Modelling Renewable Energy Consumption

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Abstract

This thesis questions whether macro-economic variables impact the consumption of renewable energy. I run a panel regression for 76 countries from 2000 to 2006 controlling for GDP per capita, electricity imports and exports, distribution losses, installation and natural proved reserves. The results show that for a given country electricity imports, grid installation and distribution losses consistently impact the consumption of renewable energy sources. Based on the results, I come with long and short term policies that can be implemented to ensure a sustainable mode of energy consumption.

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Introduction

Power being generated through renewable energy has been debated for years. From an economic point of view, the current state of technology does not permit public and private sector to generate power through renewable sources at a minimum cost. On the contrary, the exhaustive nature of current energy sources such as oil and gas and their market price volatility raises question whether cost minimizing should be given priority. With the present state of the world economy, where financial markets are struggling to survive, the discussion on renewable energy consumption and their macro economic prospect may be thought to be less important. However, the analysis of macroeconomic variables that may affect the usage of renewable energy consumption can be an important area to explore to come up with strategic policy tools to increase investment.

Does macro-economic variables impact the consumption of electricity generated from renewable sources? The research question of the thesis neither sets an argument for or against the usage of power generated through renewable energy. The question of the thesis has been posed to study whether the usage of renewable source is a mere decision in response to some environmental concern or there are some macro economic factors that drive the usage of such resources. Previous studies have explored how renewable energy has positively effected employment, balance of payment, investment, energy security. For instance, a study completed by Kemmen et. al (2004) shows how employment is effected by the usage of renewable energy. 13 studies from the United States and Europe were examined in terms of gross employment effects differentiated by technologies. The study shows that every technology in the renewable industry generates more jobs per average megawatt of power in the construction, manufacturing and installation sectors, as compared to the coal and natural gas industry. The effect of renewable energy on investment can be better understood from a development perspective which has been conceptualized by Wu (2007). He states that RETs (Renewable Energy Technologies) such as solar photovoltaic (PV), biogas digesters, small wind-electric turbines, and micro-hydro are often ideal for providing electricity in rural areas, ranging from a few watts to thousands of watts. The author adds that in developing countries investment in Small and Medium Enterprises depends heavily on availability of funds as the market for credit is not structured. Wu (2007) mentions that RETs reduces the share of household income spent on lighting as more-expensive conventional fuels are replaced. By making light more affordable and reliable; RETs also permit income generation beyond daylight. RETs are already spurring industrial growth and business opportunities for the urban and rural poor. They boosted involvement of the local supply chain, and have brought in foreign direct investment, while also increasing access to global markets and trade.

However, this thesis tries to answer whether different macro-economic variables such as electricity imports and exports, GDP Per Capita, Electricity Distribution losses, Population, Nuclear and Hydro Power, Primary Energy Production and Consumption, European Union Member State, Electricity Installation and Proved Oil and Gas Reserve have a role to play to promote electricity generated through renewable energy. The thesis does not repeat previous studies to find the stream of benefits that flows from the usage of renewable energy but focuses on factors that impact the usage of renewable energy. If the above stated variables are found to be significant then it can be statistically shown that such variables can be used as strategic macroeconomic tools to influence the usage of electricity generated through renewable sources. The research question itself makes the thesis different from previous studies. Instead of emphasizing the causal effect of renewable energy sources, the question analyzes macroeconomic variables that may play a role to influence the usage of it.

In this thesis I hypothesize that electricity imports and exports, GDP Per Capita, Electricity Distribution losses, Population, Nuclear and Hydro Power, Primary Energy Production and Consumption, European Union Member State, Electricity Installation and Proved Oil and Gas Reserve do not effect the electricity consumption from renewable sources. Electricity consumption from renewable sources is considered as dependable variable and the rest as independent. I first run a panel data regression for 76 countries from 2000 to 2006 to answer the posed question. It is worth mentioning that among these 76 countries there are countries that have zero nuclear power generation. To set a comparison, a separate regression for 29 countries which have a positive nuclear power generation is run to observe whether the results changes notably. I expect that electricity imports, European Union Member State, Electricity Installation and Electricity Distribution losses have a positive effect on electricity consumed by renewable sources.

The first chapter of the thesis looks at different literatures that link the dependent and independent variable with the consumption of renewable sources. In addition, it discusses how such a relationship has been empirically or logically established. After the literature has been reviewed, in the second chapter I describe the methodology. This chapter of the thesis describes why panel data analysis has been chosen and the limitations of the method. Along with the methodology, the description of the dependent and independent variables are briefly described. In addition, the units that have been used to measure the quantity of the variables are mentioned in the chapter. The third chapter describes the model used to analyze the data and what kind of result is expected from the regression. In chapter four, I state the results from the regression and analyze the relationship between the independent variables and renewable energy consumption. I aim to reason why such relationship has been observed and what could be the econometric interpretation. In the conclusion, I conceptualize policies that can be formulated and influenced with the help of fiscal and monetary measures.

Chapter 1

Literature Review

This thesis models electricity power consumption generated through renewable energy sources. Why did the thesis emphasize on electricity rather than the cost, benefit or some other socio-environment aspect of renewable energy consumption. The reason mainly relates to the consequences of electricity generated through primary energy sources. From the time Otto von Guericke first applied the modern application of electricity, the world did not look back in questioning the importance of its usage. However, after three hundred and fifty years of electricity application, it has been reported in UK that electricity supply industry is responsible for emitting 30% of total CO_2 emissions (DEFRA 2002). Gilland (1995) briefly discusses the impact of CO_2 emissions and explains that CO_2 might have an impact on climate change based on a study done by Greenland and Antarctica. The study shows that temperature fluctuations are highly correlated with fluctuations in atmospheric concentration of CO_2.The study adds that ocean contains large amount of CO_2 and rise in ocean temperature decreases its solubility of CO_2. This causes the ocean to release CO_2 in the environment changing the temperature. On the contrary, Lindzen (1995) concludes that current GSM (general circulation model) models are inadequate to prove that CO_2 can significantly effect the climate change.

The question is not whether CO_2 is responsible for climate change or it is a natural course for earth's climate to change. The model in the thesis deals with electricity and "burning fossil fuels to generate electricity causes over a third of the greenhouse gas emissions, as well as two-thirds of the emissions that cause acid rain, and one-third of the emissions that cause smog" (AWEA, 2007). To show insight how renewable energy reduces CO_2 emission it has been reported by Boyle (1998) that the newest generation of geothermal power plants emits only .2% of CO_2 per MWh compared to the cleanest fossil fuel plant. CO_2 emission is one of the major components that human beings can influence, and reducing it through policies and measures can be a vital step to undertake. The consequence of climate change from a socio-economic perspective is important to depict the role of renewable energy to mitigate CO_2 emission.

The Intergovernmental Panel on Climate Change (IPCC) predicts that global average temperature will increase by 2 to 3 °C during the course of this century. Temperature rise can result loss of rain forests and melting of large ice sheets which may increase water level in the sea causing natural calamities such as flood for low lying areas. Moreover, temperature increase during summer time can cause less rain and drought resulting an acute water scarcity and return of pests and disease. In addition, harsher climatic conditions could trigger new migration patterns from Africa to Southern Europe, develop food shortages as a result of crop failures due to prolong droughts, loss of wildlife and increase in the density of urban areas with unshaded buildings (DTI, 2006). To contradict with the adverse impact of CO_2, biochemist Harrison Brown (1954) suggests that tripling of the atmospheric CO_2 will allow a doubling of world food production because there will be more arable land for cultivation. However, the estimation only considers food production leaving aside any other consequences that may arise.

The mitigation of CO_2 emissions is not the only benefit that can be achieved through renewable energy sources. Russett (1979) analyzes the political economy behind oil and gas net exports. According to his analysis, if Ricardo’s comparative advantage is applied then countries endowed with oil and gas reserves should export and countries without any reserve should import to minimize cost. However, natural reserve exports lead to current account surplus for exporting countries and a deficit for importing countries. He states that the balance is set by an arms trade. According to his analysis Europe, the United States and the former Soviet countries are exporting arms to the Middles East to balance the finance current account deficit. The author adds that there is a vicious cycle that circulates around the oil and arm industry. It is in the interest of importing countries to continue conflicts in oil rich region and support military conflicts and war to maintain the balance of payment. The consequences of war are dreadful causing death to innocent civilians, war crimes and genocides. I believe that there is not yet any econometric method that can calculate and show that exchange of oil and arms trade surpasses the cost it imposes.

The prospect and potentials of renewable energy to reduce CO_2 is not a new concept. A good example is set by Denmark which enjoys 21% of its electricity being supplied by wind turbine. Spain's northern industrial province of Navarra is now producing over 55% of its electricity from wind. Three provinces in Germany generate 30% of its electricity from wind and Germany's total electricity accounts for 8%. Energy produced by wind has increased fifteen times from 1996 to 2007 which clearly shows countries interest in investing on wind power (Papachristou, 2007). In addition, "the learning curve parameter of wind energy is around 15% meaning every doubling of the installed capacity, the price of wind power drops by 15% "(Czisch n.d). In 2001, European Parliament set a target of 22.5% electricity being generated from renewable sources by 2010 for Europe Union member states (Turmes, 2001).

In producing Photovoltaic (PV) Germany is the leader, Japan taking the second in position. Japan wants to install 4800MW of PV by 2010 with the help of rebates, net-metering, low-interest rate loans, and public education programs (Sawin, 2003). The solar cell industry started in the United States and the market was at its peak in the mid 90' (Sawin, 2003). However, US-based manufacturing produced only about 11% of global PV production in 2004 down from a peak of 46% in 1995 (Martinot, n.d).

The numbers clearly show how renewable energy is being widely accepted across the world. Some regions such as Europe accepted it whole heartedly. Strategies such as "Towards a European Strategy for the security of energy supply" are aimed at substituting 20% of conventional fuels by alternative fuels by 2020 (European Commission 2000). Czisch (n.d) in his paper analyzes the prospect of 100% electricity being generated from renewable sources in Europe and its surrounding countries with the help of HVDC overlay grid. The author claims that with the help of HVDC grid the need for backup storage for renewable energy sources decreases, making the cost competitive. Moreover, with such grids exports of electricity will be much easier within the region.

Though the United States is known to be less likely to accept power generated through renewable energy; policies such as renewables portfolio standards (RPS), public benefit funds (PBF) and net metering, subsidies, tax rebates, low interest loan have been applied independently in different states. The policies have positively affected the usage of renewable sources. However, unlike Europe the United States lacks a concrete national policy to address renewable energy usage (Martinot et al. n.d).

The above discussion may give the impression that the usage of renewable energy is without any obstacles and barriers. Whittington, (2002) analyzes the obstacles faced by renewable energy sources. According to the author, the use of wind energy is not a long term solution because the network to support a long term energy supply has to be modified to cope with wind's intermittent nature. He adds that for hydroelectricity the prospect of large scale projects is only confined to developing countries as the best schemes in the developed world have already been explored. Golder et al. (1984) states that limited size of municipal refuse or wood supply increase the supply cost of biofuels. The authors lists conventional fuel prices, high cost technologies and lack of economies of scale as factors creating barriers to supply energy from renewable sources at a competitive cost. The authors add that the value of renewable energy is determined largely by the value of conventional fuel. The reason is in most cases importing countries subsidize oil and gas to support economies to grow. This creates less incentive for the market to move towards an expensive energy source as it increases the cost of production. Subsidies towards conventional energy sources discourage innovation and R&D expenditure on non-conventional sources. He further adds that turning waste to energy plants faces major challenges. The need for CHP plants to capture the energy release for solid waste combustions increases the cost. In addition, the anaerobic digestion plant requires licenses to maintain the standards of odour, storage of wastes and operation. These plants have to be maintained away from the residential area which may cause distribution losses.

Inhaber (1979) calculates the entire fuel or energy cycle between nuclear power and conventional and non conventional energy sources, and states that risk to human health is substantial in the latter source. His results are based on centralize and decentralize energy source systems, and on materials used in the production lines. His analysis supports the usage of nuclear power because the probability of catastrophe is very little and the risk is lower compared with the average risk face in the conventional and non conventional systems. The author adds that nuclear power generation emits zero carbon at a lower cost than energy from renewable sources. He points out that policy makers should not be directed based on end use but should consider the entire system. However, his analysis is based on US data and can not be generalized for all countries. The security issue of using nuclear power plant is avoided from the quantitative analysis.

Table 1 Relationship between renewable energy consumption and the parameter based on literature

Parameter	Relationship with Renewable Energy	Reason/s
European Member Countries	Positive	• Target of 22.5% from renewable sources by 2010
Grid Connection	Positive	• Reduce cost of storage facility • Added advantage for electricity export and import
Oil and Gas Reserve	Negative	• Current account surplus • Cheaper to produce electricity from conventional sources
GDP Per Capita	Not known	• Countries with gas and oil reserve may have GDP Per Capita • EU countries- Policy at play
Hydroelectricity	Negative	• Cheaper • Simpler technology
Nuclear Power generation	Negative	• Low cost • Zero Carbon emission • Economies of scale
Primary energy/ Production/ Consumption	Negative	• Cheaper
Population	Negative	• Density discourages windmill and bio plants

From the discussion above which reflects the prospect, acceptance and obstacles of renewable energy, some hypothetical relationships can be drawn. Table 1 shows the relationship between renewable energy consumption and the explanatory variables that can be abstractly sketched from literature. The arrangement is done based on the impact the variable is expected to have on dependent variable. The variables which may have a positive impact are listed at the beginning. In the middle, the variables whose affect are difficult to anticipate from the literature is stated. Lastly, variables whose impact is expected to be negative are listed.

Chapter 2

2.1 Methodology

The thesis runs an analysis for 76 countries from Asia, Africa, Europe, Middle East, the United States and Latin America. Countries which do not have data for electricity imports and exports, GDP Per Capita, Electricity Distribution losses, Population, Nuclear and Hydro Power, Primary Energy Production and Consumption, European Union Member State, Electricity Installation and Proved Oil and Gas Reserve from 2000 to 2006 are dropped from the analysis. To have precise estimates of the variables the econometric method to pool cross section across time has been applied. For applying pool cross section across time a panel data set which has a cross sectional and a time series dimension has been used.

There are several reasons why Panel Data Set is used to answer the research question. One reason is Panel Data gives a large number of date points as it pools sample at different points in time. For instance, when the thesis runs a regression for 76 countries which includes all the independent variables from 2000 to 2006 the total panel observation is more than 500. The large number of observations allows the analysis to increase degrees of freedom and reduce the collinearity among explanatory variables. In addition, using a simple cross section regression is likely to suffer from an omitted variable problem and it also fails to provide a precise estimate for dynamic coefficient. To avoid the problem of omitted variables, the Panel Data Analysis takes into consideration unobserved factors that are constant over time and factors that vary over time. Within the panel regression the fixed effect model captures the unobserved and time constant factors that may affect the dependent variable. (Woolridge, 2006).

Another reason to apply Panel Data Set is it can avoid the measurement error problem which usually leads to unidentification of a model. Availability of multiple observations for a given country or at a given time allows the thesis to identify an otherwise unidentified model. Moreover, Panel Data generates more accurate predictions for an individual outcome than time series data alone. This is because country behaviour is conditional on certain variables and panel data provides an option of learning the country's behaviour by observing the behaviour of others countries. (Hsio, 2003)

There are couple of limitations of using panel data regression for an analysis. The sample countries for analysis are not randomly chosen. A selectivity bias takes place when countries that do not have data for the independent variables for the specified years are dropped. In addition, in the model the problem of heterogeneity bias occurs as country or time specific components that exist among cross sectional or time series units are ignored. (Hsio, 2003)

2.2 Data Description

The variable REN_CON_{it} describes electric power consumption through geothermal, solar, wind, wood and waste measured in billion kilowatt-hours. In modeling renewable energy usage, REN_CON_{it} is considered as it only takes into account electric power consumption supplied by wind, waste and solar. The Environment Protection Agency (2006) considers hydroelectricity as renewable energy. However, for the purpose of the analysis hydroelectricity is regarded as explanatory variable as its usage depend on topology (Whittington, 2002).

GAS_RES_{it} and $OIL\_RESERVE_{it}$ represent proved reserve of crude oil and natural gas. The former is measured in billion barrels and the latter in trillion cubic feet. Prediction or potentiality of oil or gas reserve is excluded from the analysis. Considering only the proved reserves allows the analysis to avoid over or underestimation of the impact. I assume that oil and gas reserve will negatively impact the usage of electricity of consumption from renewable sources. This is because countries that are endowed with such reserves can generate electricity burning fossil fuels with oil and gas without being effected by market prices or diplomatic relations.

NUC_POW_{it} describes nuclear electric power generation and $HYDRO\_POW_{it}$ describes power consumption through hydroelectricity both are measured in billion kilowatthours. I assume that both the variables negatively affect REN_CON_{it}. The negative relationship is based on the analysis done by Inhaber, (1979) who considers the entire system of process to compare the cost between nuclear energy and other energy sources for United States. He concludes in his analysis that electricity from nuclear power is the cheapest followed by hydro electricity.

$ELEC\_IMP_{it}$ and $ELEC\_EXP_{it}$ describes electricity imports and electricity exports measured in billion kilowatt-hours. It is expected in the result that electricity imports will have a positive impact on REN_CON_{it} for a given country. I assume that importing countries will prefer renewable energy sources as it positively affects their current account. The relationship between REN_CON_{it} and $ELEC\_EXP_{it}$ can be positive or negative. It can be positive for countries that have a comparative advantage in producing electricity from renewable sources. Such countries are in a position to export electricity after meeting domestic demand. On the contrary, negative for countries that can produce electricity cheap from conventional sources and export to other countries. The sign for $ELEC\_EXP_{it}$ will be an interesting variable to analyze.

$L\_PRIM\_ENER\_PRO_{it}$ and $L\_PRIM\_ENER\_PRO_{it}$ are total primary production and consumption in log format measured in quadrillion btu. Both the variables are expected to have a negative sign in the results as I assume that a country which relies on primary energy production or consumption are less reluctant to switch to renewable energy due to cost factor.

$TOTAL\_ELECTRICITY\_INSTAL_{it}$ and $ELEC\_DIS\_LOS_{it}$ describe total electricity capacity and distribution losses of conventional energy sources measured in million kilowatts and billion kilowatt-hours. Both the variables are expected to positively affect REN_CON_{it}. I assume that losses in distributing electricity via existing power system create incentive for a country to increase renewable energy consumption. The relationship is based on a study done by Czishch (N.D) who concludes that installation of grid connections makes supplying electricity produced through renewable sources cheaper. He reasons that with the help of grid installation the need for backup storage decreases making the supply from source to end-point easier and cheaper.

POP_MIL_{it} describes population in millions and $L\_GDP\_PERCAPITA_{it}$ is in log format measured in current dollar prices. Population is expected to have a negative impact on REN_CON_{it} as density of population creates obstacles in building wind mill and bio plants as described by Whittington (2002).The reasons for such obstacles were discussed in the literature review based on the analysis by Golder et al. (1984). $L\_GDP\_PERCAPITA_{it}$ will be an interesting variable to analyze as it may positively or negatively impact renewable energy consumption. The logical reasoning of expecting such confusion is countries having high GDP per capita can afford energy which is more expensive than conventional ones. On the contrary, countries with high GDP per capita may be endowed with oil and gas reserves. As GDP per Capita can have a positive or negative sign it would be interesting to observe how GDP Per Capita responds to different specification described in the model.

DCE is a dummy variable to indicate whether a country is from the European Union. Based on a policy paper of the RES-E Directive (European Parliament and the Council 2001) it can be inferred that European Member states have more policies and laws to promote renewable energy to reach the target of 22.1% by 2010. So, the expected sign of DCE is considered to be positive.

Chapter 3

Model Setup

The model controls for Electricity Imports ($ELEC\_IMP_{it}$) and Exports ($ELEC\_EXP_{it}$); GDP Per Capita ($L\_GDP\_PERCAPITA_{it}$); Electricity Distribution losses ($ELEC\_DIS\_LOS_{it}$); Population (POP_MIL_{it}); Nuclear (NUC_POW_{it}) and Hydro Power ($HYDRO\_POW_{it}$); Primary Energy Production ($L\_PRIM\_ENER\_PRO_{it}$) and Consumption ($L\_PRIM\_ENER\_CON_{it}$); European Union member state (DCE); Electricity Installation ($TOTAL\_ELECTRICITY\_INSTAL_{it}$) and Proved Oil ($OIL\_RESERVE_{it}$); and Gas Reserve ($GAS\_RES_{it}$). The data for the mentioned variables, except GDP Per Capita, are taken from the U.S Energy Information Administration. The statistics for GDP Per Capita is taken from The United Nations website. The data can be categorized as macro variables and others. The macro variables are $ELEC\_IMP_{it}$, $ELEC\_EXP_{it}$ and $L\_GDP\_PERCAPITA_{it}$. For all the specifications the base year is 2000 and the base country is Canada. The quantity for the variables is measured on annual basis.

The subscript *i* represent a particular country and *t* time period. The time period varies from 2000 to 2006 and the country specific notation *i* varies across countries. U_{it} is an idiosyncratic error or time varying error other than the independent variables to indicate unobserved factors that change over time and affect the electricity consumed from renewable energy sources. The time constant variable which does not change over time is denoted by a_i. In the model it is assumed that U_{it} is uncorrelated with all other explanatory variables.

When a fixed effect model is applied, the idiosyncratic error is replaced with composite error. In the fixed effect model, the composite error is $V_{it} = a_i + U_{it}$ and based on a standard OLS assumption it is uncorrelated with all other explanatory variables. Heterogeneity bias may occur even if it is assumed that U_{it} is uncorrelated with all the independent variables but a_i is correlated with independent variables. The heterogeneity bias occurs just because a time-constant variable gets omitted and its impact on estimators is negligible (Woolridge, 2006).

Specification (1) includes all the variables stated above and applies a pooled, fixed effect, cross-section fixed and time period fixed. Inclusion of all the variables may be correlated with each other leading to the problem of multicollinearity. For instance, it might be the case that GDP Per Capita and natural resource reserves can be positively correlated. The reason behind such a statement is countries that have natural resources may earn foreign currency by exporting the resources and can fall into the category of countries with high GDP Per Capita. To avoid the problem of multicollinearity several specification of the model with pooled, fixed effect, cross-section fixed and time period fixed is attempted.

Specification (2) assumes a correlation between $L\_PRIM\_ENER\_PRO_{it}$ and $L\_PRIM\_ENER\_CON_{it}$, and it drops $L\_PRIM\_ENER\_CON_{it}$, GAS_RES_{it}, $OIL\_RESERVE_{it}$, and POP_MIL_{it} from the regression. On the other hand, specification (3) does not control for $L\_PRIM\_ENER\_CON_{it}$, $L\_PRIM\_ENER\_PRO_{it}$, POP_MIL_{it}, assuming a dependency between primary energy and natural reserve. The reason for such an assumption is countries that are endowed with natural reserves would tend to consume and produce more of primary sources to generate energy. Specification (4) drops $L\_GDP\_PERCAPITA_{it}$ and DCE along with the variables stated in (3). The reasoning behind excluding $L\_GDP\_PERCAPITA_{it}$ is similar to that of primary sources. Excluding DCE is done to observe whether the results are robust if member states of the EU are excluded from the regression.

All the specifications are run for 76 countries that may or may not have a positive nuclear power generation. In addition, specification (5) repeats (4) for 29 countries that have a positive nuclear power generation from 2001 and 2006. This is done as many countries have zero nuclear power generation, which causes the problem of non-singular matrixes. Moreover, to have a precise estimate of the specification white diagonal standard error is applied for each specifications described above to check for heteroskedasticity. Results are interpreted based on White diagonal standard errors.

Chapter 4

Results

The thesis runs four specifications to conclude the results. The results are described in Table 02 in detail. For all the specifications pooled and fixed effect is applied, and fixed effect is applied to observe whether the results changes when the impact of cross country differences and trend is excluded from the regression.

Specification (1) includes all the variables and runs a regression with pooled and fixed effect taking into account the time and country differences. $GAS\_RES_{it,}$ becomes significant with a negative sign in pooled and period fixed effect. Controlling for all other variables the magnitude of $GAS\_RES_{it,}$ indicates that a trillion cubic feet increase in proved gas reserve significantly decrease the consumption of electricity generated through renewables by .01 billion kilowatt-hours at pooled and period fixed effect. Otherwise, the effect is zero for both fixed effect and fixed cross section. One reason may be the prevalence of countries without gas reserve in less than 30%. From the data it can be observed that some of the countries without gas reserve are consuming more electricity from renewable sources in relative terms compared to others. When fixed effect and cross country fixed effect are applied, it nullifies the negative impact considering the above mentioned fact into account. The negative impact of $GAS\_RES_{it,}$ supports the thesis argument that a country with gas reserves will be reluctant to use electricity for renewable sources as it is cheaper to use gas to generate electricity. On the contrary, controlling for all other variables $OIL\_RESERVE_{it}$ has a positive sign and the magnitude of the variable shows that a billion barrel of proved oil reserve increase the consumption of electricity generated through renewables by .02 billion kilowatt-hours. The magnitude of $OIL\_RESERVE_{it}$ remains constant even after the time and across country differences are considered and significant at a 10% level. The positive impact of the effect of oil reserve contradicts the thesis assumption which states that high natural resources discourage the usage of renewable energy sources. The contradiction can be due to the fact that top oil rich countries like Canada, Brazil, Mexico and the United States are consuming more electricity from renewable sources than other countries like Colombia or Chile in absolute terms. For instance, in 2006 Canada consumed 11.03 billion kilowatt-hours of electricity from renewable sources having a proved reserve of 178.8 Billion Barrels. On other hand, Chile consumed 1.07 having 0.15 billion barrels of proved oil reserve. This shows that even though countries with low oil reserves are consuming more electricity from renewable sources in relative terms, the consideration of absolute value raises the contradiction.

The magnitude of DCE refer that controlling for all other variables and excluding country differences and trend, a country belonging to the European Union is likely to have 2.89 billion kilowatt-hours less electricity generated from renewables compared to other non-EU countries. The magnitude gets smaller to .81 billion kilowatt-hours when cross country differences are considered and insignificant in time fixed effect and pooled results. The results in fixed cross-country differences and fixed effect contradicts with the literature which discusses the commitment set by the European Union to ensure more than 20% electricity coming from renewable sources. The explanation lies in the data file. The average consumption of EU member states is more than 5.3 billion kilowatt-hours for a given year; where else other countries have less than 4 billion kilowatt-hours. The positive affect of EU member state on renewable energy consumption is not captured in the results due to the dominance of countries with certain characteristics. Besides, the insignificant result when time period is held fixed represent the time constant variable which can be policies and initiative undertaken by the EU member state from 2000 to 2006, thus nullifying the negative effect. The insignificant result in period fixed effect may show that a spurious relationship may exist that negatively effect the renewable energy consumption in EU. For instance, during 2000 and 2006 the EU member states progressed economically and thus increased the demand of electricity from the conventional sources. The economies may not have decreased the consumption of electricity from renewable sources in relative terms, but an absolute decreased may have occurred. This may result the negative impact European member states on renewable energy consumption.

$ELEC\_DIS\_LOS_{it}$ and ELEC_IMP positively affect electricity consumed from renewable sources. The significance level for the variables varies as time and cross country differences are considered. POP_MIL_{it}, $ELEC\_IMP_{it}$ and $ELEC\_DIS\_LOS_{it}$ are significant at 1% only in period fixed and pooled regression, and for $ELEC\_EXP_{it}$ and NUC_POW_{it} the opposite. Controlling for all other variables the magnitude of the $ELEC\_DIS\_LOS_{it}$ shows that a billion kilowatt-hour increase in distribution loss of conventional energy sources increase the consumption of electricity through renewables by .10 billion kilowatt-hours in fixed and cross section fixed, and jumps to .12 billion kilowatt-hours in pooled. For $ELEC\_IMP_{it}$, a billion kilowatt-hour import of electricity increases the dependent variable by .07 billion kilowatt-hours in fixed effect and jumps to .29 billion kilowatt-hours when pooled and time effect is held constant. Otherwise, the magnitude is less than .13 billion kilowatt-hours. One reason for the wide difference between the magnitudes can be in cross section fixed and fixed effect there is an offsetting mechanism that underestimates the results. The sign for $ELEC\_DIS\_LOS_{it}$ and $ELEC\_IMP_{it}$ is positive and supports the assumption that loss in distributing conventional energy sources and high electricity imports encourages substituting conventional means of power generation with renewables.

Interestingly, NUC_POW_{it} and $ELEC\_EXP_{it}$ changes its sign having the same magnitude in fixed effect and period fixed. The explanation for $ELEC\_EXP_{it}$ can be misleading as the sign changes and controlling for all other variables the magnitude jumps from a positive effect of .43 billion kilowatt-hours to a negative insignificant result of .02 billion kilowatt-hours. If cross country differences are considered, the magnitude of the variable shows that electricity exporting countries are more likely to make use of renewable sources. This indicates that exporting countries with the help of renewable energy sources can meet the domestic demand and earn foreign currencies through exports. The same pattern of inconsistency can be seen for NUC_POW_{it} as its effect becomes zero in pooled and time period fixed results. The negative impact of nuclear power of .05 billion kilowatt-hours in fixed and cross country fixed supports the thesis assumption that the presence of nuclear plant decreases the use of other renewable sources. The change in sign can be caused as majority of the countries are with zero nuclear power generation. The specification that runs for countries that have a positive nuclear power generation can show some more insight for the variable.

The magnitude of POP_MIL_{it} in pooled and period fixed indicates that an increase of a million of people reduces the consumption of renewable energy sources by .02 billion kilowatt-hour supporting the argument that population density creates obstacle for renewable energy plants to function and a positive effect of .03 billion kilowatt-hours in fixed and cross section fixed contradicts the thesis assumption. The positive insignificant result can be caused because of a trend in the time series data. From the data it can be observed that in most countries population increased during

2000 to 2006 but the change in renewable energy consumption did not increase vary substantially. As a result, the insignificant positive result shows up when trend is not solely excluded from the regression. For $\mathrm{ELEC\_EXP}_{it}$, $\mathrm{NUC\_POW}_{it}$ and $\mathrm{POP\_MIL}_{it}$ a spurious relationship can be anticipated as the sign changes abruptly when the trend is eliminated from the regression.

$\mathrm{HYDRO\_POW}_{it}$, $\mathrm{L\_PRIM\_ENER\_CON}_{it}$, $\mathrm{L\_PRIM\_ENER\_PRO}_{it}$ and $\mathrm{TOTAL\_ELECTRICITY\_INSTAL}_{it}$ are significant and have the desired sign as expected. The variable $\mathrm{HYDRO\_POW}_{it}$ shows that controlling for all other variables a billion kilowatt-hour increase in electricity generated through hydro power reduces electricity generated through renewable by .08 billion kilowatt-hours when cross country differences and tine effect is held constant. The magnitude becomes .03 billion kilowatt-hours in pooled and timed fixed effect. Variables $\mathrm{L\_PRIM\_ENER\_CON}_{it}$ and $\mathrm{L\_PRIM\_ENER\_PRO}_{it}$ show that controlling for all other variables a percentage increase primary production and consumption of resources reduces the dependent variable by 4.36 and .69 billion kilowatt-hours in fixed effect. The magnitude for both the variables substantially decreases in absolute terms, showing that the effect is much less when the differences in cross countries and time period are held constant.

Controlling for all other variables the magnitude $\mathrm{TOTAL\_ELECTRICITY\_INSTAL}_{it}$ shows that if the installation capacity of electricity increase by 1 million kilowatts, the energy consumption from renewables increase by .08 billion kilowatt-hours and increases to .10 billion kilowatt-hours when cross section differences are held constant. For $\mathrm{L\_GDP\_PERCAPITA}_{it}$ there is a change of more than 1 billion kilowatt-hours if the GDP of a country changes by 1%. The change is negative in fixed effect and positive in cross section fixed. The positive sign only appears in cross section fixed and the reason may be the data file countries with high GDP per capita with high renewable energy consumption are few in numbers. As a majority of the countries have low GDP per capita with low renewable energy consumption, the dominant impact of such countries fails to reflect the positive impact of GDP on the dependent variable. When cross country differences are considered the sign becomes positive and insignificant, capturing the effect of the presence of few countries having a high GDP per capita with high renewable energy consumption.

There is an interesting trend that can be observed from the results. Except for L_GDP_PERCAPITA$_{it}$ the magnitude, sign and significance level is almost same for all the variables in pooled and period fixed effect. One reason may be pooled effect does not takes into consideration the differences that might be caused across time period or across countries and incorporate the trend in the regression. The affect of trend in pooled regression is neutralized by cross country difference if they are moving in the opposite direction and making it similar to period fixed which successfully eliminates the trend.

I tested the robustness of the results and tried out several specifications. Here the results for each specification will not be described in detail; to avoid repetition only the variables which show a consistent effect will be described. Specification (2) is applied to avoid the problem of multicollinearity between natural reserves and GDP per Capita. From the results in Table 2, it can be observed that the negative effect of L_PRIM_ENER_PRO, HYDRO_POW$_{it}$, DCE and the positive effect of ELEC_IMP$_{it}$, TOTAL_ELECTRICITY_INSTAL$_{it}$ remains consistent while significance level varies. The changes in signs are observed in GAS_RES$_{it}$,, ELEC_EXP$_{it}$, L_GDP_PERCAPITA$_{it}$ and NUC_POW$_{it}$. In specification (3), L_PRIM_ENER_PRO$_{it}$, L_PRIM_ENER_CON$_{it}$, L L_PRIM_ENER_CON$_{it}$ and POP_MIL$_{it}$ are not controlled. This specification is modelled assuming that GDP per capita can be positively correlated with primary energy production and consumption. The results show that the negative impact of HYDRO_POW and DCE, and the positive impact of $ELEC\_IMP_{it}$, $TOTAL\_ELECTRICITY\_INSTAL_{it}$, and $OIL\_RESERVE_{it}$ are consistent. In (4) $ELEC\_IMP_{it}$, $TOTAL\_ELECTRICITY\_INSTAL_{it}$ and $HYDRO\_POW_{it}$ show the same consistent impact as in (1), (2) and (3). Specification (5) replicates (4) for countries with more than zero power generation. The results are described in table 3 and to make the comparison easier the results of (4) are described in the table. This has been done to check whether the zeros in the regression for countries without nuclear power are not responsible for the inconsistent behaviour of some variables. The variables that were consistent and inconsistent in (4) are similar in (5). Even after the cross country differences are considered constant, NUC_POW_{it} becomes negative in fixed and cross section fixed, and positive otherwise. Compared to (4) $ELEC\_DIS\_LOS_{it}$ in (5) is the only variable which has a consistent positive impact supporting the argument that loss in distributing conventional energy encourages the usage of renewable sources.

Variables that show consistent behaviour in all the specifications especially in fixed and time period fixed results can be concluded to have a genuine impact of renewable energy consumption. The impact of $TOTAL\_ELECTRICITY\_INSTAL_{it}$, HYDRO_POW, DCE $OIL\_RESERVE_{it}$ and $ELEC\_IMP_{it}$ are consistent in all the specifications. Though the magnitude and significance level varies but the impact in fixed and period fixed are similar. Based on the result, it can be conclude that oil rich and EU countries with hydro power have the opposite impact on renewable energy consumption. Oil rich countries positively affect the consumption of renewable and countries belonging to the EU with a substantial hydro power are reluctant to use other renewable sources. In addition, countries that are importing electricity and are facing the problem of distribution loss are more inclined to consume electricity from renewable sources compared to others. I was successful in showing that the macro-economic variable electricity import consistently affects the renewable energy consumption. With the results it can be statistically argued that imports of electricity encourage countries to consume more of electricity from renewable sources. Thus, renewable energy is a substitute for conventional energy sources for such countries.

One limitation of the results is the predominance of some countries with particular characteristics and the consideration of absolute values. As described above, the data shows that EU countries on average are consuming more electricity from renewable sources. However, the results give a different picture as the relationship fails to show up due to the dominance of other countries with totally different characteristics. To analyze how the result changes when such limitation is considered is not within the scope of the thesis. For future research, it would be interesting to observe how the variable reacts when the predominant characteristics are avoided from the data file.

Conclusion and Policy Recommendations

The thesis modelled electricity consumption from renewable sources and aimed to figure out the variables that have a significant impact. Along with macro-economic variables such as GDP per capita, electricity imports and exports, variables such nuclear or hydro power, distribution loss, installation were considered to explain the consumption pattern. The thesis was successful in showing a consistent behaviour of total electricity installed, electricity imports and hydro power. The mentioned variables supported the literature and showed the expected impact. However, oil reserve and the dummy for European member states were consistent in the specifications but showed the opposite impact. This might be due to lack of balance of country characteristics in the data file. The thesis was successful in coming up with statistical results that explained the consumption pattern of renewable energy sources. The thesis contributed to figure out the casual relationship of renewable energy consumption pattern.

Some long and short term policies based on the results might be useful to promote and ensure efficient renewable energy consumption. As for the long term policies, I recommend a well managed grid system based on the fact electricity from renewable sources can be positively affected by a well managed grid installation system. A well managed grid system ensures continuous supply of electricity for the end users removing the uncertainty of irregular power supply. To promote renewable energy consumption for a country which lacks adequate grid system, the government can encourage private and public-private investment in installing and managing grid system. Secondly, from the data analysis it has been observed that electricity importing countries are more inclined to consume electricity from renewable sources. To take advantage of the market niche foreign investment should be encouraged. Tax exemption and holiday can help the market to grow domestically as well as internationally. Thirdly, the result shows that countries that have a substantial hydro power installation negatively affect the consumption of renewable sources. Countries that are facing a shortage of clean water supply should not encourage the installation of hydropower as it may divert the flow of river and lakes. To make the generation of electricity from renewable sources at reasonable price, small medium enterprises should be brought into the broader picture and encouraged through soft loans. Fourthly, a global investment fund for renewable energy sources can be initiated to encourage and support countries. In addition, a detailed cost-benefit analysis and long term benefits should be considered while choosing the means of energy generation. Lastly, for developing, transition and third world countries choosing energy generation can be a hard choice to make; as the cost factor and short term economic benefits dominate the choice, government should encourage the participation of international community to provide technical support and soft loans.

The mentioned policies above are long term and require time and cooperation among countries. Taking the time lag into consideration, some other policies can help to generate consumption of renewable within a short span of time. Firstly, awareness and information regarding the economic benefits in investing on renewable sources should be distributed to the business community. Moreover, a domestic channel to transfer knowledge and know-how should be developed. In addition, to overcome the technological barriers that increase the opportunity cost of electricity from renewable sources, R&D expenditure should be devoted towards technological development of providing electricity at a minimal cost. Besides, to increase market incentive, subsidization on fuel prices should be removed. Nevertheless, to develop a pool of technicians, vocational training should be encouraged in the field of renewable energy sources. Lastly, commercial banks should encourage initiative of small project plants and entrepreneurs by making credit easier to access.

The policies described above may not be applicable for all countries. Some of the policies are based more towards cooperation among countries and some are more internal. It's not practical to expect countries undertaking all the policies at the same time. I believe a combination of long and short term policies can help a country to set a balance between what is required and what is achievable.

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Tables

Table 2

Variables	Pooled (1)	Fixed Effect (1)	Cross-section fixed (1)	Period fixed (1)	Pooled (2)	Fixed Effect (2)	Cross-section fixed (2)	Period fixed (2)	Pooled (3)	Fixed Effect (3)	Cross-section fixed (3)	Period fixed (3)	Pooled (4)	Fixed Effect (4)	Cross-section fixed (4)	Period fixed (4)
C	0.62 (1.36)	11.61** (3.78)	11.72*** (2.82)	1.24 (1.37)	-1.75 (1.23)	12.89*** (3.82)	-8.81*** (2.57)	-1.020 (1.20)	-0.11*** (0.19)	0.834 (1.49)	-0.72 (1.3)	-0.09 (0.19)	-0.35 (0.32)	-0.184 (1.22)	-1.11 (1.24)	-0.33 (0.32)
L_PRIM_ ENER_CON	- 0.41** (0.16)	-4.36*** (1.13)	-1.57** (0.72)	-0.40** (0.17)									-0.89*** (0.18)	-4.129*** (1.10)	0.41 (0.75)	-0.89*** (0.18)
L_PRIM_ ENER_PRO	0.20*** (0.06)	-0.69*** (0.15)	-0.19** (0.09)	0.21*** (0.06)	-0.08 (0.07)	-0.86*** (0.20)	-0.28** (0.11)	-0.07 (0.07)					0.30*** (0.08)	-0.47*** (.14)	-0.19** (0.10)	0.30*** (0.08)
GAS_RES	-0.01*** (0.00)	0.00 (0.01)	0.00 (0.01)	-0.01*** (0.00)					-0.00*** (0.00)	0.00 (0.01)	0.00 (0.01)	-0.01*** (0.00)				
HYDRO_PO W	-0.03*** (0.01)	-0.08*** (0.03)	-0.10*** (0.03)	-0.03*** (0.01)	-0.03*** (0.01)	-0.08*** (0.03)	-0.10*** (0.03)	0.03*** (0.01)	-0.03*** (0.01)	-0.10** (0.03)	-0.10*** (0.03)	-0.03*** (0.01)	-0.02*** (0.01)	-0.08*** (.02)	-0.10*** (0.03)	-0.02*** (0.01)
L_GDP_ PERCAPITA	-0.07 (0.15)	-1.43** (0.49)	1.14** (0.39)	-0.14 (0.15)	0.18 (0.14)	-1.52** (0.50)	0.99** (0.36)	0.09 (0.14)	-			-	-		-	-
NUC_POW	0.00 (0.01)	-0.05** (0.02)	-0.06** (0.03)	0.00 (0.01)	-0.03*** (0.01)	-0.05** (0.02)	-0.06** (0.02)	0.04*** (0.01)	0.04*** (0.01)	-0.07** (0.03)	-0.06** (0.03)	0.04*** (0.01)	0.04*** (0.01)	-0.054** (.02)	-0.05** (0.02)	0.04*** (0.01)
OIL_RESERV E	0.02* (0.01)	0.02* (0.01)	0.02* (0.01)	0.02* (0.01)	-	-	-	-	0.042** (0.01)	0.02* 0.01	0.02* (0.01)	0.04* (0.02)				
TOTAL_ELE CTRICITY _INSTAL	0.08*** (0.01)	0.08*** (0.02)	0.10*** (0.03)	0.08*** (0.01)	0.07*** (0.01)	0.090*** (0.02)	0.10*** (0.03)	0.07*** (0.01)	0.07*** (0.01)	0.09*** (0.02)	0.10*** (0.03)	0.06*** (0.01)	0.07*** (0.01)	0.07*** (0.01)	0.090*** (.03)	.06*** (0.01)

Variables	Pooled (1)	Fixed Effect (1)	Cross-section fixed (1)	Period fixed (2)	Pooled (2)	Fixed Effect (2)	Cross-section fixed (2)	Period fixed (2)	Pooled (3)	Fixed Effect (3)	Cross-section fixed (3)	Period fixed (3)	Pooled (4)	Fixed Effect (4)	Cross-section fixed (4)	Period fixed (4)
POP_MIL	-0.02*** (0.00)	0.02 (0.02)	0.03 (0.02)	-0.02*** (0.00)												
ELEC_IMP	0.29*** (0.04)	0.07 (0.09)	0.12 (0.09)	0.29*** (0.04)	0.38*** (0.05)	0.120 (0.08)	0.15* (0.08)	.1493* (0.083)	0.38*** (0.05)	0.00 (0.01)	0.00 (0.01)	-0.01*** (0.00)	0.40*** (0.04)	0.40*** (0.04)	0.096 (.08)	0.40*** (0.04)
ELEC_ DIS_LOS	0.12*** (0.02)	0.10 (0.07)	0.10 (0.08)	0.11*** (0.02)	-0.02* (0.01)	0.080 (0.06)	0.09 (0.06)	-0.02* (0.01)	-0.01 (0.01)	0.11 (.07)	0.11 (.07)	-0.01 (0.01)	-0.02 (0.01)	-0.02 (0.01)	0.092 (.06)	-0.02 (0.01)
ELEC_EXP	-0.02 (0.05)	0.43*** (0.11)	0.45*** (0.12)	-0.02 (0.05)	-0.14** (0.06)	0.424*** (0.12)	0.43*** (0.12)	-0.14** (0.06)	-0.13** (0.06)	0.11 (0.07)	0.47*** (0.11)	-0.13** (0.06)	-0.14** (0.05)	-.14 (.05)	0.411*** (.11)	-0.15 (0.05)
DCE	-2.89*** (0.73)	-0.36 (0.55)	-0.81*** (0.25)	-0.28 (0.54)	-2.07*** (0.54)	-0.85 (0.56)	-0.62** (0.22)	-0.73 0.56	-0.78 (0.55)	-1.14*** (0.29)	-0.13 (.16)	-0.77 (0.55)				
N=532	R^2=.90	R^2=0.98	R^2=0.98	R^2=0.90	R^2=0.87	R^2=0.985	R^2=0.981	R^2=0.8	R^2=0.88	R^2=0.98	R^2=0.98	R^2=0.8	R^2=0.9	R^2=0.87	R^2=0.98	R^2=0.87

Table 3

Variables	Pooled (4)	Fixed Effect (4)	Cross- section fixed (4)	Period fixed (4)	Pooled (5)	Fixed (5)	Fixed Effect (5)	Cross- section fixed (5)	Period fixed (5)
C	-0.35 (0.32)	-0.184 (1.22)	-1.11 (1.24)	-0.33 (0.32)	2.97*** (1.12)	22.16** (7.14)	-4.42 (5.39)	-4.42 (5.39)	-2.77** (0.93)
L_PRIM_ ENER_CON	-0.89*** (0.18)	-4.129*** (1.10)	0.41 (0.75)	-0.89*** (0.18)	-0.37 (1.02)	-13.40** (6.64)	4.78 (4.74)	4.78 (4.74)	-0.50 (0.84)
L_PRIM_ ENER_PRO	0.30*** (0.08)	-0.47*** (.14)	-0.19** (0.10)	0.30*** (0.08)	-0.07 (0.80)	-4.99* (2.82)	-9.71** (3.35)	-9.71** (3.35)	0.07 (0.70)
GAS_RES									
HYDRO_PO W	-0.02*** (0.01)	-0.08*** (.02)	-0.10*** (0.03)	-0.02*** (0.01)	-0.03 (0.01)	-0.04 (0.03)	-0.07** (0.02)	-0.07** (0.02)	-0.03*** (0.01)
L_GDP_ PERCAPITA									
NUC_POW	0.04*** (0.01)	-0.054** (.02)	-0.05** (0.02)	0.04*** (0.01)	0.04*** (0.01)	-0.03 (0.03)	-0.01 (0.03)	-0.01 (0.03)	0.04*** (0.01)
OIL_RESERV E									
TOTAL_ ELECTRICIT Y _INSTAL	0.07*** (0.01)	0.090*** (.03))	0.10*** (0.03)	0.06*** (0.01)	0.06*** (0.01	.07** (0.03)	0.09*** (0.02)	0.09*** (0.02)	0.06*** (0.01)
POP_MIL									
ELEC_IMP	0.40*** (0.04)	0.096 (.08)	0.19** (0.08)	0.40*** (0.04)	0.00 (0.01)	0.56*** (0.05)	0.14* (0.08)	0.01 (0.11)	0.56*** (0.04)
ELEC_ DIS_LOS	-0.02 (0.01)	0.092 (.06)	0.08*** (0.06)	-0.02 (0.01)	-0.16*** (0.05)	0.00 (0.01)	0.08 (0.05)	0.11* (0.06)	0.00 (0.02)
ELEC_EXP	-0.14** (0.05)	0.411*** (.11)	0.45*** (0.12)	-0.15** (0.05)		-0.16*** (0.05)	0.51*** (0.06)	0.44*** (0.13)	-0.17*** (0.03)
DCE	-0.35 (0.32)	-0.184 (1.22)	-1.11 (1.24)	-0.33 (0.32)					-
N=532	N=532 R^2=0.90	N=532 R^2=0.98	N=532 R^2=0.98	N=532 R^2=0.87	N=203 R^2=0.90	N=203 R^2=0.98	N=203 R^2=0.98	N=203 R^2=0.98	N=203 R^2=0.90