition to the low root mean squared error in comparison to the descriptive statistics from table 1.5 such as the mean and range of the data.

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| **Table 1.5: Descriptive Statistics**  **Fossil Fuel Wealth and Renewable Energy Consumption**  *Dependent Variable: Renewable Energy Consumption* | | | | |
|  | **Mean** | **Standard Deviation** | **Minimum Value** | **Maximum Value** |
| **Energy RD&D (in millions of US Dollars)** | 169.1227170 | 315.8421768 | 0.0980000 | 2302.42 |
| **Natural Resource Rents (% of GDP)** | 7.4806327 | 11.2641138 | 0 | 43.3615465 |
| **FDI (Millions of US Dollars** | 39366.93 | 63525.60 | -24926.47 | 333000.00 |
| **Energy Imports (% of energy use)** | -2.2310047 | 149.8182699 | -611.5012802 | 93.9186266 |
| **Adult Tertiary Education Rate (% of Adult Population)** | 33.5910197 | 9.0876767 | 14.3003788 | 52.9714394 |
| **Renewable Energy Consumption (% of total energy consumption)** | 19.3958995 | 14.9747604 | 3.9838669 | 58.4937331 |
| **Perception of Corruption (scale of -10 least corrupt to -1 most corrupt)** | -7.6113208 | 1.3235105 | -9.4000000 | -4.4000000 |

**Conclusions and Limitations**

The overall conclusion that can be drawn from this research is that there is some statistical evidence to demonstrate that a country’s greater economic dependence on fossil fuel wealth is associated with lower renewable energy consumption. The statistical evidence shows that education and energy RD&D are positively associated with renewable energy consumption. Possible explanations for the relationship included the ability of education to improve institutions and therefore offer a better political environment and overall skill set for the general populace for renewable energy industries to thrive. Innovation resulting from energy RD&D could also help renewable energy industries to become more efficient. In terms of the corruption parameter, it was shown that corruption within this data set had a weak relationship with renewable energy consumption, which could have been because the data set was composed of mostly developed countries. Energy imports and FDI had a surprisingly negative relationship with renewable energy consumption, which could be due to the fact the countries can have political paralysis and as a result delay reforms that could follow from greater net energy imports. FDI also could entail a broad variety of investment projects in the energy industry, which could explain the negative relationship if FDI was going toward fossil fuel investments. The regional dummy variables also were consistent with predictions in the original model. The Western European region had the highest renewable energy consumption, followed by North American region, and then the Asia Pacific region.

Some questions that need to be answered from research study is the question of whether campaign contributions from the fossil fuel industry could play a part in stifling renewable energy consumption. This could provide a more direct link between fossil fuel wealth and renewable energy consumption, especially if those campaign contributions are leading to the creation of greater political barriers to the development of the renewable energy industry. Additionally, it is important to also look at the difference between developed and developing countries, because developing countries often have fledgling institutions of governance and could be an important part of the political economy argument that fossil fuel wealth can be used to build up political capital and therefore institutional barriers to the development of the renewable energy industry.

One limitation from this model include the lack of more extensive time series data sets for the variables of interest. Total observations for this data set were 106, which is not enough to do an extensive cross country study that can explore the various trends in the energy industry over time. Another limitation from this research study is the fact that energy RD&D variable was not specific to renewable energy. An energy RD&D variable specific to renewable energy could allow for a more direct relationship to be established between the parameter. Limiting the tertiary education rate to scientific fields could also help to create a more reliable institutional report on the state of the education system in relation to renewable energy. Furthermore, the insertion of an economic variable that measures the state of the economy could help to paint a better picture as to whether the fiscal health of the economy in general could be affecting renewable energy consumption. Finally, the variable inflation rate for the energy RD&D variable was rather high at 17.37551. This was due to the insertion of the quadratic component to energy RD&D, because regressing the two variables against each other yielded a very high T value at 26.80, which means that more controls need to be made in the future to prevent issues of multicollinearity.

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