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WEALTH AND RENEWABLE ENERGY

A Statistical Analysis across European Countries

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Abstract

With national governments increasingly under pressure to meet climate change actions goals and ensure secure supplies of energy for their states, the issue of renewable energy has never been more topical than it is today. Switching to these technologies for supplies of energy instead of fossil fuels is an essential means of guaranteeing a sustainable future and providing energy resources for populations. Despite rising concerns of CO_2 levels across the globe, the renewable energy sector still faces fundamental challenges in how to infiltrate the energy market more deeply. Perhaps most significant of these challenges is the economic conundrum that is presented by a switch to renewable energy forms. As many of these technologies are still in their infancy, it has not been possible to produce the economies of scale which have been amassed by fossil fuel industries and thus are often more expensive to consume. This thesis will therefore investigate whether there is a relationship between the economic wealth of a country and how much renewable energy is consumed in that country, with examples from European nations. In the field of renewables, Europe is arguably the continent which has progressed the furthest out of any in the world and has shown great strides in innovation and consumption of these sources. Using statistical analysis, wealth and other factors will be tested in determining what drives renewable energy consumption in the European context.

List of Abbreviations

CO_2 - Carbon Dioxide

GDP – Gross Domestic Product

EKC – Environmental Kuznets Curve

EU – European Union

kWh – Kilowatt-Hour

NAFTA – North American Free Trade Agreement

RES – Renewable Energy Sources

Content

1. Introduction

In the 21st century, it is arguable that the most severe challenge facing the globe is that of climate change (Feulner, 2015, p. 5). Human interference with the natural climate system has prompted widespread fears of heightening temperatures which can have significant ramifications for mankind. Data collected from 2016 show that the earth's surface temperatures were the highest since records began in 1880, and this was the third year in a row to break this record (NASA, 2017). It is generally accepted amongst most people that the root cause of this increased human activities - namely rising carbon dioxide (CO_2) levels. Natural resources such as fossil fuels have helped contribute to increasing industrialisation and fuelled this process across the developed and increasingly the developing world. On the one hand, these energy forms have been pivotal for this process and, in doing so, have assisted towards raising living standards and eradicating poverty. Conversely however, the burning of fossil fuels for energy resources has already caused considerable damage to the natural environment through CO_2 emissions and their damage to the world's atmosphere may be irreversible.

CO_2 emissions that are released into the world's atmosphere by burning fossil fuels is argued to be a major contributor to heating temperatures across the globe – a process commonly referred to as global warming. This global warming is predicted to lead to rising sea levels, extreme flooding and weather events as well as significant health issues (Pacesila et. Al, 2016, p. 157). At the current point in time, CO_2 levels in the atmosphere are at the highest in human history and the trajectory is expected to worsen in the future.

1.1. Renewable Energy

One response to the global warming crisis has been the mounting pressure on governments to pursue policies which support the use of renewable energy sources (RES). The International Energy Agency (2017) define renewable energy as "energy derived from natural processes that are replenished at a faster rate than they are consumed. Solar, wind, geothermal, hydro and forms of biomass are common sources of renewable energy."

1.1.1. Renewables and Climate Change

Substituting fossil fuel based sources with renewable energy is argued to be one of the major mitigation attempts for the climate change phenomenon (Verbruggen et. Al, 2010, p. 851). Compared to fossil fuels, there are typically either no or drastically fewer emissions from carbon dioxide for renewable energy systems. There is therefore a clear environmental advantage of using renewables for national governments to diminish the threat of global meeting and meet their respective climate action goals.

1.1.2. Renewables and Energy Security

Further than the threat of climate change that comes with fossil fuel use, renewables can also provide an advantage in providing security of energy resources for national governments. If governments are to encourage the growth of renewable energy it will help the future security of energy supply, and reduce the risk of national economies being subjected to a situation where there is not sufficient access to energy (Pacesila, et. Al, 2016, p. 157). It can be advantageous for national governments to produce renewable energy in order to secure this supply. Through domestic production of renewable energy, states can help avoid energy deficiencies when exogenous shocks to the global energy market occur. In the near future, oil and gas will increasingly come from sources at great distances from many Western countries with possible geopolitical risks, and renewable energy can therefore satisfy many of the major energy challenges which economies are confronted with (Menegaki, 2010, p. 257). Currently, much of the concentration of global energy sources is situated in the OPEC countries or Russia. Events such as 1973 and 1979 oil crises have exhibited the significance of guaranteeing energy supply for national governments.

1.2. At the European Level

Nowhere in the world has the transition towards renewable energy been embraced quite like in Europe. The emphasis of endorsing renewable energy technologies is now visible at the forefront of the EU's energy policy. Despite concerns about installation costs, renewables are considered a key feature in this policy as they could cover a large portion of the EU's energy policy needs whilst maintaining its leadership in innovation globally (Pacesila et. Al, 2017, p. 157).

Numerous directives have been enacted at the European level which highlight this emphasis of the production and consumption of renewables. Such examples include 2001/77/EC which promoted renewable electricity production, 2002/91/EC which sought to improve the energy performance of buildings and 2003/30/EC which promoted the use of biofuels.

Perhaps the most significant directive for renewables was 2009/28/EC however, which mandated a reduction of carbon dioxide emissions of 20% of 1990 levels (Menegaki, 2013, p. 363). This directive went even further in mandating that 20% of EU energy was to be sourced from renewables and a 20% increase in energy efficiency from 1990 levels by the year 2020. All of these targets came together under what was the 2020 Climate and Energy Package. In addition to this, the directive establishes binding renewable targets for member states to meet by 2020 based on their original starting point of the sector as well as general potential of these technologies in respective countries. These range at the lowest level from a 10% consumption target for Malta to the highest of a 49% target for Sweden. How exactly these targets are to be achieved, however, are left to the decision-making of member states (European Commission, 2017).

1.3. Challenges for Renewables

Given that renewable energy technologies can provide valuable energy security for governments as well as help towards addressing climate goals, as well as EU's efforts to encourage the sector, it may be natural to ask why renewable sources do not have a deeper market penetration than the aspired 20% target by 2020. The fact remains that there are still some fundamental challenges facing the renewables sector in order to become more competitive.

One of the issues is that the sector is currently dealing with is the technological capacity of renewable industries. It goes without saying that solar power cannot operate without sunshine and wind power cannot function without there being wind (Heal, 2010, pp. 143-144). Issues with efficiency have also been cited as potential barriers to the renewables sector as technical difficulties remain in attempting to extract all the potential energy from sustainable sources i.e. solar, wind. As a consequence, the concern is that renewable energy will not be able to fulfil all the world's energy needs at once. This issue of capacity is one which must be amended if renewables are to penetrate the market more deeply.

More crucially however is the economic conundrum that renewable energy poses to its producers. Most renewables share certain economic characteristics such as large fixed costs (Heal, 2010, p. 140). As renewables industries are relatively new in comparison to the more traditional energy companies, they have typically not been able to amass the same economies of scale and subsequently demand higher costs of consumption. It stands to reason therefore that if consumers do wish to use energy from renewable sources, it is likely they must pay higher prices to do so.

1.4. Aim and Research Questions

With the imperative placed on renewables to become the world's dominant energy resource and ensure a sustainable future, it is fundamental to understand what drives this usage of these technologies in Europe. This thesis will attempt to understand the conditions which encourage renewable energy technologies across the continent. The potential availability to produce many renewable energy sources vary greatly across different European countries. Energy from wind, solar and biomass depend on a variety of factors in different locations: variations such as resource characteristics (soil), geographical (land use & cover), techno-economic (scale, labour cost) and national policies/institutional structures (de Vries et. Al, 2007, p. 2590). As such, there a multitude of factors which could be seen to aid the sector.

Using examples across thirty countries in Europe, the central aim of this thesis is to investigate if there is a correlation between the relative wealth of a country and how much renewable energy is used in that country. Additionally, it will test whether the population density of a country could also be an equally important factor in determining renewable energy usage.

The thirty countries which have been chosen to take data from for this analysis are the EU-28 countries, as well as Iceland and Norway. Although Iceland and Norway are not fully participating members of the EU, they both enjoy membership of the European Economic Area and thus have somewhat compatible institutional and economic structures to the EU-28 countries.

In performing this analysis across European countries, this thesis can be valuable in underlining some of the conditions which are necessary for renewable energy sources to thrive. A report from the European Commission (2015, p. 8) recently proclaimed that Europe had achieved global leadership in renewable energy technologies via its ambitious policies and pioneering businesses. If this status of Europe as a leader of the sector is accurate, this analysis can be useful to other regions wishing to emulate the success of the European renewables industry. This is because it will attempt to capture what exactly is fostering the expansion of renewables, and might provide ideas for countries of how to develop their own industries accordingly.

The central questions that this thesis will be addressing are as follows:

Does the economic wealth of a country determine how much renewable energy is used in European countries? What other factors could explain renewable energy usage across the continent?

1.5. Research Hypotheses

Before undertaking this analysis, it should be noted that there are two fundamental hypothesis which are fuelling this analysis. These are as follows:

> *H1: The higher the GDP per capita of a country, the more renewable energy that country will use.*
>
> *H2: The lower the population density of a country, the more renewable energy that country will use.*

2. Thesis Outline

The structure of this study will be separated into a number of different categories. The first section will discuss and analyse the previous literature surrounding this topic. Though there may not exist an abundance of academic material dedicated to the wealth-renewables relationship, there are a few studies which may indicate methods that an analysis such as this one can be conducted. The next section will be dedicated to some of the theoretical constructs that could be applied to this relationship. Whilst these theories may not directly address renewable energies, they are useful in understanding the context in which they are situated. Following this, the next chapter will consist of a methodological discussion of how the study will take place, why the particular method of analysis was chosen and potential influencing factors which have not been included in the investigation. The data and analysis will then be presented followed by some discussion of the findings. Finally, a concluding chapter will be presented discussing the implications of the analysis and what it reveals about renewable energy consumption in Europe.

3. Previous Literature

Although the relationship between wealth and renewables might not be one of the most documented in academic circles, it is one which has begun to be explored increasingly in recent years with examples from both developed and developing countries across the globe. In previous literature, the relationship between these two variables has most commonly been investigated largely with the use of panel data, as will be discussed below.

One of the first and most prominent studies to be conducted on this nexus was from Perry Sadorsky (2009a). This study modelled the relationship between real GDP per capita, renewable energy consumption per capita, CO_2 emissions per capita, and oil prices in the G7 countries. Sadorsky produced a model using panel data collected from 1980-2005 from these countries. All four of these variables were transformed into natural logarithms. Using panel cointegration techniques, the long-term elasticities provide support that both real GDP per capita and CO_2 per capita are the main drivers amongst renewable energy consumption. These elasticities suggest that a 1% increase in real per capital GDP equates to a per capita renewable energy increase of between 7.247% and 8.440%. Oil prices however, for both FMOLS and DOLS, have a negative effect on renewable energy consumption and therefore real oil prices do not appear to have a strong affect in this instance.

In addition to his study on the renewable energy-growth nexus for G7 countries, Sadorsky (2009b) also undertakes a study with evidence from 18 emerging economies based on activities surrounding rapid growth and industrialisation. Like his study on the G7 countries, here he utilises panel data rather than individual time series to account for the difference in countries and uses statistics from 1994 to 2003. The samples are separated into two models – one consisting of all 18 countries and the second utilising a subsample of 10 countries. The first sample tests just two variables – per capita energy consumption and per capita income – and reveals that for every increase in real GDP of 1% suggests an increase in per capita renewable energy consumption of 3.39% to 3.45%. The second sample includes these two variables for ten countries with the addition of a variable for electricity prices as a proxy for renewable energy cost. This model constructs a very similar correlation between income per capita and renewable energy per capita, as well as similar sign significance with the first model. However, the FMOLS result shows a negative elasticity of demand at -0.70, meaning that the higher electricity prices are the lower amount of renewable energy is consumed.

A further study linked to this relationship comes from Apergis & Payne (2010), who studied examples from 13 Eurasian countries from 1992-2007. A panel data framework is used to capture the relationship between income and renewable energy usage in this. Unlike these studies however, inclusion of measures for capital and labour have been included to avoid omitted variable bias. There is a slight alteration with this model in that it appears that GDP is the dependent variable yet it can still prove to be of some value. The variables included in the analysis are the natural logarithm for GDP, gross fixed capital formation, labour force and renewable energy consumption. One potential flaw with this design is the variable for renewable energy consumption. This variable is taken by a net consumption, and therefore may not account for different factors such as population size or total energy demand. Nevertheless, the results are significant and suggest that a 1% increase in renewable energy consumption increases real GDP by 0.195% in these countries. Two models are conducted, one with results including Russia and one without Russia, to account for the country's significant size, yet the findings do not drastically change from model to model.

In a rather different vein, Menyah and Wolde-Rufael (2010) posit CO_2 emissions as the main focus of attention in analysing a selection of developing and developed countries from 1984-2007. Here they model the causal relationship between emissions (millions of metric tons), nuclear energy (net consumption), renewable energy (net consumption in kWh) and economic growth (real GDP). Despite they central focus being CO_2 emissions, there are some noteworthy deductions made for what determines renewable energy usage. The results reveal that both emissions and nuclear energy consumption have a statistically significant negative effect on renewable energy consumption whilst economic growth has a positive and statistically significant impact.

The relationship between renewable energy consumption and economic growth is one which has also been observed by Cetin (2016). Again using panel cointegration, the study investigates this nexus for what he describes as the emerging (E7) countries: Brazil, China, India, Indonesia, Mexico, Russia and Turkey. The panel data statistics for these countries span from the period 1992-2012. Cetin has used natural logarithms for all four of the variables in the study: real GDP, renewable energy consumption, real gross fixed capital formation and labor force. Ultimately, the long-run elasticities reveal a positive correlation amongst renewable energy usage and real GDP. The DOLS estimates indicate that a 1% increase in renewable energy consumption equates to a rise in real GDP of 0.068% whereas the FMOLS suggests a 1% increase in renewables consumption leads to a 0.067% raise in GDP. Both of these results suggest renewable energy consumption has a positive impact on GDP. What is furthermore noteworthy about Cetin's study is he continues to break down the results by the specific countries. Interestingly, when looking at the individual country level, only 5 of the 7 countries reported a positive relationship between the two variables. The examples of China and Indonesia highlighted a negative relationship within this nexus, and Cetin sites the particular characteristics of these two countries. This is important to note as often the conditions – be they geographic, economic, political or other – of a country can often alter the overall results.

Akin to Menyah and Wolde-Rufael, Aydin (2013) centres an investigation with the dependent variable as levels of CO_2 emissions. This study focuses on the G-7 countries in a timespan ranging from 1991-2009.[2] In order to explain what causes CO_2 emissions in these countries, Aydin uses renewable energy consumption (% share of renewables in primary consumption), population density (people per square km of land area) and economic growth (GDP in US dollars). What is particularly noteworthy about this study is the inclusion of this second explanatory variable, population density. This variable has largely been neglected in much of the previous literature. Though this study is essentially explaining what drives rising CO_2 rather than renewable energy consumption, it is an important consideration that can be very influential. Ultimately, the random effect model suggests that a one unit increase in renewable energy consumption leads to a decrease of 2.14% in CO_2 emissions whilst a one category increase in population density leads to a decrease of 23.94% in CO_2 emissions. It should be noted however that it is likely that renewable energy consumption levels will change more regularly than population density, so this finding should be treated with some caution.

By far the study which comes closest to what this thesis aims to achieve comes from Menegaki (2010). In a study spanning from 1997 to 2007, she looks at the impact of renewable energy usage as percentage of total consumption on the growth rates in the EU27 countries - before Croatia joined the EU. Other variables used in the random effect model are final energy consumption, greenhouse emissions and employment rate. A noticeable variable here which has been included is employment. Unlike many of the other papers, this study makes attempts to account for social factors which might influence the usage of renewables and avoid omitted variable bias. Ultimately, the results exhibit that a 1% increase in renewable energy usage results in a 4.4% increase in GDP per capita in PPP. This was found to be statistically significant at the 5% level. Interestingly, greenhouse gas emissions cause a bigger effect on GDP with a 1% increase leading to a 6% increase in PPP. Whilst Menegaki's study does come close to the heart of what this thesis is attempting to understand, this thesis will go further in attempting to explain alternative factors which can influence renewable energy usage, as will be discussed in the methodology chapter.

4. Theoretical Framework

There are a number of theoretical frameworks which attempt to explain the impact that wealth, or more specifically income, can have on environmental degradation. The focus of these theories does not evolve around renewable energy necessarily, but rather the environment in a wider context. Regardless of this factor they can help provide useful constructs to understand the debate in which renewables are situated within. It is important to note also that these theories will not be actively tested for in this analysis, as this thesis is not deductive in nature.

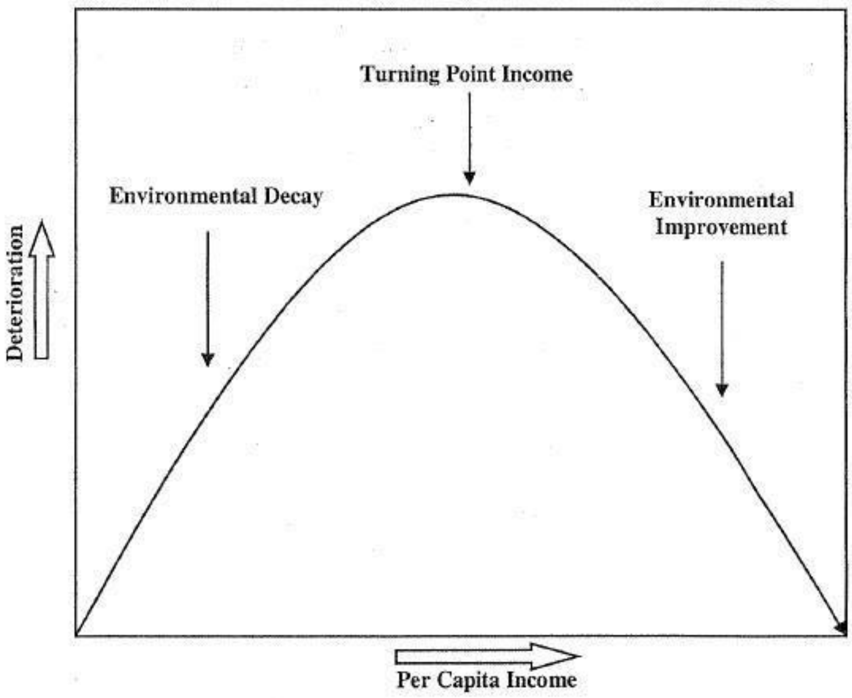
4.1. The Environmental Kuznets Curve

4.1.1. The Environmental Kuznets Curve

Undoubtedly one of the seminal theories surrounding the wealth-environment nexus is the Environmental Kuznets Curve (EKC). This curve is a hypothesised relationship between increasing incomes and environmental degradation. Essentially what this theory postulates is that, as countries experience rapid growth economically, the amount of polluting toxins in the atmosphere rises sharply due to increasing industrialisation. For this industrialisation to take place an increasing level of energy is consumed which emits more pollutants into the environment. Over time, however, the scale of these toxins in the atmosphere is reduced due to the technology improvements afforded from increased wealth as well as higher demands for environmental protection from citizens.

This theory originally emanated from Simon Kuznets' work in the 1950s. This curve exhibits the distribution of income is more unequal in the early stage of economic growth but as this growth continues a greater equality is restored (Dinda, 2004, p. 433). Therefore, over time the wealth experienced from growth trickles down further into the economy and more economic equality is restored. The trend takes the form of an inverted U-shape between income per capita and income inequality on a graph. In the 1990's, many academics further extended this hypothesis to the relationship between income and environmental degradation which would come to be known as the EKC. Figure 1 as shown below provides a visual representation of this inverted U-shape, and how EKC theory expects environmental degradation to react at different levels of increasing levels of wealth.

Figure 1 - Environmental Kuznets Curve



Source: Intelligent Economist (2017)

There were threee key moments aided the development of the EKC: Grossman and Krueger's 1991 working paper on NAFTA, the World Bank's 1992 Development Report and Panayotou's 1993 working paper (Dinda, 2004, p. 434).

Looking at the impact that the founding of NAFTA would have on the environment, Grossman and Krueger were amongst the first to coin the EKC. Responding to calls that this free trade agreement would lead to the worsening of the environment, they found that when a country experiences per capita incomes of $4,000 to $5,000 the air quality in these countries begins to improve and contain less harmful contaminants. The justification for this argument was that as societies become wealthier its citizens realise and intensify their arguments for a healthier environment, and pressurise government to impose more environmental defence (Grossman and Krueger, 1991).

The World Bank Development Report in 1992 further publicised the notion that increasing wealth and eradicating poverty could alleviate environmental degradation. This report emphasised economic activity was only a small part of what drove environmental deprivation.

It highlighted that as incomes rise, the demands for protection of the environment will increase and so too will the resources available for protection. When societies no longer needed to worry about their basic survival needs, it would be possible to invest in cleaner technologies to bring about conservational improvements (World Bank, 1992, pp. 39-41).

In another working paper, Theodore Panayotou (1997) took examples from developed and developing countries and arrived at very similar conclusions. Crucially however, Panayotou highlighted that rising income does not automatically lead to improvements in the environment. Instead, it was argued that these improvements would depend on effective policies and institutions. Like the previous paper and report, growth provided the conditions for conservational improvement by raising the demand and improving the resources available for it.

From this perspective, it is rather easy to see the appeal of the EKC for policymakers during this period. It essentially posited that a "business as usual" approach would be sufficient in preventing environmental degradation and help towards a sustainable future (Stern et. Al, 2004, p. 1419). This approach centred on income raising demands for a cleaner world, providing more resources available for policies and institutions to enact environmentally protectionist policies and more resources for technological development for cleaner energy solutions.

Following the logic from this theory, it is natural to assume that increases in the wealth of a country would therefore lead to increases in renewable energy usage. This is because, with increased wealth, the desires for environmental protection such as air quality would be higher than in poorer countries and this demand would likely lead to increasingly pressure for environmental reform. Renewables would provide a solution to problems such CO_2 emissions emitted by carbon intensive energy systems. One might therefore assume that wealth and growth could have this encouraging effect on usage of renewables.

4.1.2. The "Free Trade" Argument

A school of thought which has criticised the EKC theory has looked particularly at the effect that global trade has on the environment. This theory emphasises that globalisation and free trade have negative effects on environmental standards. It is argued by proponents of this theory that competition for international investment has caused some countries to lower environmental regulations so as to attract foreign capital and retain domestic investments

(Medalla, 2005, p. 5). Consequently, globalisation has encouraged a "race to the bottom" in environmental standards within predominantly poorer countries that need to attract foreign investment for economic growth.

Where the EKC argues that the number of pollutants increases and then decreases, this hypothesis stipulates that due to the difference in environmental standards heavy industries are being exported from developed to developing countries at a faster rate (Cole, 2004, p. 73). The amount of pollutants in the air therefore is not seen to decrease like the EKC suggests, but are rather relocated to different areas. This theory subsequently agrees with the EKC that as growth is experienced the number of pollutants in the atmosphere increases also.

In the context of renewables, this school of thought might ultimately suggest that increases in wealth would not equate to increases in renewable energy usage. As countries seek to expand their economies rapidly, access to energy becomes an immediate concern and so more tried and tested sources are likely to be deployed as oppose to renewables, which can take time to develop and are still arguably in their infancy.

4.1.3. New Toxins

Further criticism directed at the EKC has drawn attention to the fact that only some forms of pollutants are used to model the relationship between income per capita and environmental degradation. Whereas most of the early studies of the EKC were focused particularly in regards to levels of sulphur dioxide, it has been argued that the EKC does not account for all pollutants in the atmosphere. Consequently, even if some pollutants are reduced as income is increased, it is thought that industrial society always encourages new sources of pollution to appear and so the EKC is fundamentally flawed (Dasgupta et. Al, 2002, p. 148). Overall pollution, it is argued, increases with both income per capita and output, raising the question of whether the general turning point of the EKC exists across pollutants (Webber and Allan, 2004, p. 200). In fact, one noticeable pollutant which has not been very accounted for in EKC literature is carbon dioxide. Beck and Joshi (2015, p. 34) argue that CO2 suffers from an externality problem in that it does not immediately inflict the same kind of health and environmental problems as sulphur dioxide might but does have a significant impact as a greenhouse gas.

4.2. Economic Growth-Energy Consumption Nexus

Further to the relationship between income and the environment, it is also important to consider the specific impact that energy consumption and growth can have on one another. The idea of this causal relationship was first explored by Kraft and Kraft in 1978 based on evidence from the US, and the direction of this growth-consumption nexus can have significant implications for policy makers (Ozturk, 2010, p. 340). Regarding this relationship, there are four main hypotheses: *Growth*, *Feedback*, *Neutrality* and *Conservation*. These hypotheses are all deduced from employing Granger causality tests. The hypotheses do not relate to renewable energy specifically, yet they can be useful analytical tools to help categorise what drives energy consumption in general.

4.2.1. Economic Growth-Energy Hypotheses

The *conservation* hypothesis suggests uni-directional causality running from economic growth to energy consumption. Essentially, this view proposes that it is the increase in the economic growth of a country that will ultimately determine an increase in its energy consumption. To the proponents of this hypothesis, efforts from governments to conserve energy in policies will not necessarily lead to a decrease in GDP but may even lead to an increase (Menegaki & Tugco, 2016, p. 78). The conservation hypothesis is supported if an increase in GDP causes an increase in energy consumption (Ozturk, 2010, p. 340).

The *growth* hypothesis, contrary to the *conservation* hypothesis, suggests uni-directional causality running from energy consumption to economic growth. Here, increases in energy consumption lead to increases in economic growth whereas decreases lead to a decrease in economic growth (Menegaki & Tugco, 2016, p. 78). Restrictions on the use of energy or conservational-style policies will hereby hinder economic growth. Energy consumption plays a critical role in supporting growth both directly and indirectly as a complement to labour and capital (Ozturk, 2010, p. 340). Energy is therefore viewed as a limiting factor to economic growth and lack of energy resources or shocks to the energy supply will have a negative impact on the economy.

The *feedback* hypothesis suggests bidirectional causality running between energy consumption and economic growth and vice-versa. Ultimately, these two components are viewed to be inextricably linked with one another. An economy can therefore experience a rise in both GDP and energy consumption if just one is promoted by a government or market. Yet, if one of these is restricted then both may eventually be hindered (Menegaki & Tugco, 2016, p. 79). Like the growth hypothesis therefore, this hypothesis propels that any excessive attempts to reduce energy consumption can contribute to an economic downfall.

Finally, the *neutrality* hypothesis indicates that there is no causal relationship at all between energy consumption and economic growth. This means that neither expansionist nor restrictive energy policies will impact GDP as they are not correlated. Instead, growth is determined to be driven by other factors (Menegaki & Tugco, 2016, p. 79).

4.2.2. Economic Growth-Energy Literature

Since Kraft and Kraft's original 1978 paper, a breadth of literature has emerged on the growth-energy nexus. In a recent study conducted, Omri (2014) collected 48 articles which have investigated this relationship to find which of these hypotheses was proved the most often. He found that 23% supported the conservation hypothesis, 29% supported the growth hypothesis, 27% supported the feedback hypothesis and 21% for the neutrality hypothesis.

In the same paper, Omri also surveyed examples relating to the renewable energy-growth nexus. 40% of the literature here was in support of the conservation hypothesis, 20% was in favour of the growth hypothesis and 40% in favour of the neutrality hypothesis. It is worth noting however that this survey was based on a total of only 5 papers, all of which related to studies conducted within the US.

4.3. Industrial Ecology

Advancements in technology also provide an ample example of a factor which could also improve environmental protection. Technological advancements have the possibility to play a significant role in climate change abatement, environmental protection and the development of renewable energy technologies. Technical advancements can help realise these improvements through more efficient energy solutions and innovative methods.

In the early 1990's, an approach known as Industrial Ecology was established with the aim of improving the environmental efficiency and technological development for industrial systems (Mulder, 2007, p. 256). The central aim behind this research movement is the notion of a sustainable path for industry without the usual environmental degradation its activities can impose. Though industrial ecology is composed of a number of disciplines, one of the crucial components of the research field is that of technological change. At the heart of this idea of technological development is ecotechnology. This is defined as the use of technological methods designed for management of the environment in a way to minimize the harm. Ecotechnology, it is argued by Gianetti et. Al (2004, p. 363), should be achieved through promoting links between firms to improve environmental efficiency yet not from country to country transfer of technologies as this process not take into account the economic and geographical individualities of each country. Opposing this attitude however is the idea of *technology transfer* in aiding the abatement of climate change. As the name suggests, technology transfer implies the sharing of either expertise or knowledge between countries and companies. The Intergovernmental Panel on Climate Change report on *methodological and technological issues in technology transfer* defined technology transfer as a process "covering the flows of know-how, experience and equipment, for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, NGO's and research institutions" (Karakosta et. Al, 2010, p. 1547).

Technical expertise can have a profound impact on environment as it can provide innovative methods to either have more efficient use of energy forms or inspire new methods in which to extract energy i.e. renewable energy. Having an established scientific infrastructure can therefore be a huge advantage for countries wishing to improve renewables by providing the scientific means to do so. On a side note however, if a country were to focus on having more efficient uses of energy the incentive to improve their renewables sectors might not be as great. This is because when energy is used more efficiently the supply is not likely to be exhausted as fast as countries that have poor levels of energy efficiency. The issue of energy security is therefore not as great and so the necessity of producing renewables for energy security reasons is very high.

5. Methodology

This study will conduct a quantitative analysis in order to discover if there is statistical inference for the relationship between wealth and renewable energy. The statistics that have been taken in order to conduct this analysis have been done so from a number of sources predominantly from the World Bank Database (2017), but also Knoema (2017) and the German Foreign Ministry (2015).

In undertaking this analysis, statistics found from just one point in time will be used to explain what drives renewable energy usage in Europe. The year that has been chosen to do this is 2014. It must be noted that one of the principal reasons for choosing this year in particular was because this was the most recent year in which data was available for all of the variables. Of course, adopting this approach makes sense in that it is possible to capture of most current or up-to-date image possible of what drives consumption of renewables across the continent.

However, there is another factor which makes this time period an interesting one which to observe for a reason that has perhaps eluded much of the previous literature such as Menegaki's study. This is the role that the financial and Eurozone crises have imposed upon the renewables sector. The period of austerity following these events imposed tight fiscal constraints forcing governments to realign public spending and reassess financing clean energy technologies – with France, Greece and the UK providing examples of many governments who cut renewables subsidies drastically (Ruester, 2016, p. 198). This study therefore may provide a valuable insight into the more recent state of the renewables sector following the crash and how this might have affected consumption.

5.1. Research Design

The choice for undertaking a quantitative based analysis has been motivated based on the principal that the aim of this study is to fundamentally understand what is the biggest driving force, or what has the biggest effect, on renewable energy consumption in Europe. When a research problem centres around identifying the aspects that influence an outcome or understanding the best predictors of outcomes, then a quantitative approach is the most suitable method to do so (Cresswell, 2003, pp. 23-4). By obtaining individual coefficients. a quantitative method clearly exhibits which of the explanatory variables exerts the largest impact on renewable energy consumption. This experiment favours a more objective approach to understanding this relationship.

5.1.1. Linear Regression

In order to conduct this analysis, this study will employ both bivariate and multivariate linear regressions techniques. Put simply, the method of linear regression is essentially a model which creates a straight line that best describes the chosen data. In doing so, the line that is generated helps us to predict the value of the dependent variable based on where the explanatory variable is (Field, 2009, p. 198). As an example for this study, the regression model would predict renewable energy consumption to be at a certain percentage at a given level of economic wealth.

Adopting the method of linear regression can be advantageous largely due to its simplicity. This approach will offer a clear analysis of the effect of the explanatory variables on renewable energy consumption at this certain point of time. The coefficients produced will exhibit a clear comparison in respect to one another, and seeing which exerts the greatest effect on consumption of renewables.

On the other hand, it must be noted that this study has taken a slightly different approach in relation to previous literature which has addressed the wealth-renewables nexus. Given that all of the previous literature has utilised time-series methods as analysis, it is conceivable that this study might yield contrasting findings as it is just one moment in time. Using time-series has an advantage as it allows to see change over time as well as often having the benefit of more observations.

5.1.2. Multicollinearity Issues

Further to a linear regression, a test for multicollinearity issues has been conducted to ensure against this problem. This happens when two or more of the explanatory variables in a regression are strongly correlated. Multicollinearity poses a major issue for multiple regression techniques as, fundamentally, each explanatory variable should explain an almost unique effect on the independent variable. Where there is perfect multicollinearity between predictors this becomes impossible as there are a number of combinations of coefficients that would work equally well (Field, 2009, p. 223).

Pearson’s *r* tests have been run in order to check for this issue in relation to all of the six explanatory variables. This is a statistical technique which measures the linear correlation between two variables. The technique essentially gives a coefficient to see the degree to which two variables are be correlated, ranging from +1 to -1. A coefficient of +1 indicates that two variables are perfectly positively correlated, whereas a coefficient of -1 indicates a perfectly negative correlation (Field, 2009, p. 170). A coefficient of 0 indicates no correlation at all. By checking the correlations between the explanatory variables using this method, it is possible to detect and protect against multicollinearity issues.

The results of this test can be seen in Table A1 in the appendix. Beldjazia and Alatou (2016, pp. 26-27) cite that the generally accepted parameters for Pearson's *r* coefficients showing correlation between variables are as follows: 0.00-0.19 "very weak", 0.20-0.39 "weak", 0.40-0.59 "moderate", 0.60-0.79 "strong" and 0.80-1.00 "very strong". Looking at Table , the strongest level that the coefficients have in relation to one another is at the "moderate" level grouping. Though some of the variables may exhibit some linear similarities therefore, they have not been deemed substantial enough to omit from the analysis.

5.1.3. Standardised Coefficients

Standardised coefficients will be used to interpret the effect that the individual variables have on the dependent variable as oppose to unstandardized coefficients. Given that the explanatory variables all have different units of measurement, this is the most useful method to ascertain which of them has the most individual influence. Unstandardised coefficients are predominantly used when finding the effect that one unit change in an explanatory variable will have on the dependent variable. The case for using standardised coefficients is therefore relatively straightforward and appropriate for this study.

It is also worth noting that using standardised regression coefficients is the same process as using Pearson's correlation (Cramer, 1998, p. 174). As noted above, these coefficients will therefore potentially range from +1 to -1 and the weight of their effect will also be measured as listed above.

5.1.4. Statistical Significance Levels

For this study, the statistical significance parameters will be lengthened slightly perhaps in comparison to what is usual in scientific research. As Cramer (1998, p. 67) notes, the conventional cut off point for interpreting results as being statistically significant is at the $p<.05$ level. However, this boundary can be extended based on a number of conditions which may apply to a particular investigation. Defining a *p*-value as large would most likely be at the $p<.1$ level. What is seen as a small or large sign significance typically depends on the context. If an experimenter is seeking to explain new or different results, they might be happy to report at the $p<.1$ level as being statistically significant (Mcguiness, 2015, p. 4). Given that this study is looking to do this, the $p<.1$ will be used as the cut off point for statistical significance instead of $p<.05$.

A further justification for using this level of statistical significance is due to the limited number of cases or observations this study is using. As using thirty observations is generally seen as the minimal accepted number of observations for a large-N style study such as this, widening the parameters further allows to include factors which may be influencing renewable energy consumption given the small sample size. If there was a considerable amount of more observations, this factor may have been reconsidered.

5.2. Operationalization and Rationale of Variables

5.2.1. Dependent Variable

Renewable Energy Consumption

This is the dependent variable being investigated in the analysis. Statistics for the year 2014 have been taken from a database conducted by Knoema (2017). These statistics have been compiled based on data in accordance to the framework of EC regulation No. 1099/2008 and complemented by data submitted by national administrations to Eurostat. This variable has been calculated as the share of renewable energy in the gross fixed final energy consumption of the European countries, based on four indicators: transport, heating and cooling, electricity and overall RES share. Using percentages of RES in final consumption is a preferable method to capture consumption levels as it finds a more balanced average to study to account for different population sizes. If the variable was to be judged on total consumption of renewables in kWh for instance, this would not account for different population sizes of the countries and thus the results would not be accurate.

5.2.2. Independent Variables

GDP Per Capita

A central component to this study, per capita income provides a clear example of how to test the effect of wealth on renewable energy consumption. Of course, the expectation here is that the higher that the average wealth is of a country the higher share of renewable energy. This expectation is consistent with the EKC theory in many respects in that it is likely that citizens of wealthier countries are likely to have higher demands on environmental performance and will thus be in favour of RES.

Population Density

A factor which has largely been overlooked in the literature, population density can have an extremely significant effect on the production of renewables. Countries with sparse populations in comparison to land have a sizeable advantage as many forms of renewables required large spaces of land to cultivate. Bioenergy, as an example, is produced from a variety of biomass resources such forestry and agricultural residues (IPCC, 2012, p. 7), and therefore it stands to reason that it requires large swathes of arable land to produce energy. Because Population Density has often been neglected in the literature, this variable could be both an interesting and a key factor in explaining use of renewables. Data for this variable has again been collected from the World Bank database (2017) and has been calculated as people per square km of land area. The prediction is that the fewer people per square km, the more renewables will be consumed.

5.2.3. Control Variables

Energy Consumption Per Capita

The total level of energy per head that a country consumes can also be an influential driving factor for renewable energy. It stands to reason that if a country consumes a high amount of energy per capita, there is an increasingly need to ensure a secure supply. To ensure the continuance of supply, renewable energy could provide an option and so the expectation is the higher the overall consumption of energy per capita, the higher the share of RES. Again, this data has been taken from the World Bank (2017) database and the measurement is kg of oil equivalent per capita.

Energy Intensity

Energy Intensity is a measure to analyse the energy efficiency of a nation's economy. Essentially, this measure is calculated by taking the energy consumption of a country and dividing by the GDP. Given that both of these variables are already included in per capita form in the analysis, including this measure might appear questionable. It can nevertheless be of worth to test the correlation between energy intensity and RES consumption. This is because energy intensity can be used as a proxy for technological change in many respects, as it could be expected that these two indicators are be correlated with one another. The lower the energy intensity, the higher one would expect the technological development of a country to be as energy is used more efficiently. The expectation with this variable is the higher the Energy Intensity, the lower the share of renewables would be. As was noted earlier in relation to Industrial Ecology approach, if a country does have efficient uses of energy then the incentive to improve their renewables consumption might not be as pressing. Again, statistics for this variable have been extracted from the World Bank (2017).

Energy Imports

Energy imports have also been taken from data provided by the World Bank (2017) database for the year 2014, and been calculated as the net import as a percentage of energy use. The prediction here is that the higher the rate of energy imports, the lower the share of renewable energy consumption.

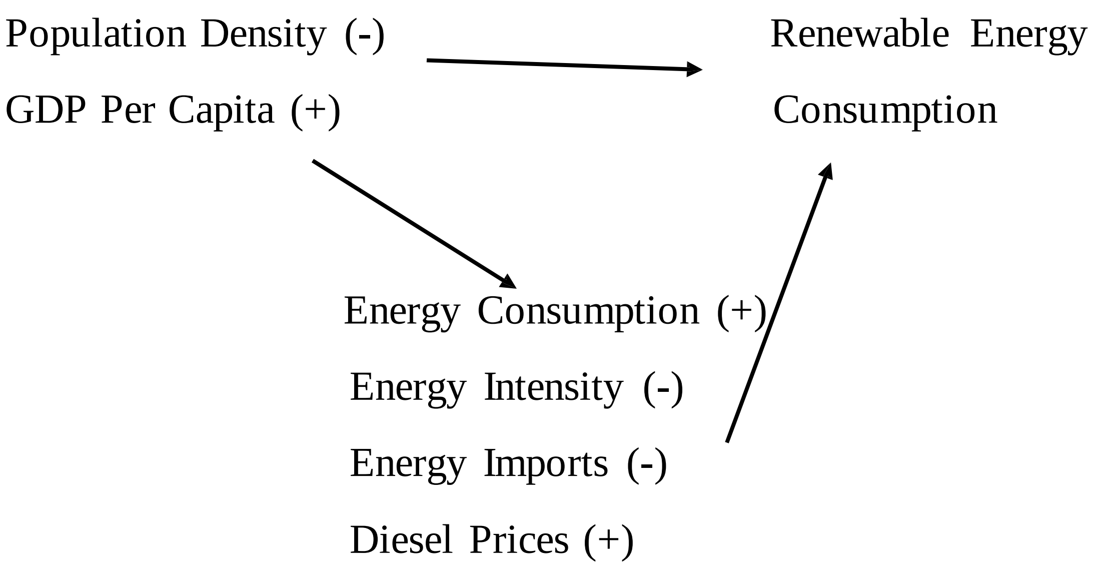
Diesel Prices

These statistics have been compiled from the German Foreign Ministry (2015) and are listed in US cent. The expectation is that the higher the price of diesel in each country, the higher the share of RES consumption. The more expensive that fossil fuels are, such as diesel prices, the more futile the economic argument for using them is and so renewables are more likely to be viewed as a credible alternative.

5.2.4. Causality Diagram

Below is a visual representation of the causality flows of the explanatory variables, and the possible effects they may have on renewable energy consumption. In brackets are the expected outcome of the explanatory variables on renewable energy consumption, negative meaning a reduction and positive meaning a contribution. Of course, both the independent and control variables are expected to exert an influence over the dependent variable. Note also that, in line with the conservation hypothesis outlined in the growth-energy nexus, GDP Per Capita may have an influence on the levels of energy consumption, yet this will not be expressly tested for.

Figure 2. Explanatory Variables



5.3. Delimitations

Before proceeding onto the analysis, it is crucial to discuss what exactly this study will not be covering. This is important as it necessary to realise the boundaries or parameters that this study has, and acknowledge that the analysis cannot cover every possible aspect of what affects renewables consumption.

5.3.1. Omitted Variables

Attitudes Towards Climate Change

Unfortunately, there does not appear to exist any database or country index about citizens' attitudes in all the 30 countries chosen towards climate change. This is a blow to understanding RES as energy sources as the climate change component is a fundamental feature in the context in which has seen renewables begin to be popularised. If it were possible to measure where environmental attitudes were strongest between the 30 cases, one would expect that such countries which have a larger share of renewables consumption. This expectation comes from the notion that, as all of the 30 countries are functioning democracies, national governments would respond to the desires of their citizens and endorse the use of renewables. Possibly in response to the growing political salience of climate change however, the European Social Survey (2016) has incorporated a 'Public Attitudes to Climate Change' questionnaire as a theme. Regrettably, this study has been conducted in 2016 and does not align with the rest of the results timewise and, moreover, the results have not been released at the time of writing. In not capturing any measure of attitudes towards climate change there may be a perceived weakness with this study, yet the development of this social survey does provide an exciting avenue for future research.

Nuclear

Nuclear power remains an influential energy resource in many countries in Europe and may interfere with countries' desires to use renewable energy. Nuclear power does not have the same affect as many fossil fuel forms in that it does not emit high concentrations of CO_2 into the atmosphere, thus alleviating the pressure to invest in RES as a result. Yet nuclear energy is a controversial and dangerous energy resource publicly. Major accidents on Three Mile Island in the US, Chernobyl and Fukushima have exacerbated support for this sector (Glomsrød et. Al, 2013, p. 1511). Many European countries such as Austria, Denmark, Greece, Ireland, Italy, Latvia, Luxembourg, Malta, Norway and Portugal have no nuclear power and remain opposed to the idea. As not all of these countries in this analysis use nuclear, this variable has been omitted from the study.

Political Incentives/Tax Subsidies

A further variable which could explain renewables consumption is the number or weight of incentives that governments offer for producers. Many member states have implemented policies aimed at increasing the production and these policies have been very influential in bringing down costs for the sector (Nicolini & Tavoni, 2017, p. 412). The various policies – often financial incentives or tax subsidies – can thus be considered a factor which might be likely to have contributed to the rise of renewables. The International Energy Database (2017) does list all of the policies and regulations currently in action within European countries. Unfortunately, not all of the countries have such policies in their legislation.

5.3.2. Other Variables

In addition to these variables, a number of other influencing factors have been considered yet not included in the final model. The main variable which was intended to be included into this analysis but has been left out is GDP growth. This was meant to be one of the independent variables in the thesis, and would have offered a valuable comparison to GDP per capita to see which of these variables is more influential as indicators of wealth. A mean average of growth rates over the past ten years was calculated, yet was not found to be statistically significant at any point and so has not been included in the final analysis.

Carbon Dioxide emissions levels for each of the countries were taken as a consideration for a possible control variable, representing an environmental aspect which might explain renewable energy usage. Unlike much of the previous literature found however, these figures were not statistically significant in explaining renewable energy usage. As a consequence, this variable has not been included in the analysis.

A number of other considerations were investigated as control variables but had the same issue in that they were not statistically significant in explaining what determines renewable energy usage. R&D expenditure as a percentage of GDP was one of these factors, in which a technological aspect was attempted to explain consumption levels as an indicator for the innovation of a country. Electricity prices in respective European countries was also not found to be significant. Education scores of the Human Development Index were also registered in attempting to explain some social dimension, yet were not significant.

Table 1 shown on the next page exhibits the bivariate models of these five variables which were considered, but were not found to be statistically significant.

Table 1. Statistically Insignificant Variables Tested

Variable	**Model 1 (Bivariate)**
GDP Growth (10 Years)	-.002 (2.545)
R&D Spending	.275 (3.685)
Electricity Prices	-.296 (86.939)
Carbon Dioxide	-.075 (1.063)
Education	.177 (64.438)
N	**30**

***p<.1 ** p<.05 ***p<.001. Standard Errors in Parentheses.**

6. Analysis

6.1. Results

Table 2, listed below, reveals the findings of the different regressions.

Table 2. Renewable Energy Consumption (% in Gross Fixed Final Energy Consumption)

Variables	Model 1 (Bivariate)	Model 2 (Multivariate)	Model 3	Model 4	Model 5	Model 6
GDP Per Capita	.250 (.000)	.255 (.000)	-.002 (.000)	.327** (.000)	.052 (.000)	.126 (.000)
Population Density	-.429** (.012)	-.432** (.012)	-.342** (.010)	-.262 (.012)	-.333** (.010)	-.453** (.008)
Energy Consumption	.589*** (.001)		.534** (.001)			
Energy Intensity	-.449** (.894)			-.398** (.930)		
Energy Imports	-.588*** (.022)				-.504** (.005)	
Diesel Prices	.367** (.176)					.349* (.170)
Constant		21.057*** (5.386)	14.769** (5.049)	40.091*** (9.782)	27.185*** (5.084)	-34.033 (27.281)
R^2		**.249**	**.461**	**.373**	**.453**	**.354**
N	**30**	**30**	**30**	**30**	**30**	**30**

***p<.1 ** p<.05 ***p<.001. Standard Errors in Parentheses.**

The first model represents the bivariate models of the two independent variables and the control variables. Model 2 comprises of the multivariate model including both independent variables. Model 3 includes energy consumption as a control variable, model 4 includes energy intensity, in model 5 energy imports is the control variable and diesel prices is controlled for in model 6.

Looking first at the bivariate models it can be seen that, out of the two main independent variables, the population density variable coefficient is stronger than the GDP Per Capita variable and also has the benefit of being statistically significant. The standardised coefficient for Per Capita is at the .250, meaning an increase in wealth does technically suggest an increase in renewables. However, this coefficient is not statistically significant and therefore the null hypothesis (or there being no relationship between the variables) cannot be rejected when testing Per Capita and RES usage. Population Density, conversely, is statistically significant at the *p<.05* level and has a standardised coefficient of -.429. Given that this variable was measured as people per square km of land area, this means that the fewer number of people per square km the more renewables are consumed on average. This variable is also statistically significant, so we can reject the null hypothesis of no relationship between these two variables.

Turning to the control variables, Energy Consumption Per Capita exerts the strongest individual influence on renewable energy consumption with a .589 standardised coefficient. This is the strongest coefficient of any of the explanatory variables included in the analysis. It means that the higher the average energy consumption within a country, the higher the share of renewables consumption. This variable is statistically significant at the *p<.001* level also, so the null hypothesis can be refuted. Energy Imports has just a slightly weaker standardised coefficient with -.588 and is also significant at the *p<.001* level. This means that the higher the percentage share of energy imports, the lower percentage of renewable energy consumed is likely to be. The bivariate model for Energy Intensity also exhibits a moderate effect on the dependent variable, with a coefficient of -.449. This result suggests that the higher the Energy Intensity of a country, the less the share of renewables should be. This variable is also significant to the *p<.05* level. Finally, Diesel Prices exhibits the weakest standardised coefficient of all the control variables at .367, being statistically significant at the *p<.05* level. This suggests that the higher the Diesel Prices, the higher the share of renewables consumption.

Model 2 shows the multivariate regression for both of the independent variables. When both of these variables are considered together, Population Density exerts the stronger influence on RES consumption and is also more statistically significant. GDP Per Capita, like in the bivariate model, shows no statistical significance here and a coefficient of .255. The coefficient for Population Density stands at -.432 and is significant to the *p<.05* level. This is an ever so slightly stronger effect that this variable had in the bivariate model, and again suggests that the sparser a population is the more renewables are likely to be used on average. This model exhibits the lowest R^2 of any of the multivariate regression at .249. The R^2, or squared multiple correlation, represents the amount of variance that a regression model can account for or explain (Cramer, 1998, p. 176). Therefore, the R^2 score of .249 reveals that this model can account for almost 25% of the variance in the dependent variable, RES consumption.

Model 3 shows the multivariate regression for the independent variables as well as Energy Consumption Per Capita as the control variable. Interestingly, when this is included as a control variable, GDP Per Capita exhibits an adverse result in comparison to the other models with a negative coefficient of -.002. Again however, this variable proves to be statistically insignificant meaning that there is a possibility that there is no relationship between Per Capita and RES consumption in this model. The effect of Population Density is lessened in model 3 comparing to the previous 2, with a standardised coefficient of -.342. This is statistically significant in the model, again at the $p<.05$ level. Of all the three explanatory variables, it actually turns out that Energy Consumption Per Capita exerts the greatest impact on RES consumption share. The coefficient for this variable is .534 – slightly lower than its bivariate model coefficient – and significant at the $p<.05$ level. Of all the multivariate models in the analysis, the model has the highest R^2 of .461 meaning that it can account for 46.1% of total variation. This fundamentally also means that this model fits the data most appropriately.

Model 4 is the multivariate model that includes the Energy Intensity of a country as the control variable. For the first and only time in the analysis, GDP Per Capita produces a statistically significant result when Energy Intensity is factored into the equation at the $p<.05$ level. GDP Per Capita, in the model, furthermore has a stronger coefficient in this model than in any other model at .327 although this is still a relatively weak influence in comparison to other variables. Also for the only time in the analysis, Population Density does not yield any statistically significant results in this model. The standardised coefficient is also the lowest in this model for Population Density than any other model. Energy Intensity exerts the greatest effect on renewables over any of the independent variables in this model with a coefficient of -.398 and is significant at $p<.05$. The R^2 result for this model stands at .373, revealing that 37.3% of variation can be explained in model 4.

The regression for Model 5 includes Energy Imports as the control variable this time. GDP Per Capita once more is statistically insignificant in this model, and exhibits a lower correlation coefficient than normal of .052. Population Density yields a statistically significant result at the $p<.05$ level, with a slightly weaker coefficient than usual of -.333. Of the three explanatory variables, Energy Imports has the greatest effect of the RES consumption at -.504 and significant at $p<.05$. This is a slightly diminished correlation than the bivariate model for Energy Imports, and not at the same significance accuracy. Model 5 has one of the highest R^2 of all the models at .453, thus explaining 45.3% of the variation.

Finally, Model 6 includes the Diesel Prices of the countries as a control variable. Once more, GDP Per Capita is not statistically significant in this model meaning that it is not possible to reject the null hypothesis. Population Density, interestingly, exerts its greatest influence of all the models here with a coefficient of -.453. This result is also statistically significant, again at the $p<.05$ level. The coefficient for Diesel Prices stands at .349 in this model, and with a statistical significance of $p<.1$. 35.4% of the variation can be explained with this model, according to the R^2.

6.2. Discussion

By interpreting the results from Table 2, it is clear that there is very little validity in the argument that the relative wealth of a European country determines how much renewable energy is consumed. In five out of six of the models included, GDP Per Capita was not found to be a statistically significant factor in explaining what encourages RES consumption. The bivariate model for GDP Per Capita notably did not yield a significant result. This finding contrasts with what Menegaki (2010) found in her study of a similar nature. Whether this is due potentially to a different time frame or a different method of analysis is unsure, but the fact that wealth cannot explain renewable energy usage at this particular time frame is arguably a finding in itself.

Only when Energy Intensity was positioned as a control variable did Per Capita yield any sort of statistical significance, as well as a stronger coefficient than usual. This means that when the energy efficiency of a country is a consideration, there is evidence of a relationship between GDP and renewable energy consumption. However, even going by this model where

GDP Per Capita exerts its strongest influence of any of the regressions, this correlation coefficient is still rather weak in comparison to the other variables.

On the whole, due to the statistical significance of this variable through most of the models, it does not appear possible to support the first hypothesis that "*the higher the GDP per capita of a country, the more renewable energy that country will use"*. There is a possibility that no statistical relationship exists between these two variables, except when Energy Intensity is included.

The alternative independent variable, Population Density, does prove to be effective in explaining what encourages renewables usage. In five of the six models in the analysis, this variable is significant. It is worth reminding here of Beldjazia and Alatou's (2016) classifications of various strengths of correlation coefficients, and particularly that a correlation of .40-.59 is a moderate effect. In three out of the six models, notably the bivariate, Population Density exhibits a 'moderate' negative correlation and is statistically significant in these three. As predicted, the more sparsely populated a country is therefore the more renewable energy they are likely to consume. Only in model 4 is Population Density not statistically significant so the null hypothesis of no relationship between the two variables cannot be rejected. Coincidently, this is the same model where GDP Per Capita is statistically significant. Overall however, this variable does prove to be a valuable factor in explaining consumption of RES. The findings for Population Density support the second hypothesis that "*The lower the population density of a country, the more renewable energy that country will use."*

An interesting finding of the analysis moreover is that three of the four control variables have a greater impact on renewable energy usage than Population Density.

Energy Consumption Per Capita has the strongest of all the coefficients in model 1 (bivariate) and is highly significant at $p<.001$. This variable obviously therefore has considerable explanatory power for renewables and exhibits a 'moderate' positive correlation, but is very close to being considered a 'strong' one. As was predicted with Energy Consumption Per Capita, the higher individual amount of energy consumed is, the higher the level of renewables consumption. In some sense this finding lends support to the argument of renewable energy technologies providing a form of energy security for countries, like was discussed in the introduction of this thesis. If the average individual consumption levels of a country are high, a national government might be wary of this and look to produce and consume their own renewable energy instead taking risks on importing energy. The more dependent a population is on energy, the more there is to lose if it not provided. Increasing the production of renewables could perhaps address this challenge.

With a minutely weaker coefficient, the rate of Energy Imports proves to exert a big influence on renewables and is also highly significant. The results align with the original prediction that the higher the amount of Energy Imports, the lower the share of renewable energy consumption. Despite its correlation, it could possibly be paradoxical to argue that the amount of energy that a country imports is necessarily a driving factor for production of renewables. What is telling about these results however is that it seems to suggest that energy that is imported is mostly from non-renewable sources. By definition, this variable could explain that renewable energy consumption is highly related to whether it is domestically produced. Renewable energy is more likely to be consumed in a country that is less dependent on imports i.e. which can provide its own energy resources. The inference given is that countries would rather consume the renewable energy they produce domestically. One possible reason for this is to support domestic producers of renewables and encourage the sector. Another explanation for this in the context of Europe could be for individual countries to meet the renewables targets set by the EU in the 2020 Climate and Energy Package.

The Energy Intensity of a country furthermore proves to be a control variable which exerts a moderate negative effect on the dependent variable. As envisaged, the coefficients confirm that the higher the energy intensity of a country is then the likelihood is that share of renewables will be smaller also. As Energy Intensity is essentially a measure of how efficiently a country uses its energy, the results indicate that the more efficient this energy use is the smaller quantities of renewables are consumed on average. In some ways this finding could be paradoxical given that Energy Intensity was supposed to represent or be a proxy for technological change. The rational thinking for technological change would be that the higher levels of technological development, the more renewables are consumed as renewables do require high levels of expertise to produce. However, the findings do not support this notion. Though this analysis has not necessarily set out to test the grounds of Industrial Ecology, the results from this variable do appear to contradict this approach.

Most important about the Energy Intensity variable is the impact that it has on the two independent variables. As mentioned, when this control variable is factored into the regression, the role GDP Per Capita suddenly exhibits a significant relationship whereas Population Density does not. When Energy Intensity is considered therefore, GDP Per Capita has a much higher probability of having a causal effect on renewable energy whereas population has a much lower likelihood of explaining what drives renewables.

Finally, Diesel Prices exhibit a relatively weak correlation with renewable energy usage – weaker than Population Density - but it is nevertheless a relationship that is statistically significant. As hypothesised, the findings indicate the trend that the higher the diesel prices are in a country then the more renewable energy is used. This relationship could indicate that fossil fuels tend to lose their appeal where they are more expensive, and renewables are likely seen as a valuable replacement.

7. Conclusion

By using a method of quantitative analysis, this thesis has set out to investigate whether the wealth of a country determines how much renewable energy is consumed in that country in Europe. In addition, it has sought to explain alternative factors that may be driving renewable energy consumption in Europe. It has been conducted by using a linear regression technique, taking statistics from the year 2014.

Ultimately what has become apparent, from this point of time at least, is that there is not much evidence in support of the notion that the level of wealth of a country can determine how much renewable energy is used in Europe. Despite having a positive correlation coefficient in most of the models conducted, only in one model was Per Capita income statistically significant for RES consumption. Further than this, the standardised coefficients for this variable were relatively weak in comparison to the coefficients of other variables included in the analysis. The other independent variable under investigation in this analysis however, Population Density, did appear to be an influencing force for renewables.

Of all the explanatory variables included in the analysis it turned out that a control variable, Energy Consumption Per Capita, which had the largest effect on renewable energy consumption and at a very high level of statistical significance. This finding tends to lend support for the idea of RES being used for the purpose of energy security. Energy Imports had an almost similar effect on renewables usage that was also highly significant. Energy Intensity was found to be a driving factor, and Diesel Prices also influence renewable energy consumption. Due to the sizeable and significant results exhibited by many of the control variables, these would provide interesting examples to base another study around as main independent variables.

Turning to the original hypotheses that were the foundation for this analysis in many respects, it is clear that the first hypothesis cannot be proved for certain whereas there is evidence that the second hypothesis is true in this study. Due to the number of models in which the data for GDP Per Capita were not found to be statistically significant, it is not possible to argue that '*The higher the GDP per capita of a country, the more renewable energy that country will use'*. This is in spite of the fact that GDP Per Capita also usually showed a positive correlation coefficient. Conversely, the second hypothesis that '*The lower the population density of a country, the more renewable energy that country will use'* is largely confirmed by the data. In all the models the coefficient suggested this effect, with all but one of them being statistically significant.

Overall, the findings of this thesis can provide a valuable contribution to the growing literature in the field of renewable energy technologies for three pivotal reasons.

Firstly, it has provided an up-to-date study of renewables in Europe and the factors which fundamentally foster the sector. Menegaki's similar study took data all the way up to the year 2007, leaving a lengthy time-frame in which to provide a more current analysis and attempt to discover changes that may have occurred for renewables. International developments such as the financial crisis, for instance, may have had an impact on renewable energy consumption and this can consequently be tested for.

Secondly, a host of new variables have been included and been found to be statistically significant in this analysis. Many of these variables have been absent not only in studies of renewables in Europe but moreover in studies of what drives renewable energy usage all over the world in different regions. Population Density, for instance, is a factor which has largely been ignored in previous literature. The evidence included here revealing that these variables are influential in supporting renewables could potentially be factors which are explored or investigated by other academics in the future.

Finally, as was detailed in the introduction, the European Commission views Europe to be somewhat championing the renewable energy sector on the global scale. If this leadership in the field is apparent, then discovering what the central factors are that are making the sector so prosperous can only be an advantage. The European example can provide valuable lessons for other countries or regions looking to augment their own renewables sectors, and take on some of these factors as considerations accordingly.

Going forward, there are two fundamental ways in which this study could be furthered in the future. The first of these ways is to potentially develop the model that has been used here to incorporate changes over time, like the previous literature has done in their respective studies. Not only would this allow observing how these variables interact with renewables over a given time frame, but would also increase the sample size of the study. Given there would be more observations to work with in this type of study, such an analysis might be better placed to explain what drives renewable energy across the continent.

Secondly, there are certain influencing factors that may be necessary for renewable energy but that have not been able to quantify for this analysis. Notably, this study has not been able to capture any statistics relating towards European citizens' attitudes towards climate change for the year studied. This is a potential limitation of this study as the role of climate change is a seminal element in the context of renewable energy. However, as mentioned in the methodology section, the European Social Survey is conducting statistics for climate change concerns and this would be interesting to test in relation to renewable energy consumption. Furthermore, testing the amount and strength of domestic policies towards renewables is an area that would be important to study due to their importance in supporting the sector.

It is clear therefore that even if this thesis has succeeded in explaining some of the factors influencing renewable energy usage in Europe, there remain many exciting avenues for further research into what drives renewable energy technologies.

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Appendix

Table A1
Correlations Between Explanatory Variables

	GDP Per Capita	*Population Density*	*Energy Consumption*	*Energy Intensity*	*Energy Imports*	*Diesel Prices*
GDP Per Capita	*1*					
Population Density	.011 (.952)	1				
Energy Consumption	.479** (.007)	-.163 (.388)	1			
Energy Intensity	.187 (.323)	.430* (.018)	-.564** (.001)	1		
Energy Imports	-.401* (.028)	.191 (.312)	-.214 (.250)	0.93 (.624)	1	
Diesel Prices	.369* (.045)	.064 (.738)	.251 (.181)	.170 (.368)	-.487** (.006)	1

Comment: Pearson Correlation. Sig two-tailed. N=30. *p<.05 **p<.01

Table A2

Individual Country Level Renewable Energy Consumption (2014)

Country	RES share (% of Gross Fixed Energy Consumption)
Austria	33.10
Belgium	8.00
Bulgaria	18.00
Croatia	27.90
Cyprus	9.00
Czech Republic	13.40
Denmark	29.20
Estonia	26.50
Finland	38.70
France	14.30
Germany	13.80
Greece	15.30
Hungary	9.50
Iceland	71.10
Ireland	8.60
Italy	17.10
Latvia	38.70
Lithuania	23.90
Luxembourg	4.50
Malta	4.70
Netherlands	5.50
Norway	69.20
Poland	11.40
Portugal	27.00
Romania	24.90
Slovakia	11.60
Slovenia	21.90
Spain	16.20
Sweden	52.60
United Kingdom	7.00

Chart A1

Individual Country Level Renewable Energy Consumption (2014)