UNIVERSITY OF HULL

Three Essays on the Evaluation of Renewable Energy Investments and the Effectiveness of Support Schemes

Being a Thesis Submitted for the Degree of Doctor of Philosophy in Finance

by

Alhassan Alolo Mutaka (BA, MSc)
Hull University Business School

July 2015

Acknowledgment

The path to the successful completion of this research was not an easy one. My sincere gratitude goes to the Almighty God for His grace and guidance. I would also like to take this opportunity to express my sincere gratitude to my supervisor, Dr Alcino Azevedo, for his patience, guidance, and support throughout my time as his Ph.D. student. His enthusiasm for research has been contagious and motivational for me, even during tough times in the pursuit of my Ph.D. His advice and guidance as a mentor have been immeasurable. I would also like to acknowledge and thank my second supervisor, Dr Yilmaz Guney, for his enormous time and guidance throughout the research process. His comments have been very useful throughout the process. Both Dr Alcino Azevedo and Dr Yilmaz Guney have been very supportive and concerned about my progress and wellbeing, as well as my future career plans, and for that I am very grateful. I would also like to acknowledge my parents, Alhaji Alhassan Alolo and Hajia Mariam Alolo, for their prayers and support throughout the course. To my sisters, Dr Namawu Alolo and Dr Sahada Alolo, I thank you for your continuous motivation, support and guidance throughout my study. I also thank my brother, Arimeyawu Alolo, and the rest of the family for their prayers and support over the years. I am indebted to Akeem and Sheriff Adewuni for not giving up on me in my desperate moments.

Needless to say, the list is endless. I would however like to single out inspirational friends such as Ernestina Mireku, Kwame Ohemeng Gyane, Stella Wristberg, Elizabeth Brew-Smith, Sheila Wrystberg, Albert Afriyie, Majid Andani, Angela Carr, Seif Muba, Salman Al Rasheed, Mohammed Nazri, Rizwan Ahmed, Naaja Ampa and Kennedy Abrokwa for their continuous support and encouragement. Of course, without the continuous interaction with colleagues and the Faculty of the University of Hull Business School, this Ph.D. endeavour would have remained but a mirage. I am therefore grateful to all my colleagues and the staff of the University of Hull Business School for the rigorous academic training I received over the past few years.

I acknowledge helpful comments on earlier versions of part of this thesis from the participants at the 32nd International Association for Energy and Economics Conference, 2013, Alaska, and I am grateful to Centrica plc for providing me with data on the daily energy production of the Lynn and Inner Dowsing wind farms.

Declaration

A version of chapter 1 is currently under review for publication in *Economics Letters (Joint with Alcino Azevedo and Yilmaz Guney)*.

Conference Presentation:

Chapter 2 was presented at the 32nd International Association for Energy and Economics Conference, 2013, Alaska.

Chapter 2 was presented at the 5th PhD experience Conference at the University of Hull, April, 2014.

Chapter 5 has been accepted for presentation at the 11th International Interpretive Policy Analysis Conference, July 2016, Hull University, UK.

Abstract

Renewable energy development is a critical aspect of the political agenda of the European Union (EU) due to its environmental friendliness as well as enhancing economic development. Electricity markets in the EU have changed due to rising capacity and generation from renewable energy sources of electricity (RES-E) as a result of policy intervention. However, there have been increasing and inconclusive debates on the growth of RES-E technologies and the effectiveness of support scheme policies. The uncertainty regarding continuing the support schemes for RES-E technologies makes it relevant to evaluate the effectiveness of the existing support schemes in driving RES-E capacity development.

This thesis presents three empirical chapters which evaluate RES-E investments and the effectiveness of the RES-E support policies in the EU. In the first empirical chapter we use a real options framework to analyse the investment timing of a wind farm, considering the electricity price and production uncertainties and the impact of the correlation between these two variables on the timing of the investment, neglecting the existence of support schemes. In the remaining two empirical chapters, we use econometric analyses to examine the effectiveness of RES-E policies in driving capacity development in the EU. More specifically, we use dummy variables to account for the existence and the experience of enacted policies while controlling for market and macroeconomic factors. We also analyse the impact of the heterogeneity in Feed-in-System (*FIS*) on the capacity development of wind and solar photovoltaic (PV), while controlling for country specific effects.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AC3-5	Appendix Chapter (3-5)
ACEP	Average Cost of Electricity Production
CDM	Clean Development Mechanism
COALP	Coal Price
DECC	Department of Energy and Climate Change
EC	European Commission
EEA	European Environment Agency
EIA	Energy Information Administration
ELECP	Electricity Price
EU	European Union
EU-ETS	European Union Emission Trading Scheme
FE	Fixed Effects
gBm	Geometric Browning Motion
GDR	Generation Disclosure Requirement
GHG	Green House Gases
GW	Gigawatts
IEA	International Energy Agency
INCRQMTSHARE	Incremental Requirement
IRENA	International Renewable Energy Agency
JI	Joint Implementation
KWh	Kilowatts Hour
LIDO	Lynn and Inner Dowsing Offshore Wind Farm

LM	Lagrange Multiplier
Ln	Log Natural
LO	Links Offshore Wind Farm
Max	Maximum
MGPO	Mandatory Green Power Option
Min	Minimum
MWh	Megawatts Hour
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NTGP	Natural Gas Price
OBS	Observations
OECD	Organisation for Economic Co-operation and Development
OILP	Oil price
OLS	Ordinary Least Squares
PBF	Public Benefits Funds
PCSE	Pearson Correlated Standard Errors
PV	Solar Photovoltaic
R&D	Research and Development
RC	Retail Choice
RE	Random Effects
RES-E	Renewable Energy Source of Electricity
Rev	Revenue
ROI	Return on Investment
ROV	Real Option Value
RPS	Renewable Portfolio Standard

Std. Dev.	Standard Deviation
TGC	Tradable Green Certificate
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United State Dollar
VAT	Value Added Tax
VIF	Variance Inflation Factors
WE	Wind Energy

List of Variables

AC	Added Capacity
Cap	Cap policy
CC	Cumulative Capacity
CO2	CO2 Emissions (metric tons per capita)
Coal Price	Coal Prices Euro per MWh
Coal Share	Electricity Production from Coal Sources (% of total)
Elect.Consumption	Electricity Power Consumption (kWh per capita)
Elect.Price	Electricity Prices Eurocents per MWh
Elect.Production	Total Electricity Production (kWh)
Energy Import	Energy Import Dependence
Energy Use	Energy use
FIP	Feed-In-Premium
FIP_ABS	Absolute Monetary value of FIP
FIS	Feed-In-Systems
FIT	Feed-In-Tariff
FIT&FIP	Interaction of FIT and FIP
FIT&TENDER	Interaction of FIT and Tender
FIT_ABS	Absolute Monetary Value of FIP
GDP	Gross Domestic Product per Capita
Natural Gas Price	Natural Gas Prices Euro per MWh
Natural Gas Share	Electricity Production from Natural gas Sources (% of total)

Nuclear Share	Electricity Production from Nuclear Sources (% of total)
Oil Price	Oil Prices Euro per MWh
Oil Share	Electricity Production from Oil (% of total)
P	Average Daily Spot Electricity Price
Popul.Growth	Population Growth
Potential	Wind and Solar Photovoltaic Technical Potential (Land Dimension)
PvRev	Present Value of Net Revenue
Q	Daily Wind Farm Production
Quota	Quota and Tradable Green Certificates
Renewable Share	Electricity Production from Renewable Sources, Excluding Hydroelectric (% of total)
Tax	Tax Breaks and other Fiscal Incentives
Tender	Tender Policy

1 Introduction

Natural factors, such as variations in the climate system, volcanic activity and minute changes in the pathway of the earth around the sun, have been cited as the primary causes of the climate changes that have impacted the earth throughout history. However, as science makes inroads into the understanding of climate change and its causes, much has been revealed about the significant impact of human activities, such as burning of fossil fuels, cutting down of rainforests, as well as farming of livestock, on the climate. There is a strong, credible body of evidence, based on multiple lines of research documenting that carbon dioxide (CO2), resulting mainly from the combustion of fossil fuels is reported to form 63% of global warming caused by man.[1] While much remains to be learned, the fundamental findings from contemporary research have revealed that the amount of fossil fuels burnt to power machines, generate electricity, heat buildings and provide transportation, has increased the concentration of carbon dioxide in the atmosphere by 37%, and there is still evidence of a rise despite recent efforts.[2]

Following mounting scientific evidence for warming of the climate, the European Union nations (including the UK) developed several strategies and became the forerunners of international negotiations for the reduction of Greenhouse Gas (GHG) emissions, and were co-signatories to the United Nations Framework Convention on Climate Change (UNFCCC, 1992) and the Kyoto protocol (1997). The EU in 1997 agreed to reduce its emissions by at least 20% relative to 1990 levels by the year 2020, through a package of binding legislation among member states and also committed to reduce emissions by 30%

---

[1] http://europa.eu/pol/clim/index_en.htm

[2] See http://europa.eu/pol/clim/index_en.htm for an in depth description of the climate change, its causes and consequences.

by 2030. This was based on a condition that other developed and developing nations will commit to reduce their emissions. The first commitment of the Kyoto protocol expired in 2013. Since the commitment to the 1997 Kyoto protocol, three flexibility mechanisms have been introduced as means of assisting in the overall management of carbon emissions. The main aim of these flexibility mechanisms is to help reduce the entire cost involved in the management and achievement of carbon emission reductions targets. This is to prevent severe economic effects on any nation trying to reduce its emissions. The Joint Implementation (JI), the Clean Development Mechanism (CDM) and the Emissions Trading are the three flexibility mechanisms adopted by the Kyoto protocol to aid in the management of GHG emissions (UNFCC, 2007).

With the aid of these mechanisms in the management of carbon emissions, various emission reduction technologies and projects are developed and adopted by nations and firms. Some specific firms are shifting to the adoption of RES-E technologies as a means of reducing and managing their level of carbon emissions cost effectively. This cost is occurred from the use of fossil fuel and coal to power generators for electricity generation. Renewable technologies, such as wind farms, solar panels and biomass, are some of the technologies most commonly adopted as substitutes for other traditional ways of power generation in the EU (Meyer, 2003).

The EU, in its quest to reduce carbon emissions, has set mandatory carbon emissions reduction targets for 2020 and 2030. These targets are likely to be met with a shift from traditional fossil sources of electricity generation to RES-E technologies. For that matter, the EU has also set mandatory percentages of electricity to be generated from renewable sources by the years 2020 and 2030 (see Table 1.1 for reference targets). However, the initial cost of technology for electricity generated through renewable sources and the cost of production are very expensive rendering electricity from renewable sources uncompetitive in the market (Jenner et al., 2013). Producers of electricity are therefore concerned with the return on their investments in RES-E technologies which makes investments in such technologies unattractive to power producers in the absence of support schemes, (see for instance, Dinica, 2006; Lyon & Yin, 2010).

Therefore, achieving these environmental targets would be unlikely without support schemes for RES-E technologies (Dinica, 2006; Carley, 2011). They also posit that most energy policies and support schemes implemented in the pre-liberalisation era fell short of aiding the achievement of environmental targets and hence has either been scrapped or amended. As a result of this, the EU has set various directives forcing countries to roll out and implement support policies to encourage investments in renewable energy technologies. Member states have consequently developed and implemented new support schemes which aim to be more consistent with the new energy markets and to help them achieve their indicative carbon emissions reduction targets vis-a-vis increase in their RES-E installed capacity (Meyer, 2007).Therefore, there is the need to evaluate RES-E investments in the absence of support schemes as well as examining the effectiveness of the implemented support schemes in driving capacity development.

1.1 Motivation and Research Questions

There is a growing concern regarding increasing CO2 emissions and their impact on the climate and hence significant efforts are required to reduce the level of CO2 emissions in order to avoid negative impact on economic development, welfare and ecosystem as a result of severe temperature increase(see for instance, IPCC, 2011; Bozkurt & Akan, 2014). Therefore the enhancement of RES-E technologies for electricity generation is important in reducing the increasing levels of CO2 emissions (Hanley & Owen, 2004; Stern, 2007). In addition to helping reduce the increasing CO2 emissions as a result of electricity generation from fossil fuel sources, RES-E has the potential of increasing energy security by way of reducing energy import dependence (Valentine, 2011). Moreover, increased deployment of RES-E technologies has the potential of impacting positively on economic development by way of increasing employment and competition as well as sustainable growth (see, European Parliament, 2009; Ragwitz et al., 2009).

The increasing levels in capacity and generation of RES-E in national energy mix among countries in the EU have significant impact on the electricity markets in the EU. Both capacity and generation of electricity from RES-E have increased over the years in the EU; for instance, RES-E capacity increased by 61% from 24.5% of total power capacity in 2000 to 39.6% in 2013(European Wind Energy Association, 2014). Yet, there are several impediments preventing further deployment and much remains to be done to limit the impediments and help countries meet their indicative RES-E targets. There are some market barriers and failures (explained in section 1.3.1 below) which hampers the further deployment of RES-E technologies (Brown, 2001; Painuly, 2001). These market barriers and failures often result in the use of fossil fuel sources above the socially optimal levels, which leads to high levels of CO2 emissions and hence contributes to climate change. The use of fossil fuels above the socially optimum levels directly impacts on RES-E investments leading to RES-E consumption below the socially optimal level (Stern, 2007). With stated RES-E targets and the presence of these impediments, there is the need for the intervention of governments by way of implementing support policies to enhance RES-E investments (Brown, 2001; Painuly, 2001).

For over two decades now, various European governments have implemented different support schemes to enhance investments in RES-E technologies. These support policies for RES-E are long supported by the theoretical literature which suggest that, to correct the market barriers and failures, government intervention by way of environmental policy implementation is essential (Weitzman, 1974). These support policies are the likely reasons for the current development of RES-E technologies (European Wind Energy Association, 2014). However, while investors face a certain level of uncertainty regarding RES-E policies, governments in EU are also faced with the challenge of the most efficient policy portfolio that will eliminate the current barriers and failures and help them achieve their set RES-E target. Despite the fact that some existing support policies have been reported by the literature to be effective in driving RES-E capacity development, there is still an ongoing debate on which specific policies are very efficient and which technologies could be profitable in the absence of support schemes. While there are contradictory reports about the effectiveness of support policies, we appreciate the fact that the structure of markets could have an impact on the effectiveness of RES-E policies and hence policies which might have been effective in the US might not necessarily be effective in the EU.

The majority of the studies on the effectiveness of RES-E support schemes use qualitative techniques and mostly apply to the US context. The few quantitative studies which examine the effectiveness RES-E policies often pay less attention to the experience of the policies, the specific policy design features and the market context in which the policy is being implemented which could potentially have a direct impact on the investment and deployment of RES-E technologies. For instance, while some policies are more popular and applied more than others, there is the likelihood that these more familiar policies could be properly designed, due to learning effect, to efficiently drive the development of

RES-E technologies. Also, the Feed-in-Tariff (*FIT*) which is the most implemented policy in the EU, differs significantly across countries in terms of tariff amount, contract duration, priority access to the grid or not (see Table 3.3 in Chapter 3 for the number of countries using *FIT* and Table 3.4 for summary of policies adopted to support RES-E development). Neglecting these factors when examining the effectiveness of RES-E policies make the actual impact of the support schemes on development blurred (Jenner et al., 2013; Bolkesjø et al., 2014).

Also, due to the financial crisis and restrictions on budgets, government continued support for RES-E technologies is uncertain. For instance, the plan by the UK government to end support for onshore wind farms by April 2016, as well as the introduction of caps on the support of RES-E by the Spanish government in 2012 are uncertainties underlining the government support for RES-E technologies. Hence, the need for ex ante evaluation of RES-E investments in the absence of support schemes. This research, therefore, contributes to the existing literature by examining the impact of output quantity and out price on investment timing of wind farms in the absence of support schemes and also the impact of support policies on the capacity development of RES-E technologies by answering the following questions;

i. What is the impact of electricity production and electricity spot price uncertainty on the timing of investment of a wind farm in the UK in the absence of Government support schemes?
ii. Does the correlation between electricity production and electricity spot prices have an impact on the timing of investment of a wind farm in the UK in the absence of Government support schemes?

iii. What is the impact of the availability of a policy and the experience of the policy on RES-E development in the EU?

iv. Are implemented support policies to enhance development of RES-E effective if specific policy design features and market conditions are controlled for?

v. Does the interaction between policy design features and market characteristics have an impact on the ability of the policy to drive capacity development?

vi. Can the market price of electricity drive RES-E development in the absence of support schemes?

More specifically, in this thesis, we provide analysis of investments with a timing decision model and the effectiveness of RES-E policies in driving the capacity development in the EU. This thesis contributes to the literature by addressing three main issues and answering the research questions relating to RES-E investments and policies outlined above. These three main areas are grouped into three main empirical chapters specified below:

i) In the first empirical study in chapter 2, "**Price-Quantity Correlation Coefficient Effect on Wind Energy Investments: A Gift of Nature?,** we adjust Paxson and Pinto's (2005) model to a monopoly market, considering the criticism of Armada et al. (2013), and illustrate the effect of the correlation coefficient between the electricity spot market price and the electricity production on the timing of wind farm investments. We use a dataset comprising information on the UK electricity spot market price and the electricity production of the Lynn-Inner Dowsing Offshore (LIDO) wind farm of Centrica plc, for the time period between January 2011 and December 2012, and show that the correlation coefficient between these variables is -0.23. We find that this correlation coefficient can work as a hedging factor in wind farm projects, accelerating investments if it is more negative, and conjecture that there might be wind farms in the UK which persistently exhibit more negative correlation coefficients and, therefore, *ceteris paribus*, are more valuable. We also find that the volatility of the spot electricity market price and the electricity production from wind sources both delay significantly the timing of investments.

ii) The second empirical chapter is "**The Effectiveness of Renewable Energy Policies: Evidence from the Wind Energy in the European Union**". We use dummy variables to represent the existence of policies, and the number of years a policy has been in existence to represent the experience of policies, and with a panel dataset comprising information from 1992-2013 for 27 EU countries, we conduct econometric analysis in order to determine the most effective RES-E support policy, if any. We apply pooled Ordinary Least Squares (OLS), Random Effects and Fixed Effects and PCSE techniques to gather more results in determining the most effective support policy in the EU. Due to the nature of our data, our analysis is based on the results from the fixed effects models which indicate that, with the exception of the Quota and Green Certificates Trading (*Quota*) policy and *Tender*, the enactment of support policies alone does not enhance wind energy capacity development. The results also reveal that the number of years *Quota* policy has been in existence positively affects both cumulative and annual added capacity of wind energy. The number of years *FIT* exist also drives both cumulative wind energy capacity and annual added capacity. We therefore conjecture that the experience of a policy is much more important in the capacity development of wind energy than the mere existence of the policy.

iii) The third empirical chapter is "**The Effect of Feed-in-Systems Incentive Policies on the Development of Wind and Solar Photovoltaic Energy Capacity: Evidence from the European Union**". In this chapter we assess the strength of Feed-in-Systems (*FIS*) policies considering the heterogeneity in the design (such as variations in tariff amount, duration of tariff, type of tariff, digression rate of tariff) and market conditions (such as electricity price, cost of production and interest rates) that has an impact on the strength of the policy. We develop an indicator which captures all the components mentioned above to estimate the resulting expected present value of revenue of the investment in wind or solar photovoltaic capacity. Using various panel models, we gather data for 27 EU countries from 1992 to 2013 and regress our new indicator on the annual added capacity (AC) of wind and solar photovoltaic (PV). Our fixed effects model specification indicates that there is no significant relationship between the dummy variable representation of *FIS* policy and capacity development of wind and solar PV.

On the other hand, the stringency or the incentive provided by the *FIS* policies which is captured by our new indicator present value of revenue (*PvRev*) has significantly driven both wind and solar photovoltaic capacities in the EU. This implies that, without accounting for policy heterogeneity and market factors, the impact of the *FIS* on capacity development would not be observed, and would be overstated without controlling for country fixed characteristics. Since we could not find robust evidence about significant impact of the enactment of policy alone on wind and solar capacity development, we therefore conjecture that policy design features, and their interaction with the prevailing market factors, are more sensitive, and a stronger driver of capacity development, than the mere existence of a policy alone.

A clearer understanding of the importance of RES-E support policies in supporting capacity development and the dynamics of the EU electricity industry is provided in section 1.3.1 of this chapter, while section 1.3.2 presents an overview of the EU RES-E policy regimes. In section 1.3.3 we present an overview of EU RES-E directives while section 1.3.4 presents EU RES-E growth, statistic and targets. In sections 1.3.5 and 1.3.6 we present an overview of features of the EU electricity industry and electricity generation sources and price evolution respectively. Section 1.2 of this chapter presents an overview of the thesis.

1.2 Organisation of the Thesis

The structure of this thesis is organized as follows:

i) Chapter one presents the introduction, research motivation and stylised facts of the electricity industry in the EU.

ii) Chapter two addresses the "Price-Quantity Correlation Coefficient Effect on Wind Energy Investments: A Gift of Nature?

iii) Chapter three presents the methodology, policy variables, data description and specification of test for empirical chapters 4 and 5.

iv) Chapter four addresses "The Effectiveness of Renewable Energy Policies: Evidence from the Wind Energy in the European Union".

v) Chapter five addresses ‘The Effect of Feed-in-Systems Incentive Policies on the Development of Wind and Solar Photovoltaic Energy Capacity: Evidence from the European Union”.

vi) Chapter six concludes the thesis with policy implications, limitations and suggestions for future research.

1.3 Stylised Facts

1.3.1 Market Failures and Barriers for RES-E Deployment

Under neoclassical assumptions, market failures could be explained as the situation where there is inefficient allocation of resources, in other words, a deviation from an efficient market Painuly (2001), whereas market barriers could be seen as factors preventing the adoption of a particular product, in this case RES-E technologies (Brown, 2001). According to the literature, there have been some identified market barriers and failures of RES-E deployment including,

i) market power and economies of scale; in an imperfect competitive market such as energy markets where learning by continues use and increasing returns are important, without government support, electricity generated through RES-E sources would be unprofitable as compared to traditional fossil generation sources (Brown, 2001; Painuly, 2001). The longer existence of tradition fossil sources of energy generators could be advantageous to producers who could use their long market existence to reduce future cost of production through learning as well as lobbying to prevent policy support for RES-E technologies (Marques & Fuinhas, 2011a). As emphasized by Jamasb and Pollitt (2008), while RES-E facilities are sometimes confronted with intermittency and decentralised production, well established conventional facilities could use their market strength to the detriment of RES-E facilities.

ii) Unadded cost and externalities; negative externalities occur when the social cost associated with fossil fuels are generally not reflected in their pricing resulting in their usage and consumption above the socially optimum levels (Gillingham & Sweeney, 2010). When the cost of emitting carbon dioxide as a result of using fossil fuels to generate electricity is lower than the social cost of the effect of the carbon dioxide on climate change, in the absence of policy intervention for RES-E technologies which are substitutes for fossil fuels, deployment would be slow due to the cost involved in their adoption and production (Brown, 2001; Painuly, 2001; Owen et al., 2004; Gillingham & Sweeney, 2010). Also when national security risk such as increase in military expenditure as a result of the importation of oil and gas is not reflected in the prices of electricity generated through fossil fuels, there will be underinvestment in RES-E technologies in the absence of government support policies. The perception seems to be that price signals trigger technological changes and hence as fossil fuels become progressively scarce and expensive RES-E technologies will be increasingly deployed (Fiorio et al., 2007).

iii) Capital market barriers, low interest and unfavorable fiscal policies are major obstacles to RES-E deployment (Brown, 2001; Painuly, 2001). Due to the high initial investment cost of RES-E technologies as compared to fossil fuel sources, the rate of return is higher for RES-E technologies than traditional fossil sources and hence results in high perceived risk, and without support policies, there will be less investment (Gillingham & Sweeney, 2010).

These market barriers and failures affect RES-E deployment either at the same time or different times and hence the need for intervention support policies to enhance RES-E deployment. Based on the market barriers and failures apparent in any market, which negatively affect the achievement of their indicative RES-E targets, governments across the EU have implemented different support schemes and policies to support RES-E growth (see Table 3.3 and 3.4 in Chapter 3).

1.3.2 European Union Wind Energy Policy Regimes

The EU RES-E policy is a relevant part of the political agenda. This is partly because of the continuous fluctuations in the prices of fossil fuels and the global concern about the consequences of the climate changes due to high carbon emissions as well as security of energy supply. The EU has adopted several directives to promote investments in RES-E as a result of the market barriers and failures analysed above. Since 1996, there have been three main phases and directives to support renewable energy investments. The first phase and issue of a white paper by the European Commission (EC) took place between 1996-1999, the second took place between 1999 and 2010 (Directive /2001/77/EC), and the third between 2010-2020 (Directive/2009/28/EC) (European Parliament, 2001, 2009).

1.3.3 European Union's Directives

The EU initially issued a white paper for a road map of the use of renewable sources of energy from 1996 to 2000. The first RES-E policy initiative by the EU was the Directive

/2001/77/EC[3] which was adopted on the 27th of September, 2001. The second directive was Directive/2009/28/EC implemented on 27th September, 2010 to run up to the year 2020. All directives are aimed at promoting energy generated from renewable sources in the EU electricity market and to create a basis for a future community framework in the internal electricity market of the EU. As part of the directives, the following rules and guidelines went into force: National Indicative Targets, National Support Schemes and Policies, Guarantee of Origin of Electricity Produced from RES-E sources, Administrative Procedures, and Grid Systems.

1.3.3.1 National Indicative Targets

Member states are mandated to set and publish their RES-E generation targets to be achieved by the years 2012 and 2020 respectively according to Directive 2001/77/EC and Directive/2009/28/EC. These national indicative targets should conform and align to the general and overall target of the EC.[4] The national indicative targets should also be consistent with global indicative targets of 12% of gross national consumption and 22.1% of electricity generated from renewable energy sources by 2010. Member states are also required to publish their national targets and future consumption of electricity from RES-E sources every five years from October 2002. Included in the report should be specific measures set in place by member states to achieve their specified targets by 2010 and 2020. These national indicative targets to be set by individual countries in the EU should also conform to national commitments already in place to aid in climate change mitigation issues such as the Kyoto protocol which was adopted through the UNFCCC.

---

[3] For an extensive review of the Directive 2001/77/EC (see Lauber, 2005).

[4] The EU has a reference targets for member states to set their own renewable energy targets. This reference targets are presented in Table 1.1 below.

Furthermore, from October 2002, member states were required to publish detailed reports on the achieved indicative targets every two years up to 2011. Climate factors that played a role in achieving these targets were also required to be stated in the report with much emphasis on the consistency of the measures put in place towards the national climate change commitment. The EC, however, also releases a detailed report every two years stating the extent to which member states are progressing with regards to meeting their targets and the consistency with global and already existing climate change commitments (see Directive 2001/77/EC).

Table 1.1: Mandatory EU RES-E Targets by Countries

Countries	RES - 2005	RES - 2009 (Provisional)	RES - 2020 Target	% Increase Required -2009-20
Austria	23.3%	29.20%	34%	5%
Belgium	2.2%	3.80%	13%	9%
Bulgaria	9.4%	11.50%	16%	5%
Cyprus	2.9%	3.80%	13%	9%
Czech Republic	6.1%	8.50%	13%	5%
Denmark	17.0%	19.70%	30%	10%
Estonia	18.0%	22.70%	25%	2%
Finland	28.5%	29.80%	38%	8%
France	10.3%	12.40%	23%	11%
Germany	5.8%	9.70%	18%	8%
Greece	6.9%	7.90%	18%	10%
Hungary	4.3%	9.50%	13%	4%
Ireland	3.1%	5.10%	16%	11%
Italy	5.2%	7.80%	17%	9%
Latvia	32.6%	36.80%	40%	3%
Lithuania	15.0%	16.90%	23%	6%
Luxembourg	0.9%	2.80%	11%	8%
Malta	0.0%	0.70%	10%	9%
Netherlands	2.4%	4.20%	14%	10%
Poland	7.2%	9.40%	15%	6%
Portugal	20.5%	25.70%	31%	5%
Romania	17.8%	21.60%	24%	2%
Slovak Republic	6.7%	10%	14%	4%
Slovenia	16.0%	17.50%	25%	8%
Spain	8.7%	13%	20%	7%
Sweden	39.8%	50.20%	49%	-1%
United Kingdom	1.3%	2.90%	15%	12%
EU 27	**8.5%**	**11.60%**	**20%**	8%

Source: EC Directive/2009/28/EC. This table shows the mandatory RES-E targets for various countries in the EU for 2020.

Table 1.1 above shows the percentage of RES-E installed capacity, mandatory RES-E targets for 2020, provisional percentage of RES-E installed capacity as of 2009 and the percentage required by 2020 to meet the respective RES-E targets of EU countries. As of 2009, Sweden remained the only country which achieved more than its set RES-E target. As of 2009, the percentage of installed RES-E capacity in Sweden was 50.20% exceeding the intended target by about 1%.Sweden remained the country with the highest percentage of electricity capacity from RES-E while Malta continued to have the least with about 0.70% as at 2009. It can be observed that, as at the end of 2009, about 11.60% of RES-E target was achieved by EU 27 with about 8% remaining. The UK with a set RES-E target of 15% by 2020 had achieved only 2.9% by 2009 with about 12% remaining to achieve their set target.

1.3.3.2 Support Schemes and Policies

In order for member states to meet their targets, they have the duty to roll out and implement support policies and schemes to aid in the consumption and generation of electricity from RES-E sources. The EC therefore evaluates the various support schemes to which a producer of electricity receives either direct or indirect support for generating from RES-E technologies. These frameworks are evaluated to determine their effectiveness in attaining the set renewable energy targets for 2010 and 2020. The commission therefore periodically presents a report on the experience, success and cost effectiveness of implementing the various support schemes. Any support scheme adopted by member states should:

i) Contribute to achieve the national indicative targets of member states.
ii) Be compatible with the principles of the internal electricity market.
iii) Consider the different types of renewable energy sources and the different types of renewable energy technologies and geographical difference.
iv) Be cost effective, simple and an effective scheme to promote the use of renewable energy sources.
v) Include sufficient transitional period for at least 7 years of national support so as to maintain investor confidence.

Various policies have, however, been adopted by different member countries of the EU to promote the generation and usage of electricity from RES-E technologies. Our aim is to determine the effectiveness of these support policies in the development of wind and solar PV energy capacity in the EU. Description of the various support schemes adopted by countries in the EU is presented in chapter three of this thesis.

1.3.3.3 Guarantee of Electricity Production from Renewable sources

In the Directive 2001/77/EC, member states are required to guarantee a required amount of generation and consumption from RES-E which conforms to their stated objectives. Independent bodies could be chosen from member states to monitor and supervise the issue of guaranteed generation and consumption from RES-E. A guarantee of origin shall be specific on the source, date and place of electricity production. Capacity should also be indicated in the case of hydroelectric installations.

1.3.3.4 Administrative Procedures

Member states are required to review and reduce both regulatory and non-regulatory barriers which affect the increase in electricity production from renewable sources. They are also required to streamline and expedite procedures at the appropriate administrative level.

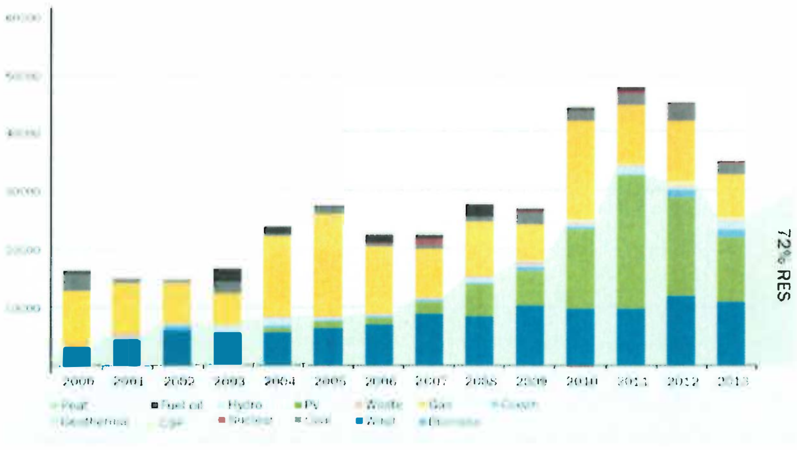
1.3.3.5 Grid System

Member states are also required to ensure that transmission and distribution system operators guarantee the transmission and distribution of electricity from renewable energy sources and if possible with priority access. In the light of these directives, most member states met their targets by the end of 2010. These targets were met based on some of the policies adopted by member states to directly and indirectly support electricity generation from renewable sources.

1.3.4 European RES-E Growth, Statistics and Targets

In 2000, new renewable power capacity installations totalled 3.6 GW. Since 2010, annual renewable energy added capacity has been between 24.7 GW and 35.2 GW, eight to ten times higher than in 2000. 11,159 MW of wind power capacity (worth between €13 billion and €18 billion) was installed in the EU-28 during 2013, a decrease of 8% compared to 2012 added capacity. Wind power investments for 2013 in the EU show the undesirable effect of market, regulatory and political uncertainty across countries in the EU according to (the European Wind Energy Association, 2014). The report cited unstable legislative frameworks for wind energy hampering investments in wind energy and hence our aim to determine the impact of policy experience on capacity development. Nevertheless, from Figure 1.1 below, it can be observed that wind power is the most installed in renewable energy technology in 2013: 32% of total 2013 power capacity installations – 5% higher than the previous year. Total renewable power installations accounted for 72% of new installations during 2013: 25 GW of a total 35 GW of new power capacity, up from 70% the previous year.

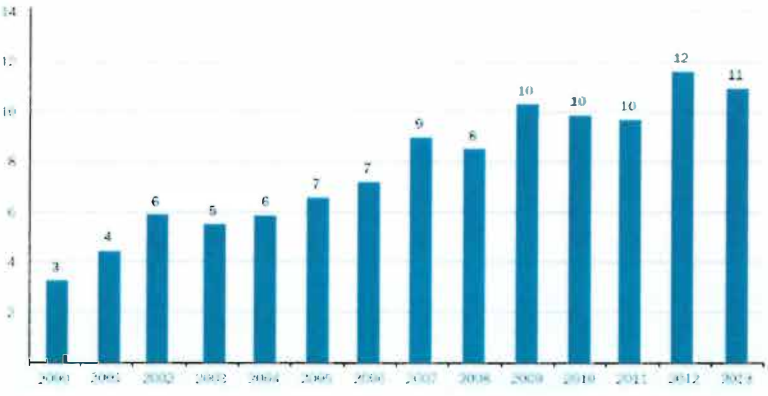
Figure 1.1: Installed Annual Power Generating Capacity and RE Share (%, MW).



Source: European Wind Energy Association 2014.

From Figure 1.1 above, by the end of 2013, total installed power capacity in the EU increased by 13 GW to 900 GW, wind energy increased by 11.2 GW representing 13% of total installed generation capacity (1% above previous years capacity installed). Since 2000, over 28% of new capacity installed has been wind power, 55% renewable and 92% renewable and gas combined. The EU power sector continues to move away from fuel oil and coal with each technology continuing to decommission more than it installs as evidenced in Figure 1.1 above. Since 2000, the net reduction in fuel oil (down 39 GW), coal (down 32 GW) and nuclear energy (down 2 GW) coincided with the net growth of wind power (137 GW), gas (120 GW) and solar PV (93 GW). The other renewable technologies (biomass, hydro, waste, CSP, geothermal and ocean energies) have also been increasing their installed capacity over the past decade, although at a slower rate as compared to wind and solar PV. There has been a continues shift in the EU's power generation capacity from oil, coal, nuclear and gas to a higher share of wind, solar PV and other renewables, as evidenced in Figure 1.1 above.

Figure 1.2: Annual Wind Power Installation in EU (GW)



Source: European Wind Energy Association 2014.

According to Figure 1.2 above, annual installations of wind power have increased over the last 13 years, from 3.2 GW in 2000 to 11.2 GW in 2013, an annual growth rate of about 10%. There have been variations in the annual installed capacity in the EU according to Figure 1.2 above. According to the European Wind Energy Association (2014), installed capacity is facilitated by policy effectiveness and hence part of our motivation to examine the effectiveness of RES-E polices implemented in the EU.

Figure 1.3: Cumulative Total Annual Wind Power Capacity Installations in EU from 2000-2013 (GW)

Source: European Wind Energy Association, 2014.

From Figure 1.3 above, it can be observed that a total of 117.3 GW of wind energy is now installed in the EU as of end of 2013, a growth of 10% compared to the previous year and lower to the growth recorded in 2012.[5] Out of the total 117.3 GW, onshore accounts for 110.7 GW while offshore accounts for 6.6 GW. Germany remains the EU country with the largest installed capacity, followed by Spain, the UK, Italy and France. Eleven of the remaining other EU countries: Austria, Ireland, Belgium, France, The Netherlands, Greece, Poland, Denmark, Portugal, Sweden and Romania have over 1 GW of installed capacity, with (Germany, Denmark, France, , Italy, Portugal, Sweden, Spain, UK), having

---

[5] There was a 12% growth in 2012.

more than 4 GW of installed wind energy capacity (European Wind Energy Association, 2012).

The volatility of electricity prices across Europe has contributed to 46% of all new installations in 2013 being in just two countries (Germany and the UK), a significant concentration compared to the trend of previous years whereby installations were increasingly spread across strong European Markets according to (European Wind Energy Association, 2014). This is a level of concentration that has not been seen in the EU's wind power market since 2007 when the three wind energy pioneering countries (Denmark, Germany and Spain) together represented 58% of all new installations that year. [6]

A number of previously well established markets such as Spain, Italy and France have seen their rate of wind energy installations decrease significantly in 2013, by 84%, 65% and 24% respectively. Offshore saw a record growth in 2013 (+1.6 GW); the outlook for 2014 and 2015 is stable, but not growing. The wind power capacity installed by the end of 2013 would, in a normal wind year, produce 257 TWh of electricity, enough to cover 8% of the EU's electricity consumption – up from 7% the year before. Wind power accounted for 32% (11.2 GW) of new installations in 2013, followed by solar PV (31%, 11 GW) and gas (21%, 7.5 GW). No other technologies compare to wind, PV and gas in terms of new installations.

Coal installed 1.9 GW (5% of total installations), biomass 1.4 GW (4%), hydro 1.2 GW (4%), CSP 419 MW (1%), fuel oil 220 MW, waste 180 MW, nuclear 120 MW, geothermal 10 MW and ocean 1 MW. Wind power's share of total installed power

---

[6] European Wind Energy Association (2013).

capacity has increased five-fold since 2000; from 2.4% in 2000 to 13% in 2013. Over the same period, renewable capacity increased by 61% from 24.5% of total power capacity in 2000 to 39.6% in 2013.[7]

1.3.5 Overview of the European Electricity Industry

Reforms for the liberalisation of EU electricity markets started in the 1990s with an effort to establish a single European market (Jamasb & Pollitt, 2005, 2008).The implementation of these reforms which include privatisation (allowing private investors and sale of state owned firms), unbundling (related to incentive regulation of the networks, third-party-access, establishing and independent regulator), and liberalization (permitting entry and competition in generation and retail) differs among countries in the EU (Newbery, 2002; Jamasb and Pollitt, 2005; Fiorio et al., 2007). Basically, four different activities with different characteristics could be associated with the electricity industry generation, transmission, distribution and retail. Producers generate electricity from oil, gas, coal, wind, solar PV, hydroelectric plants among others. Electricity cannot be efficiently stored and hence is generated as and when needed. Generation could be seen as competitive due to the fact that in most production processes, economies of scale are viewed to be minimal (Fiorio et al., 2007). The electricity generated is then transmitted in bulk from the generating source through the transmission networks to electrical substations close to demand centres from where it is then distributed through to individual customers. The distribution substations, connected to the transmission lines lowers the high voltage to medium voltage using transformers. This voltage is further reduced from medium to the utilization voltage through the distribution transformers located near customers. While

---

[7] European Wind Energy Association (2014).

transmission and distribution are described as natural monopolies due to the network fixed sunk cost, retail is seen to be competitive as a result of flexible cost associated with trading and marketing activities (Fiorio et al., 2007). The liberalisation of European markets was pursued with electricity market directives with policies aimed at achieving European a single market to introduce competition and improvement among firms and national incumbents across the EU (Jamasb & Pollitt, 2005).

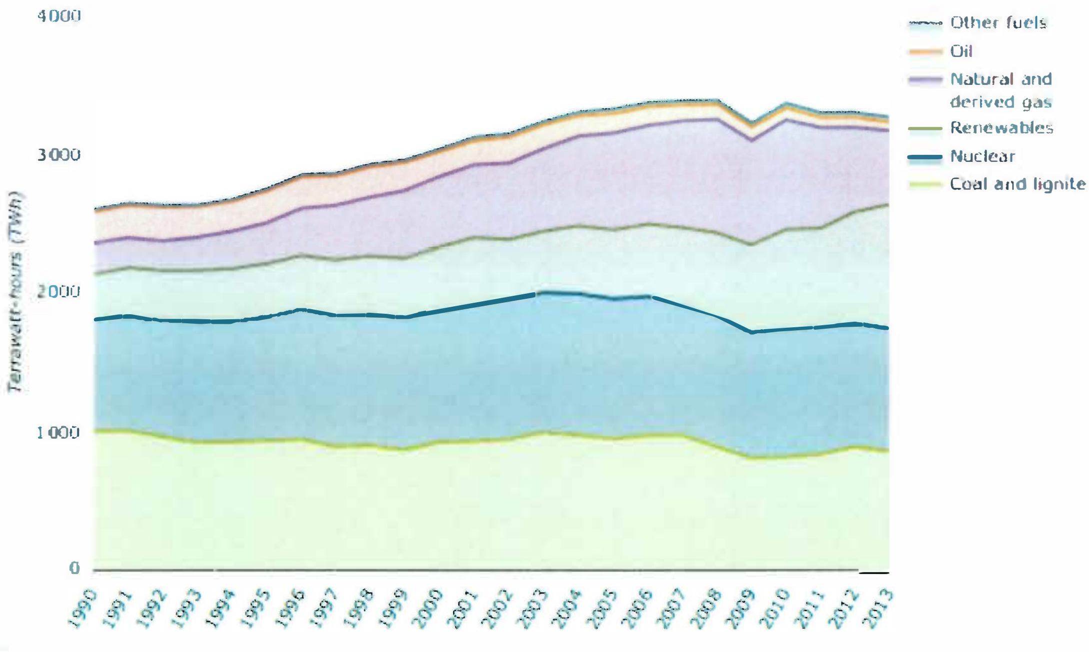
1.3.6 Electricity Generation Sources and Price Evolution

Various countries in the EU have different levels of energy mix and generation sources, which vary across time. Even though gross electricity generation between 1990 and 2013 in the EU 28, it increased by 26% with a 1% average increase a year, a decrease of 0.3% a year was observed since 2005.[8]

---

[8] http://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-1/assessment

Figure 1.4: Gross Electricity Production by Fuel



Source: European Environment Agency, 2015.

As at 2013, electricity generation from coal and ignite was 39%, nuclear energy 27%, renewables 27% (compared to 13% in 1990), 17% from natural gas, 2% from oil sources and 1% from other sources (Figure 1.4 above).[9]

According to the European Energy Agency, 2013, Germany and France had the highest net electricity generation of 19.2% and 11.0% of total EU 28 generation. Cyprus, Netherlands, Greece and UK reported negative growth in capacity while Croatia recorded 27.9% growth in generation capacity in 2013. While 15 member countries had reductions in net generation capacity, the highest reduction in net electricity generation was in Luxemburg (-24.4%) and Hungary (-13.3%). Consequently, about 49.8% of total net electricity generation in the EU-28 came from combustible fuels such as natural gas, oil

---

[9] http://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-1/assessment

and coal while 26.8 came from nuclear sources. About 12.85 of total net generation in 2013 came from hydro plants while wind and solar contributed 7.5% and 2.5% respectively. [10] Even though generation from gas sources remains highest in EU-28, it has decommissioned more than installed since 2013 (European Wind Energy Association, 2014).

There has been growth in capacity and generation of electricity through renewable sources since 1990, yet much growth is needed to attain the set RES-E targets. The complete potential of renewables have not yet been realised due to several failures and barriers to their deployment (Painuly, 2001).

Due to the fact that it is economically difficult to store electricity, balancing the demand and supply of electricity is not an easy task and hence a little change in electricity generation as observed in the EU could cause a significant change in electricity prices within a matter of hours in a competitive market (Girish & Vijayalakshmi, 2013). Factors such as climate change, businesses, private and industrial activities, and temperature are some of the factors that affect electricity consumption, which has a direct link with the demand for electricity. Due to the variations in these electricity consumption factors, the demand for electricity varies within the day, week, month and year, which affects electricity prices, making them seasonal sometimes (Girish, 2013; Girish & Vijayalakshmi, 2013). As a result, the generation capacities of different technologies in the energy mix profile of the EU and the changes in net generation with regards to technologies have a direct impact on electricity prices. When demand for electricity is high, more costly generation sources could be used to supplement the demand which could cause a rise in prices of electricity. Spot market prices are characterised with high

---

[10] http://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production/assessment-2

volatility due to their sensitivity to different factors (Karakatsani & Bunn, 2008a, b; Girish, 2013). For instance, Sensfuss et al. (2008) are of the view that electricity generation from RES-E sources have an impact on electricity prices in Germany. They also argue that gas and coal price rise increases electricity prices. This could be as a result of gas and coal having the highest share of generation capacity in the EU. These price dynamics of the EU have direct implications for deployment of RES-E technologies and are expected to affect the investment decision.

Due to the liberalisation in the EU, especially in the UK, the wholesale electricity market could be seen as a bilateral market based on self-balancing where power is traded either through recognised exchanges or over the counter. It is the responsibility of the suppliers to buy the required power from either exchanges or directly from generators to meet the demand of customers. It is however, the responsibility of the national grid to ensure real time balancing of the system, with the cost of resolving the imbalances charged to participants of the market.

At the electricity exchanges, bids are usually placed by electricity generators, suppliers and traders for buying and selling. The demand and supply curves of the bids are usually used as a basis for the determination of prices and volumes of electricity supply. The power exchanges in this case serve as brokers, whereby they match submitted bids by generators to those of suppliers and initiate a trade whenever there is a match. Participants on the power exchanges are allowed to buy and sell electricity every half hour with different prices and volumes. This allows for the possible match of sales by generators to their likely output and suppliers to align their volume of purchases to meet customer demands. Even though most suppliers and generators buy/sell in the forward market, for a significant portion of their estimated volume, they use near-term day-ahead and intra-day markets to manage their imbalances. RES-E are particularly important as the recent volume of intermittent generation on the near term markets increases near term output variability especially in the UK market. In Britain for instance, as at 2015 over 40% of generated electricity is traded on exchanges (ICE, APX and N2EX).[11]

---

[11] (DECC report: Negative pricing in the GB wholesale electricity market available at) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/441809/Baringa_DECC_CfD_Negative_Pricing_Report.pdf.

2 Price-Quantity Correlation Coefficient Effect on Wind Energy Investments: A Gift of Nature?

2.1 Introduction

Investments in energy generation projects carry uncertainty due to the uncertainty of the government policies such as the changes in the levies on carbon emissions and taxes related to auctioning or the carbon trading system. The uncertainty underlying investment projects is higher for RES-E projects, for instance wind farms and solar PV, because, apart from the usual market price uncertainty, firms often face high output production uncertainty due to the uncertainty of the weather conditions (Reedman et al., 2006). In addition, renewable energy projects are also characterized by (irreversible) investment costs (see for instance, Graham et al., 2003).

The classical investment appraisal techniques such as the net present value (NPV), when applied to the timing optimization of the adoption of RES-E technologies, make the unrealistic assumption that, ex-ante, firms can estimate with some accuracy the project's future cash flows. This is hardly the case for RES-E projects because they face high uncertainty regarding both the energy prices and the energy production, the latter being dependent on the weather conditions.

Given the uncertainty that characterizes RES-E projects' profitability and monopolistic nature of these projects- given that firms do have to get a government permission to build a wind farm and, therefore, once they get approval for the project they hold a monopoly position on the investment decision, the real options methodology is an obvious good alternative methodology to the NPV. Under such conditions, firms have the option to defer the investment if it is not yet profitable and this flexibility (option) has value (see, e.g., Boomsma et al., 2012).

Since the seminal work of Black and Scholes (1973) and Merton (1973) the theory of option pricing has opened its doors to non-tradable (real) assets. The early works by Geske (1973) and Margrabe (1978) asserted the applicability of financial option pricing to real options and paved way for more comprehensive real option models. Although these earlier models are simpler and may lack more practical applications, the new generation of real option models were built on their concepts and ideas. Below are a few of those works which are still references for academic research.

McDonald and Siegel (1986) and Paddock et al. (1988) examine the option to defer investment, or initiate investment immediately. This option to defer is also known as the value of waiting, or the time value of a call option to invest. In general, we should defer exercising any option as long as its time value is above zero and until it reaches an optimal investment threshold level. McDonald and Siegel (1986) assumed that they undertake a project which is irreversible. They derive an analytical solution for the value of option to defer an investment project assuming that the investment cost, I, and the value of future cash flow from the project, V, follow a gBm process. Paddock et al. (1988) use the option valuation theory to develop a new approach for valuing leases for offshore petroleum, where the holder of an offshore petroleum lease has three stages: exploration, development and extraction. The leaseholder has a pre-determined number of years that allows investors to wait before beginning with the exploration and development of the project, meaning that the exploration and development stages are options to the leaseholder.

Majd and Pindyck (1987) also analyse the option value to delay irreversible investments, but where expenditures are made sequentially without exceeding a given maximum rate. They conclude that the effect of the time to build increases as the opportunity cost and uncertainty increase and as the maximum expenditure rate decreases.

There is also literature on the option to shut-down, or abandon. The concept behind this option is that firms or projects can be closed as soon as they start to incur losses which make profits impossible. Obviously, managers should monitor the profitability of the project and if the prices rise sufficiently, they can decide to restart it again. Brennan and Schwartz (1985) and McDonald and Siegel (1985) analyse investment projects with a shutdown option.

Another popular real option is the option to exchange, which exists when firms have the flexibility to switch to the use of inputs or outputs. For instance, an oil refinery can be designed to use alternative forms of energy so as to convert crude oil into a variety of output products. Margrabe (1978) studies the value of the option to exchange one risky asset for another. Carr (1988) combines the characteristics of compound and exchange options to analyse American sequential exchange options.

There is also a compound (real) option which is option on another option. Geske (1979) models a call option on stock that was seen as a European call option on the value of the firm's assets. A European call compound option is the right to acquire at maturity another option. A compound exchange call option is a call option that gives the right, but not the obligation, to buy a call option to exchange an asset for another. This is extremely useful for instance for research and development projects, where development of a new drug or commodity is often broken down into stages. Compound options can value growth opportunities far better, as they take into account earlier investment opportunities as prerequisites for the rest of the event opportunities to follow.

Later on, other authors such as Pindyck (1993), Trigeorgis, (1993, 1996),), Dixit and Pindyck (1994), Amram and Kulatilaka (1999) , Brennan et al. (2000), Grenadier (2000), Copeland et al. (2001) and Paxson (2015), also made relevant contributions in terms of improvements in terms of both analytical sophistication of the models and practical application. All the above contributions are devoted to monopoly markets.

Smets (1993) initiated a new branch of real options literature, named real option games, which consider competition for duopoly markets. Among the relevant contributions are Dixit and Pindyck (1994, ch. 9), Grenadier (1996), Lambrecht et al. (1997), Huisman (2001), Paxson and Pinto (2005), Pawlina and Kort (2006), and Mason and Weeds (2010). For recent literature review on real option games see Chevalier-Roignant et al. (2011) and Azevedo and Paxson (2014).

Furthermore, on the decision to invest in RES-E technologies, Cortazar et al. (1998) study the effect of output price uncertainties on the timing optimization of the adoption of environmental technologies and the main factors affecting the investment decision. They conclude that firms should only invest in environmental related technologies when output prices are much higher than the threshold at which NPV becomes positive so as to avoid being surprised by unfavourable moves in output prices. However, their real option model was not calibrated with parameters estimated from empirical data and was not applied to the evaluation of wind farm technologies. According to the real options literature, high output price volatility delays investments. The above model does not study the effect of the correlation between output price and output quantity.

Boomsma et al. (2012) use a real options framework to examine the timing of investments and the capacity choice of RES-E technologies under various support schemes. Their results apply to the Norway wind energy industry and show that FIT policy leads to earlier investment, whereas Quota policy encourages larger investments. In their analysis, even though they consider different uncertainties relating to the policy framework and the change of policy, for simplicity reasons, they also ignore the effect of the correlation between output price and output quantity on the investment timing. Armada et al. (2013) consider a two factor model and show that the larger the correlation between output price and output quantity, the later the investment. They highlight the importance of the correlation coefficient between two stochastic underlying variables of an investment project, and provide a few adjustments and complementary remarks to the Paxson and Pinto (2005) model.

Nagl (2013) studies the effect of weather uncertainty on the financial risk of energy producers for various regimes of government incentives. His results suggest that firms operating in strict emission restrictions tend to (optimally) reduce production so as to reduce carbon emissions, instead of investing in more sustainable technologies. His simulation results indicate that although all renewable energy producers are affected by significant variance in their profits, producers of wind energy may face a lower financial risk due to market integration, while solar and biomass are affected by higher financial risk as evidenced by higher variance in their profits. He also concludes that the negatively correlated variations in output and prices of green certificates are compensated by the price effect of weather uncertainty. In this analysis, however, he considers only one source of uncertainty (weather).

Abadie and Chamorro (2014) study the option value to invest in wind farm projects, where the option to invest has a finite life with potentially different investment incentive regimes. They show that energy market prices and renewable obligation prices raise the project value significantly and delay the wind farm investment. They emphasise on the significance of correlation by arguing that investors of marginal RES-E technologies could profit from the correlation effect between prices of electricity and generation output.

Adkins and Paxson (2016) study the real options value of a renewable energy technology considering output price and output quantity uncertainty, and the scenario where output production is subsidised by government. They conclude that when quantity volatility, correlation coefficient between price and production and subsidy size increase, the project's real option value (ROV) also increases. They also posit that as the correlation between output quantity and output price increase, the revenue volatility increases. They argue that the value of an RES-E investment depends on the expected volatilities of price, output and the subsidy, even though high subsidies might enhance investment.

In this chapter we apply an available real option model to two specific wind farm investment projects calibrating the model with parameters which are estimated from our empirical datasets (see Section 1.4), and neglecting the government's support schemes. It has been argued that RES-E technologies, especially wind farms, are gradually becoming more competitive and, therefore, government subsidies should be reduced or withdrawn (Jenner et al., 2013).

Our analysis applies to monopoly markets only, i.e., markets where the investor has the propriety over the option to invest and, therefore, can delay the investment if market conditions are not yet favourable without being afraid of being pre-empted in the market by competitors. Under such economic conditions, firms should invest not when NPV is positive but when NPV is higher than the value of the option to invest, otherwise value would be destroyed. Note that often firms also have the option to expand or reduce the size of the project, or abandon the project, flexibility which is neglected by the NPV methodology. Furthermore, the real options theory suits RES-E projects well because these projects face both output price and output quantity uncertainty.

This chapter relies on Paxson and Pinto's (2005) model, adjusted to a monopoly market and considering the Armada et al. (2013) remarks on the model. Therefore, our real option model considers the uncertainty of both the energy market prices and the energy (wind farm) production. Following Paxson and Pinto (2005), we assume that these two variables are stochastic and follow independent, and possibly correlated, gBm processes. Other stochastic process could be used for the two underlying variables. Yet, we follow Paxson and Pinto (2005) assumption for the gBm processes for the underlying variables for analytical convenience. For instance, Pindyck (1999) examines the long-run behaviour of spot energy prices and argues that over a period of 20 years there has been a slow mean reversion of prices. Yet, Boomsma et al. (2012) suggest gBm processes might be suitable processes for modelling energy prices; and Adkins and Paxson (2016) also assume that the value of RES-E projects follow a gBm process .

We use the real options model to illustrate the effect of the volatility of the output prices (daily energy spot price) and output quantity (daily energy production of a wind farm) as well as the correlation coefficient between these two variables on the investment threshold. We calibrate our model with parameters estimated from a datasets, which comprises information on daily spot energy prices and daily energy output production from a wind farm in the UK over the time period of January 2011 to December 2012. The data regarding the investment cost and the size of the project were collected from two wind farm projects, one of which has operated since 2009 and the other has operated since 2014.

We neglect the effect of technological progress. For models considering technology progress for monopoly markets, see for instance Elton and Gruber (1976) and Adkins and Paxson (2013). Huisman (2001) also considers technological progress but for duopoly markets. Our aim is to determine the value of the above projects, as well as to determine the optimal time to invest, calibrating the model parameters with our empirical data, and see if both the project which was adopted in 2009 and the project which was adopted in 2014 are profitable (for the recent project we have data on the investment cost and the installed capacity - see section 2.3.1 for a detailed description).

Our findings suggest that the correlation coefficient between the output price and the output quantity significantly affect firm investment behaviour. We show that the more negative the correlation coefficient the earlier (more profitable) the investment. Our results assert that the correlation coefficient is a very important factor in the evaluation of RES-E projects and might be volatile over time and heterogeneous amongst wind and solar panel farms.

Using our dataset, we compute the monthly correlation coefficients between output price and output quantity for the LIDO wind farm and conclude that it varies significantly over the time (see Table 2.5). Unfortunately, our dataset time period is not long enough to and so we cannot perform more robust statistical analysis. As expected, the more negative the correlation coefficient, the earlier is the investment. Consequently, we argue that, if the correlation coefficient changes from one wind farm to the other, it means that, *ceteris paribus*, wind farm sites that persistently exhibit more negative correlations are more profitable. Although there are renewable energy related literature which incorporates the above correlation coefficient in their analysis (see, e.g., Boomsma et al., 2012), none of the available literature quantifies the (monetary) value of the effect of a given percentage changes in the correlation between the output price and output quantity.

Furthermore, if the correlation coefficient is very heterogeneous amongst the wind farm sites, it means that this factor should be carefully taken into account in the evaluation of wind site locations and timing of the investments, and, ceteris paribus, firms should prefer wind farm sites which are more likely to exhibit more negative (or less positive) correlation coefficients. This finding can also have implications on the allocation of government subsidies.

We suggest that a major study on the correlation between output price and output quantity be performed for the all the wind and solar panel farms in the UK in order to determine the mean correlation coefficient for the whole country and the level of heterogeneity amongst wind and solar panel sites. Since wind and solar panel farms are not able to adjust production to fit with demand, if there are wind and solar panel farms which persistently exhibit more favourable correlation coefficient values, these are more valuable and the extra value they attain can be considered a gift of nature which has implications in the wind and solar panel sites selection.

The remainder of this chapter is organized as follows. Section 2.2 presents an overview of the impact of wind energy on the spot electricity prices. Section 2.3 derives a monopoly-version of the Paxson and Pinto (2005) model, adjusted for the remarks of

Armada et al. (2013). Section 2.4 describes the dataset and the two wind farm projects, one operating since 2009 and the other operating since 2013. Section 2.5 shows some illustrative results and sensitivity analysis. Section 2.6 concludes the chapter.

2.2 Wind Energy and Electricity Spot Prices

Wind energy is expected to play a significant role in the European electricity supply. The penetration level of wind energy in the EU is expected to be 14% and 28% by 2020 and 2030 respectively (see European Wind Energy Association, 2013). There has been significant penetration of wind energy capacity in the UK. Wind energy connected to the grid and those connected to local networks contributed to about 9.3% of the UK's energy supply in 2014. There is, however, significant variations in the generation in wind energy over time (see Figure 2.4 for the daily variation in electricity generation from the LIDO wind farm).

The use of intermittent for wind energy sources is debatable. When compared to conventional energy sources, wind energy does not shut regularly as the term suggest. Also, the transition to zero power from an operational wind farm is gradual since even in bad weather conditions, such as storms, it takes a while for the turbines to be shut down.[12]

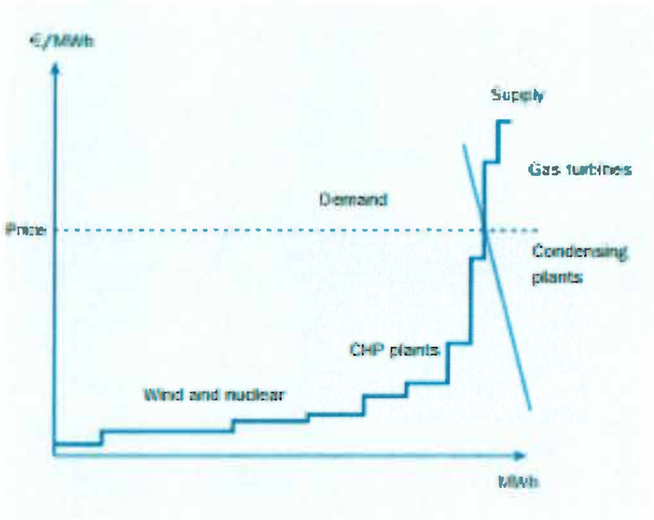
This variation in wind farms across location could have some economic benefits as suggested by this research. The time of electricity generation from wind and the location could have a significant impact on electricity prices. Electricity prices in the power markets is expected to be affected by electricity from wind energy in different ways according to (European Wind energy Association, 2009b). Figure 2.1 below shows the

---

[12] http://www.ewea.org/fileadmin/files/library/publications/reports/WETFExecutiveSummary.pdf

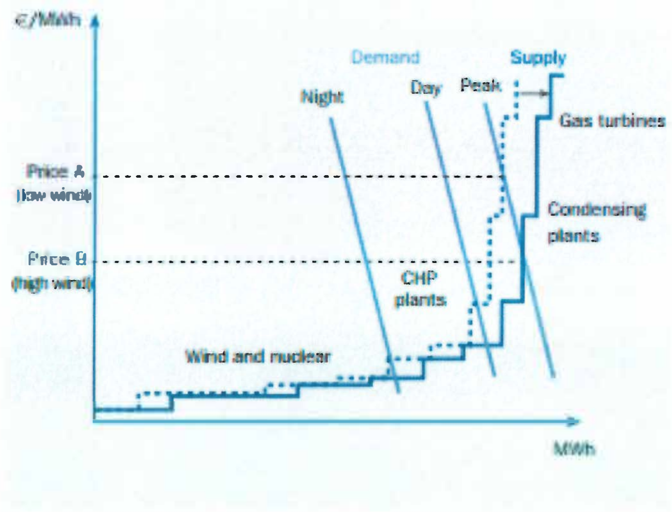
typical supply and demand curve from the NordPool power exchange while Figure 2.2 shows how wind power affects spot electricity prices at different times of the day. In Figure 2.3, the impact of wind power on the spot power price in the West Denmark power system in December 2005 is shown. All figures are adapted from (European Wind Energy Association, 2009b).

Figure 2.1: Supply and Demand Curve for the NordPool Power Exchange



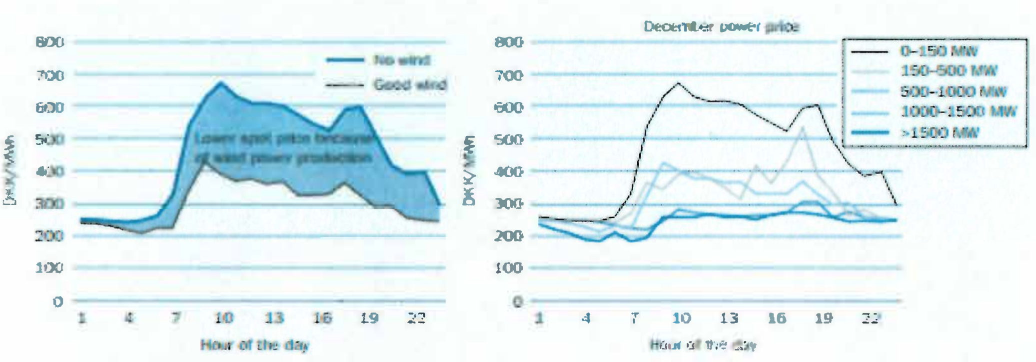
Source: Adapted from European Wind Energy Association, 2009.

Figure 2.2: How wind power influences the power spot price at different times of day



Source: Adapted from European Wind Energy Association, 2009.

Figure 2.3: The impact of wind power on the spot power price in the west Denmark power system in December 2005



Source: Adapted from European Wind Energy Association, 2009.

Wind energy usually has a zero fuel cost resulting in a lower marginal cost, hence, enters the supply curve at the lowest level. This causes a shift in the supply curve to the right ass seen in Figure 2.1 above, depending on the price elasticity of demand, and cause a reduction in electricity prices when production from wind sources increase during peak periods. When this happens, a price reduction from A to B occurs according to Figure 2.2 above. This is known as the "merit order effect" when high period of high winds are expected to reduce the prices of electricity while period of low winds are expected to increase prices according to the report. Also, during congestion in the supply of power in an area, conventional generation sources are usually required to reduce their supply since it is not economically or environmentally appropriate to shut down or reduce electricity generation from wind turbines, which usually leads to lower power prices.

While Figure 2.1 shows increase in the supply of wind energy causes a shift in the supply curve and result in lower electricity prices, it is worthy to note that this effect depends on the time of the day. For instance, high winds during the day and peak power demand will lead to almost all electricity generated from wind sources be used. From Figure 2.2, when this happens, the electricity generation from wind will be at the vertical point of the supply curve and will significantly reduce electricity price from A to B. On the other hand, at a location where high winds come at night when demand is considerably low, electricity production from wind sources will not have that significant impact on prices since most of the electricity produced would be on based load plants, as seen at the down part of the supply curve in Figure 2.2.

This scenario was further reiterated by the report where they presented two approximations of the value of wind energy in terms of lower spot power prices in west Denmark (which is not interconnected with east Denmark) in the left hand side of Figure 2.3, and also in the right-hand side of Figure 2.3, a more detail of the figures from the west Denmark area with five levels of wind power production and their corresponding hourly power prices during December 2005.

They gave a reference of '0-150 MW' curve, which approximates those hours of the month when the wind was not blowing. They show that in this particular area in Denmark, increasing levels of electricity production from wind during the day significantly reduces spot electricity prices, and slight reduction during the night. This means that there is a significant impact of electricity production from wind energy and the spot electricity prices, hence, the correlation between output and output price is expected to vary across locations with a significant impact on the investment decision and site optimisation.

2.3 The Model

In our model we assume that the instant cash flow from the investment is the selling of electricity produced from the wind farm in the competitive market in the absence of a support scheme. The revenue from the investment in a wind farm facility is the market spot price of electricity multiplied by the electricity produced from the facility, and there is no additional operating cost from operating the wind farm or there is a fixed operating cost embedded in the initial investment cost.

Furthermore, the wind farm starts operating at the instant the investment is made and we neglect the existence of subsidies, taxes and depreciation. The life time of the project is assumed to be infinite and there are no abandonment, suspension, expansion and/or contraction options. Finally, we assume that output price and output quantity follow independent gBm processes and are possibly correlated.[13] As noted by Adkins and Paxson (2016), it would perhaps be realistic to relax some of the above assumption but that would lead to a significantly more complex model and very complex numerical solutions turning the model much less practical or even not useful in practice.

Let us assume that a firm operates in a risk neutral world and the value of the project represented by F is driven by two underlying variables $P(t)$ and $Q(t)$ which represent the energy market price and the energy produced by the wind farm at a given time t,

---

[13] We note that electricity prices may be mean reverting and hence solutions using the Kummer function as shown in Dockendorf and Paxson (2010) may be appropriate instead of gBm when electricity prices reverts to the mean as suggested by Adkins and Paxson (2016).

respectively. Assume also that both of these variables follow independent and possible correlated gBm processes given by: [14]

$$dP = \alpha_P P dt + \sigma_P X dz_P \tag{2.1}$$

$$dQ = \alpha_Q Q dt + \sigma_Q Q dz_Q \tag{2.2}$$

$$E[dZ_X \cdot dZ_Y] = \rho dt \tag{2.3}$$

where α_P and α_Q correspond to the instantaneous drift rates of P and Q, respectively; σ_P and σ_Q are the instantaneous volatility of P and Q, respectively; and dz_P and dz_Q are the increment of a standard Wiener process for P and Q, respectively; and ρ is the correlation coefficient between the variables P and Q.

Following Adkins and Paxson (2011) we derive the value of any contingent claim asset on two stochastic factors modelled as a gBm process without invoking homogeneity of degree one. Accordingly, an idle firm before investing holds the option to invest which in a context of energy output price and energy output quantity uncertainty has value.

Let $F = f(P,Q)$ be the firm's value before investing which is equal to the value of the option to invest. Under the assumption of complete markets F is the solution to the following partial different differential equation:

---

[14] For simplicity of notation, henceforth, we drop the *t*.

$$\frac{1}{2}\sigma_P^2 P^2 \frac{\partial^2 F}{\partial P^2}+\frac{1}{2}\sigma_Q^2 Q^2+\frac{\partial^2 F}{\partial Q^2}+\rho\sigma_P\sigma_Q PQ\frac{\partial^2 F}{\partial P\partial Q}+\left(r-\delta_P\right)P\frac{\partial F}{\partial P}$$
$$+\left(r-\delta_Q\right)Q\frac{\partial F}{\partial Q}-rF=0 \tag{2.4}$$

where $\delta_P=\mu_P-\alpha_P$, $\delta_Q=\mu_Q-\alpha_Q$, with μ_P and μ_Q given by Equations (2.5) and (2.6), respectively:

$$\mu_P=r+\lambda\rho_{pm}\sigma_P \tag{2.5}$$

$$\mu_Q=r+\lambda\rho_{Qm}\sigma_Q \tag{2.6}$$

where $\lambda=(r_m-r)/\sigma_m$ is the market price of risk, ρ_{Pm} and ρ_{Qm} are the correlation coefficients between P and Q with the market, respectively, and σ_m is the market volatility.

Following McDonald and Siegel (1986), Paxson and Pinto (2005) and Adkins and Paxson, (2011, 2016), the homogeneous part of Equation (2.4) has the following general solution:

$$F=AP^{\beta}Q^{\eta} \tag{2.7}$$

where β and η are the roots of an elliptical characteristic equation:

$$Y(\beta,\eta)=\frac{1}{2}\sigma_P^2\beta(\beta-1)+\frac{1}{2}\sigma_Q^2\eta(\eta-1)+\rho\sigma_P\sigma_Q\beta\eta+(r-\delta_P)\beta+(r-\delta_Q)\eta-r=0 \tag{2.8}$$

These roots form four quadrants, depending on their signs, which suggest a specific solution to the homogeneous part of Equation (2.4):

$$F = A_{11}P^{\beta^+}Q^{\eta^+} + A_{12}P^{\beta^+}Q^{\eta^-} + A_{13}P^{\beta^-}Q^{\eta^+} + A_{14}P^{\beta^-}Q^{\eta^-} \tag{2.9}$$

Given the absorbing barriers, $F(0,P)=0$, $F(0,Q)=0$ and $A_{12}=A_{13}=A_{14}=0$. On the other hand, $A_{11}>0$ since if the value of the investment project increases infinitely, the option exercise price becomes negligible (i.e., $F(P,\infty)=F(\infty,Q)=\infty$).

The value matching condition is given by:

$$A_{11}P^{\beta^+}Q^{\eta^+} = \frac{P^*Q^*}{\delta_R} - I \tag{2.10}$$

The value matching condition has two smooth pasting conditions:

$$\beta^+ A_{11}P^{*\beta^+-1}Q^{*\eta^+} = \frac{P^*}{\delta_R} \tag{2.11}$$

$$\eta^+ A_{11}Q^{*\beta^+-1}Q^{*\eta^+-1} = \frac{Q^*}{\delta_R} \tag{2.12}$$

Equations (2.11) and (2.12) imply that $\beta^+ = \eta^+$, which reduces the elliptic Equation (2.8) to a quadratic equation:

$$Q(\beta) = \frac{1}{2}\sigma_R^2\beta(\beta-1) + (r-\delta_R) - r = 0 \tag{2.13}$$

where $\sigma_R^2 = \sigma_P^2 + \sigma_Q^2 + 2\rho_{PQ}\sigma_P\sigma_Q$, see, Paxson and Pinto (2005) and Armada et al. (2013).

This enables us to find out a solution for the pair of trigger values:

$$P^*Q^* = R^* = \frac{\beta^+}{\beta^+-1}\delta_R I \tag{2.14}$$

where $\delta_R = \delta_P + \delta_Q - \rho_{PQ}\sigma_P\sigma_Q - r > 0$, and β^+ is the positive root of the quadratic equation (2.13):

$$\beta^+ = \frac{1}{2} - \frac{r-\delta_R}{\sigma_R^2} + \sqrt{\left(-\frac{1}{2} + \frac{r-\delta_R}{\sigma_R^2}\right)^2 + \frac{2r}{\sigma_R^2}} \tag{2.15}$$

For each value of P^* there is Q^* which makes the investment optimal, at which the revenue is R^*. The value of the investment project is therefore given by:

$$F(P,Q) = \begin{cases} \dfrac{I}{\beta^+ - 1}\left(\dfrac{PQ}{R^*}\right)^{\beta^+} & \text{if} \quad PQ < R^* \\ \dfrac{PQ}{\delta_R} \text{ - } I & \text{if} \quad PQ > R^* \end{cases} \tag{2.16}$$

The upper branch of Equation (2.16) represents the value of the project before investing (the option value), whereas the lower branch represents the value of the project after investing. Below we provide our dataset and sensitivity analysis.

2.4 Data Sample

2.4.1 The Lincs Offshore Wind Farm Project

In this section we describe our dataset which is collected from two wind farm projects: the Lynn/Inner Dowsing offshore (LIDO), located at Skegness, and the Lincs Offshore (LO), located on the Lincolnshire coast, managed by Centrica Energy, Plc and Centrica & Dong Energy, Plc, respectively.[15] The LIDO project was initially planned to be two separate projects named as Lynn and Inner Dowsing and to be situated adjacent to each other.

However, Centrica Energy acquired the licence and merged them into a single project with a single investment cost. The LIDO project started operations in March 2009, with 54 wind turbines, and provides energy power to meet the annual demand of about 130,000 homes, whereas the LO project is yet under construction - it is planned to comprise 75 wind turbines and provide energy power to meet the annual demand of 200,000 homes and based on a new wind farm technology promoted by Siemens (the developer) as more efficient than that used in the LIDO project. Below we provide further details about the two projects (Tables 2.1 and 2.2 below).

---

[15] Centrica Energy is one of the largest energy power producers in the UK and committed to reducing its UK power generation carbon intensity to 260g CO2 per kWh by the year 2020. To cope with this goal Centrica Energy has made substantial investments on renewable energy projects, owning several wind farms in the UK (see www.centrica.com).

Table 2.1: Technical Information of LIDO Wind Farm

This table provides technical information on the Lynn/Inner Dowsing wind farm project owned by Centrica Energy, Plc, which started operations in March 2009.

Project 1- Lynn/Inner dowsing offshore (LIDO) wind-farm	
Installed Capacity	194.4 MW
Scope of supply	54xSWT-3.6-107
Distance to shore	5-6 Km
Operator	Centrica Energy
Location	Lynn/Inner dowsing
Cost	£350,000,000

Table 2.2: Technical Information of LO Wind Farm

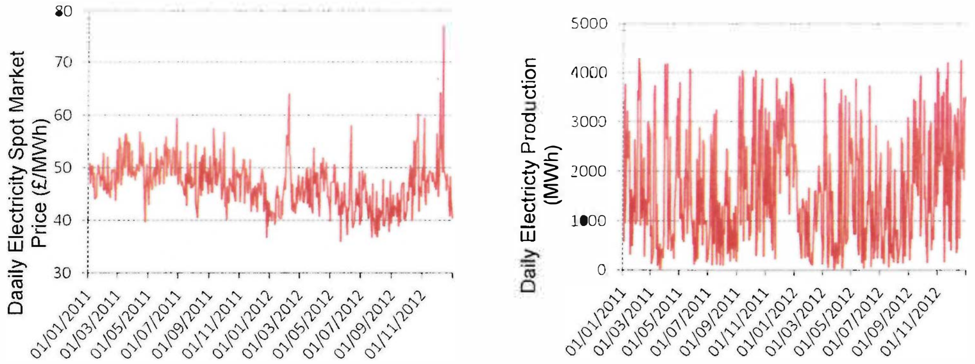
This table contains information about the Lynn/Inner dowsing wind-farm project of Centrica, Dong Energy, Plc.

Project 2 - Lincs Offshore (LO) Wind-Farm	
Installed Capacity	248.4 MW
Scope of Supply	75x SWT-3.6-120
Distance to Shore	9 km
Operator	Centrica Energy & DONG Energy
Location	East Coast of England, North Sea
Cost	£450,000,000

While the LIDO project is 5-6 km offshore, LO project is 9km offshore. The initial investment cost for LIDO and LO are £350,000,000 and £450,000,000 respectively. The installed capacity for LIDO is 194.4MW while that of LO is 284.4MW. Figure 2.4 below shows the evolution of the UK daily average electricity spot market prices (graph on the left-hand side) and the daily energy power production of Centrica Energy's LIDO wind-farm project (the graph on the right-hand side), for the period between January 2011 and December 2012.

Figure 2.4: Daily Average Electricity Spot Prices and Daily Electricity Production from LIDO Wind Farm

This figure shows the daily energy prices per MWh for the UK market (graph on the left hand-side) and the Centrica Energy's daily energy power production for the LIDO project (graph on the right hand-side), for the period between January 2011 and December 2012.

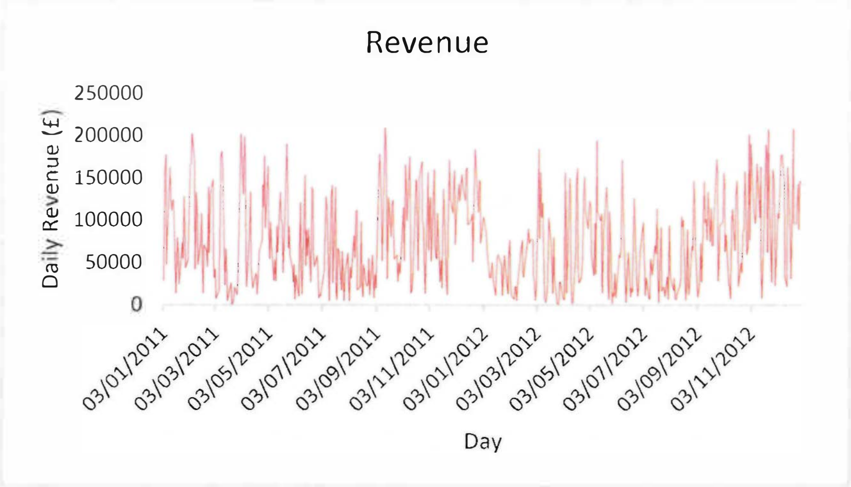


The daily electricity production data for the LIDO wind farm was obtained from Centrica energy, UK. We first requested five years data in March, 2012 and Centrica only provided us with one year's data, covering the beginning of January 2011 to the end of December 2011, with the explanation that such data is sensitive, making it impossible to provide us with all the requested years. We subsequently requested additional data for the same wind farm in April 2013, whereby they provided us with one year's additional data covering the beginning of January 2012 to the end of December 2012. Data was provided for the two separate wind farms Lynn and Inner Dowsing, which are both the same project but adjacent to each other. We add the data together to attain the complete daily production of the LIDO wind farm.

The daily average spot electricity prices was collected from DataStream on the APX spot power market in the UK. We use the Reuters commodity market price index as a proxy for the market. The time period was the same for all data (2011- 2012).

Figure 2.5: Average Daily Revenue from Daily Electricity Production

Daily Revenue from Daily Energy Generation - this figure shows the Centrica Energy's (LIDO) daily revenue (£) for the period between January 2011 and December 2012. This graph is obtained by multiplying the daily average electricity prices per MWh (£) by the (LIDO) daily electricity power production (MWh)



If we multiply "daily average electricity prices per MWh" by "daily electricity power production" we obtain Centrica Energy's daily revenues for the LIDO project, shown in Figure 2.5 above. We appreciate the fact that there is significant variations in hourly electricity prices, however, due to the difficulty in assessing hourly production data we use the daily production data and average daily spot price of electricity to determine the revenue. The information provided in Figure 2.4 shows that the daily electricity power production of a wind farm and the daily average electricity prices are volatile, which affects the daily revenue of Centrica Energy.

Table 2.3: Descriptive Statistics of Data

This table shows the mean, maximum and minimum of the daily electricity spot market price (£/MWh), and the daily electricity production (MWh), daily revenue (£), sample observations (N), skewness, kurtosis, covariance and correlation coefficient between the electricity spot market price and the electricity production.

	Daily Energy Spot Market Price (£/MWh)	**Daily Production (MWh)**	**Daily Revenue (£)**
Mean	47.46	1 ,623.21	75,004.82
Maximum	77	4,276.38	208,684.20
Minimum	36.05	0	0
N (days)	521	521	521
Skewness	0.815549	0.4718769	0.5179451
Kurtosis	3.3688125	-0.9363683	-0.78143
Covariance (PQ)	-0.03108		
Correlation Coefficient:	**-0.23**		

The mean of the daily energy spot market price for the sample time-period is £47.46 per MWh, with a maximum and a minimum of £77.00 per MWh and £36.05 per MWh, respectively, and the mean of the daily energy production is 1,623.21 MWh, with a maximum and a minimum of 4,276.38 MWh and 0 MWh, respectively.[16] The difference between the minimum and maximum values is expected due to the variations in the daily output price and output production. The mean daily revenue is £75,004.82, with a maximum and a minimum of £208,684.19 and £0, respectively.

The above results show that the energy spot market price and the energy production of the LIDO wind farm are quite volatile and have a negative correlation coefficient of -0.23. Due to the spikes and seasonality in daily prices and production, we use the annual

---

[16] Our dataset shows that on 16th June 2011 the energy power production was nil. We investigated the reasons for this outlier and found that the stop in production was due to maintenance reasons and not as a consequence of lack of wind. We took this outcome out of our sample when estimating the model parameters.

variation in electricity prices and output production for the same period as proxy for volatility which is presented in Table 2.4 below.[17] According to European Wind Energy Association (2009), the long term production of wind farms is normally distributed. From our dataset, the daily electricity price, electricity production and revenue are positively skewed indicating that the mean is higher than the mode of the distribution. This is expected since there is evidence of spikes in daily production and daily prices data according to economic theory. These variables are estimated from our dataset and are based on 521 observations (days).

2.5 Results and Sensitivity Analysis

In this section, we study the sensitivity of the real option value and investment threshold to changes in the most relevant model parameters. We compute the current value and the investment threshold of the LO wind farm of Centrica using our real option model with some of its parameters: energy market spot prices, energy market price and output volatilities, energy price and output quantity growth rates, as well as the investment cost, collected from the LIDO wind farm project, for between January 2011 and December 2012.

---

[17] According to European Wind Energy Association (2009), the annual and inter annual wind farm variation is similar across Europe with a standard deviation not exceeding 20% for a single farm.

2.5.1 Data Parameters

Table 2.4: Model Parameters

This table provides information on the base inputs used in our real option model.

Firm's value (M£)	F(XY)		422.56
RO value (M£)	ROV		422.59
Threshold	**R***		**28.2**
Output price/unit (M£/MW)	P		**0.00004746**
Output units/annum (MW)	Q		**592,395**
Current annual revenue (£)	**R**		**28.1**
Investment cost (M£)	I		**450**
Price per unit drift, μP	α_P		**0.02**
Output units drift, μQ	α_Q		**-**
Riskless rate, r	r		0.05
Market Risk	$\mathbf{r_m}$	-	**0.04**
Market price of risk	λ	-	0.58
Volatility of output units (P)	$\boldsymbol{\sigma_P}$		**0.06**
Volatility of price (Q)	$\boldsymbol{\sigma_Q}$		**0.11**
Variance of Market	$\sigma^2{}_m$		0.02
Volatility of Market	$\boldsymbol{\sigma_m}$		**0.15**
Volatility of R	σ_R		0.11
Variance of R	$\sigma^2{}_R$		0.01
	δ_R		0.03
	δ_P		0.03
	δ_Q		0.05
	μ_P		0.05
	μ_Q		0.05
Correlation P,Q	ρ_{PQ}	-	**0.23**
Correlation P,m	ρ_{Pm}	-	**0.01**
Correlation Q,m	ρ_{Qm}		**0.01**
Beta plus	β+		2.08
PV (M£)			873
NPV (M£)			423

Note: The inputs in "bolt" were estimated using the dataset we collected from Centrica, Plc, and from market data.

The data on the variables I, P, Q, μ_P, σ_P, σ_Q, σ_m, r_m, ρ_{PQ}, ρ_{Pm} and ρ_{Qm} were collected from an active project of Centrica, Plc and from market data. We devote our attention to two of Centrica's wind farm projects. One has been operating since 2009 and we analyse data on the daily output production and investment cost. The other project, which was under construction as at 2013 and now operational for which we also obtained the investment cost. Therefore, our goal in this chapter is to use the empirical data available from the LIDO wind farm which was operational since 2009, to evaluate whether the investment in the second wind farm project was profitable or not.

We are mainly concerned with the effects of ρ_{PQ}, ρ_{Pm} and ρ_{Qm} on the real option value and the investment threshold (R^*). This is for two main reasons: one, previous literature on real options (i.e., Paxson and Pinto, 2005), has highlighted the importance of the correlation between output price, P and output quantity, Q (ρ_{PQ}) on the timing of investment decisions where the future evolution of P and Q are uncertain. Two, from our brief discussions with the managers from Centrica, we acknowledge that ρ_{PQ} has not been taken into account in project evaluations due to the availability of subsidies.

The point we want to raise in this chapter is that: (i) as shown by the real options literature, the correlation should be taken in to account; (ii) the consideration of ρ_{PQ} in the evaluation of wind farm projects is essential, and much more important than for other projects where P and Q are driven by markets. This is because for most commodities ρ_{PQ} is negative and stable over time due to the law of demand-supply, whereas for wind energy the (usual) demand-supply relationship may not always hold, and is likely to differ from wind site to wind site, because it depends on the weather conditions. Consequently, our goal is to stress on the relevance of Paxson and Pinto (2005) model, adjusted according to the Armada et al. (2013) remarks. Our findings show that the value of wind farms is very sensitive to changes in ρ_{PQ}. We argue that this finding should be taken into account in the wind farm site selections and firms should select the sites which are more likely to exhibit lower correlation coefficients. Below we present the correlation coefficients between the output price and the output production for the LIDO wind farm per month.

Table 2.5: Monthly Correlation Stability

This table reports the monthly correlation between electricity production from LIDO wind farm and spot electricity price.

Month	Correlation
January 2011	-0.12
February 2011	-0.12
March 2011	-0.50
April 2011	-0.48
May 2011	-0.55
June 2011	0.06
July 2011	-0.63
August 2011	-0.53
September 2011	-0.40
October 2011	-0.62
November 2011	-0.74
December 2011	-0.39
January 2012	-0.50
February 2012	-0.73
March 2012	-0.24
April 2012	-0.60
May 2012	-0.20
June 2012	0.08
July 2012	-0.36
August 2012	-0.03
September 2012	-0.10
October 2012	-0.48
November 2012	-0.29
December 2012	-0.40

Source: Own computation from dataset

From Table 2.5 above, we conclude that the monthly correlation between the electricity production from the LIDO wind farm and the electricity price varies significantly across months. While the correlation coefficient for January and February 2011 were stable at -0.12, that of March 2011 was -0.50. The highest correlation coefficient in our sample was

June 2011 of 0.06 while the least was -0.74 in November 2011. Below we provide some sensitivity analysis regarding the real option model.

2.5.2 Sensitivity Analysis

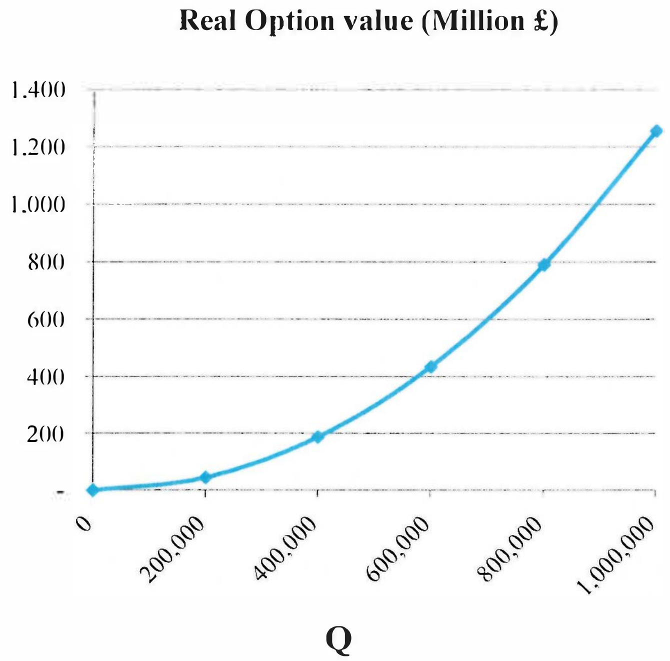
From our dataset, we can see that the wind conditions are very volatile in the LIDO's wind farm, and thereby affecting its production. This weather-related uncertainty affects the production of energy and must be taken into account in the evaluation of wind farm projects.

Table 2.6: Sensitivity of ROV and the Investment Threshold to Changes in the Output Quantity, Q.

P	0.00004746	0.00004746	0.00004746	0.00004746	0.00004746	0.00004746
Q	-	200,000	400,000	600,000	800,000	1,000,000
PQ (or R)	-	9.49	18.98	28.48	37.97	47.46
ROV	-	44.07	186.57	433.96	728.88	1,256.95
R*	27.90	27.90	27.90	27.90	27.90	27.90

Figure 2.6: Sensitivity of the ROV to Changes in Output Quantity

This figure illustrates graphically the results stated in Table 2.6 above.



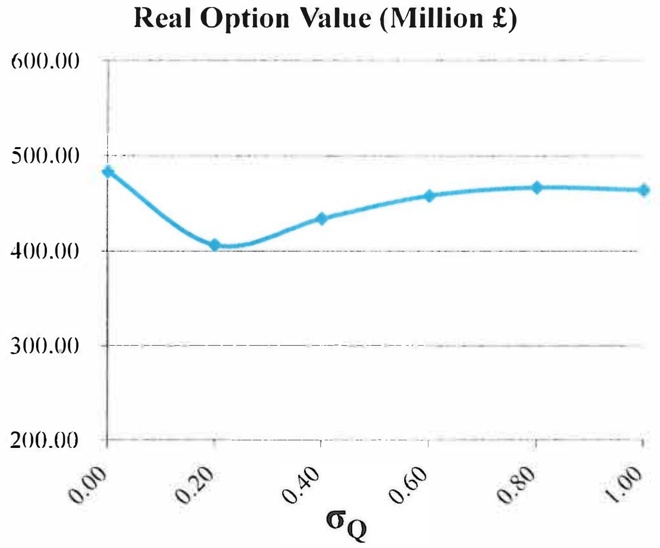
As expected, the above result shows that the higher the electricity production from wind farm the higher the real option value. From Table 2.6 above, we observe that when output quantity increases from 200,000 MWh to 400,000 MWh, R increases from 9.49 million to 18.98 million leading to an increment in ROV from 44.07 million to 186.57 million.

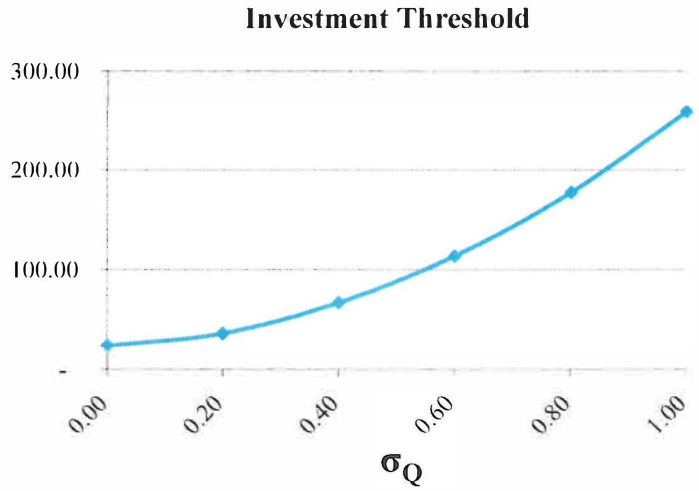
Table 2.7: Sensitivity of the ROV and the Investment Threshold to Changes in the Output Quantity Volatility, σ_Q.

σ_Q	-	0.20	0.40	0.60	0.80	1.00
σ_P	0.06	0.06	0.06	0.06	0.06	0.06
ROV	483.60	406.80	434.14	458.30	466.67	463.99
R	28.10	28.10	28.10	28.10	28.10	28.10
*R**	*24.40*	*36.40*	*66.90*	*113.60*	*177.30*	*258.70*

Figure 2.7: Sensitivity of the ROV and Investment Threshold to Changes in Output Quantity Volatility

These two figures below illustrates graphically the results stated in Table 2.7 above.

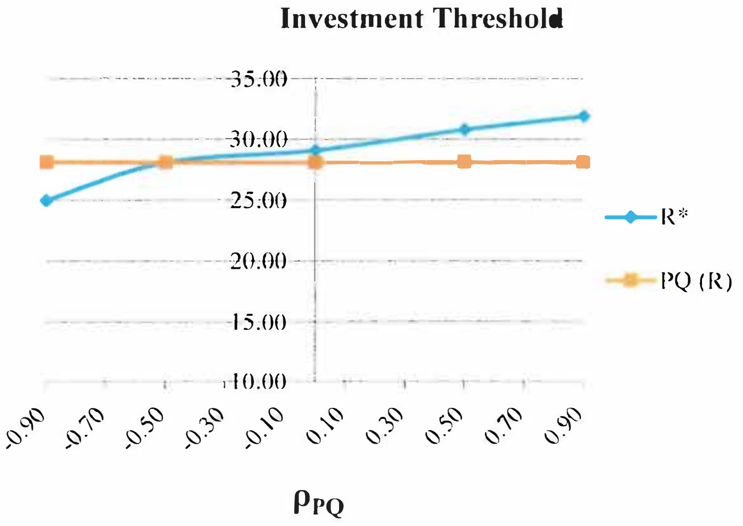




The above results show that the output quantity volatility affects both the ROV and the investment threshold. However, the effect of the output quantity volatility on the investment threshold is monotonic (the higher the volatility the higher the investment threshold, whereas the effect of the output price volatility on the ROV is not monotonic. More specifically, for low volatility; increases in the volatility decreases the ROV and, for higher volatility; increases in the volatility increases the ROV. This latter result although counterintuitive is due the negative value of the correlation between the output price and the output quantity- $\rho_{PQ} = -0.23$) -see our model base input parameters in Table 2.4 and is explained with further detail in Armada et al. (2013, p. 514).

Figure 2.8: Sensitivity of the Investment Threshold to Changes in the Correlation between Output Price and Output Quantity.

This figure shows the sensitivity of the investment threshold, R^*, to changes in the ρ_{PQ}. It also shows the underlying variable ($PQ = R$) value and how it relates to the evolution of R^*.

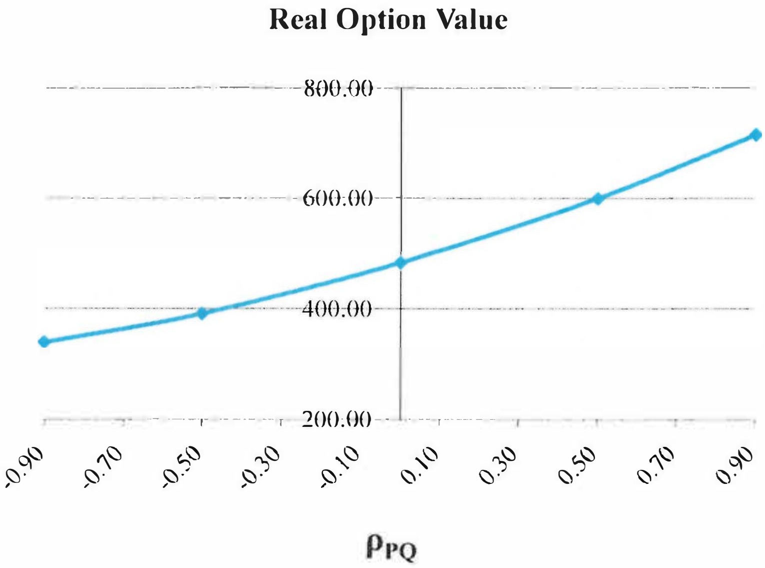


The horizontal line represents the current value of the project, which if crosses the investment threshold line (R*) the first time suggests Centrica Plc to invest and otherwise defer. Analysing the investment decision as a function of ρ_{PQ}, we conclude that the threshold value increases with ρ_{PQ} and, *ceteris paribus*, when $\rho_{PQ} > -0.32$, Centrica should defer the investment, and otherwise should invest. According to our dataset

$\rho_{PQ} = -0.23$, and, *ceteris paribus*, Centrica should not invest. Below we show the effect of the ρ_{PQ} on the real option value.

Figure 2.9: Sensitivity of the ROV to Changes in Correlation between Output Price and Output Quantity.

This figure shows the sensitivity of ROV to changes in the ρ_{PQ}.



The above results show that the ROV is very sensitive to changes in ρ_{XY} - the higher the correlation the higher the ROV. The above results suggest that the correlation coefficient can work as a hedging factor in wind farm projects, accelerating investments if it is more negative. This means that wind farm investors, when evaluating renewable energy projects using a real options approach, should consider the correlation between spot market price and electricity production, and when selecting wind farm sites should choose those which are expected to exhibit more negative correlations between electricity spot price and electricity production.

Table 2.8: Evaluation of LO Project and Investment Decision

This table shows both the value of the current underlying variable of the project (R) and the project's investment threshold (R*), for the base inputs of the model (see Table 2.4).

Parameter	**Value**	**Decision**
R (million £)	28.1	$R < R^*$ - **Therefore, delay Investment!**
R^* (million £)	28.2	

The above results show that under the economic conditions illustrated in Table 2.4, Centrica Plc should not have invested in the LO wind farm. Our results show that it was not optimal to invest. Yet, we highlight the fact that, according to the above results the project is only marginally unprofitable and that we neglect the government's support schemes. Consequently, we can conclude that this particular project would not have been sufficiently profitable without the government's support schemes. Our results show that the support schemes received by Centrica Energy on this project are more or less equivalent to the expected profit from the project and, therefore, surely have played an important role in the investment decision of Centrica Energy.

2.6 Conclusion

Investment in wind farms is characterised by high irreversible initial investment cost and uncertainty about the future cash flows. For such economic environment, the real options methodology has proved to have advantages over the classical investment techniques, such as the NPV. We use the Paxson and Pinto (2005) model, adjusted to a monopoly market and considering the remarks of Armada et al. (2013), to evaluate a wind farm investment. Our goal was to see if Centrica Plc should have invested in a wind farm which it is currently operating had it used our real options model and considering the technical and market conditions at the time. Our results show that Centrica Plc decision to invest was wrong, although the project was only marginally below the investment threshold. In addition, we show that a rise in the volatility of both output prices and output production delays the investment, since it increases the investment threshold, and the more positive the correlation between the spot electricity market price and electricity production from wind farm, the later the investment. In our results and sensitivity analysis $\rho_{PQ} = -0.23$ and we note the fact that a moderately more negative correlation value would make the investment profitable. Confronting this results with the information in Table 2.5, we conclude that the correlation value can play an important role on investment decisions since it can work as a hedging factor if more negative - i.e., the more negative correlation the earlier the investment in wind farms.

To our best knowledge, the importance of the above correlation coefficient in the evaluation of renewable energy projects is being neglected by both renewable energy firms and government when designing subsidy policies. We assume that the correlation value above (-0.23) is stable over time and homogeneous amongst wind farms, which is hardly the case. It would be interesting, therefore, to collect a major data sample with information on electricity production from all wind farms in the UK and determine for each the correlation coefficient between the spot electricity market price and their respective electricity production and perform a benchmarking analysis to identity the wind farm sites which persistently exhibit more negative correlation coefficients, if there are any. It might be possible that there are wind farm sites with much more favourable correlation coefficient and, if so, these are receiving a gift of nature.

3 Data Sample and Empirical Framework for Chapters 4 and 5

The analysis in Chapter 2 indicate that in the absence of government support schemes, investment in RES-E technologies could be unprofitable especially when the effect of correlation between output production and output prices is not considered during the selection of sites. Therefore, the growth in RES-E in the EU could be attributed to support policies implemented among governments. In Chapters 4 and 5 of this thesis, we examine the impact of RES-E policies on capacity development in the EU. This chapter presents an overview and description of the methodology and data sample we use to examine the impact of RES-E policies on capacity development in the EU. While the model and estimations are introduced more thoroughly in the respective chapters, we provide an overview in this chapter. We provide description of our policy data and control variables in this chapter and their expected impact on capacity development.

3.1 Data Sample

We compile country specific and technology specific cumulative (CC) and annual wind energy and solar PV capacity data for 27 EU countries. Malta is excluded from the sample due to incomplete data. We also identify the dominant policies implemented by EU countries to enhance wind energy and solar PV capacity development. We collect country specific and technology specific policy data from different policy documents to form a national policy database for all the countries in our sample. Our study period is from 1992-2013; a period through which different policies were implemented to encourage RES-E deployment so as to meet the renewable obligation of member states. We source information for our policy data from the IEA Policies and Measures Database (IEA, 2014) which contains information on countries from 1974 onwards. Information such as the date of enactment of a policy in a particular country and date a policy is revoked or amended if any is provided (see Appendix, AC3 Figure 1 for a diagram of changes in policy among countries). It also provides information on the type of technology being supported with a particular policy as well as eligibility criteria.

The information on the IEA Policies and Measures Database (IEA, 2014) also includes analysis of the amount of tariff available for RES-E technologies supported in a given county at a given time as well as the number of policies implemented in a country to support technology specific RES-E. This information allows us to determine the specific dates support policies were implemented to enhance technology specific capacity development and to also determine the experience of the policy in a particular country. In cases where IEA does not provide all relevant information, we supplement the data with information from Huber et al. (2004) and Haas et al. (2011) to get a complete policy database for all countries and years in our sample. For Chapter 5, our main focus is the *FIS* policy and hence we gather information such as generosity of the policy, policy enactment date, and digression rate of the policy, changes or cancellation of the policy. [18]

We also include other additional explanatory variables which according to the literature could have an impact on capacity development of wind energy and solar PV. All explanatory variables, their sources, justification for their inclusion and expected impact on capacity development are explained in the sections below. The application of the

---

[18] See Table 3.3 for the policies adopted by countries in the EU and their respective enactment dates and Table 3.4 for summary of the relevant policies and how they support RES-E development.

policy data to determine its effectiveness, their descriptive statistics and preliminary analysis and specification test for reliability are presented in the respective chapters.

3.1.1 Dependent Variables

The choice of dependent variable for the measurement of RES-E development varies among researchers in the literature. While some researchers consider actual generation or total energy supply for the measurement of RES-E development, others measure RES-E development as either added capacity Menz and Vachon (2006), Jenner et al. (2013) and Dombrovski (2015), cumulative capacity Dong (2012), Carley (2009) and Bolkesjø et al. (2014) or percentage of RES-E to total electricity generation Marques et al. (2010, 2011) and Marques and Fuinhas (2011b). We use two dependent variables to capture different aspects of the effectiveness of RES-E policies on wind energy and solar PV capacity development -i.e. CC and AC in chapter 4, and AC in chapter 5.

The CC dependent variable is the annual cumulative capacity of wind or solar PV installed in a given country at the end of each year, while AC is the total capacity of wind or solar energy installed in a given country at the end of each year. In other words, AC could be described as the difference between two continuous cumulative capacities of wind or solar PV in a given country. Justification for using CC and or AC as dependent variables are presented in Chapters 4 and 5. Data for CC and AC for wind and solar PV were collected from (Eurostat-Statistical Office of the European Commission, 2014).

3.1.2 Independent Variables

The main focus of the study is the renewable energy policy related variables, which remain our main independent variables. However, we control for other factors that could explain the development of wind and solar PV in the EU. Therefore, consistent with the literature, our independent variables are grouped into four different categories below:

i) Country specific RES-E policies.
ii) Socio economic factors.
iii) Political factors.
iv) Environmental factors.

3.1.2.1 Country Specific RES-E Policies

As mentioned earlier, the EU member states are allocated specific RES-E targets and they take the responsibility of instituting policies to help attain these targets. As part of the various renewable energy directives, member states are required to implement support schemes to enhance renewable energy investments so as to meet their targets. In the EU, there are regulatory and voluntary policies to promote electricity generation and consumption from wind energy and other RES-E technologies.

Table 3.1: Policy Groupings in the EU According to Regulatory and Voluntary

Summary of Regulatory Policies	**Voluntary**
▪ Fiscal Incentives (Tax credits Investment subsidies, Investment grant tendering system, Lower interest loans). ▪ Quota/Tradable Green Certificates. ▪ Tendering system. ▪ Feed-in-Schemes. ▪ Emission Trading Schemes/Tradable emissions allowance.	▪ Green Tariffs. ▪ Shareholder programmes. ▪ Contribution programmes.

Source: Modified from Haas et al. (2011).

Table 3.1 above shows the groupings of policies in the EU according to regulatory and voluntary. Among the voluntary programmes and policies are the green tariffs, shareholder programmes and contribution programmes usually adopted voluntarily. The regulatory policies are deliberate enacted by governments to either support the quantity of RES-E production or the price of electricity produced from RES-E, see, e.g., Table 3.2 below (Haas et al., 2011).

Table 3.2: Types of RES-E Support Policies

Price regulated Policies	Quantity regulated Policies
▪ Fiscal Incentives (Tax credits, Investment subsidies, Investment grant , Lower interest loans ▪ Feed-in-Schemes	▪ Quota/Tradable Green Certificates ▪ Tendering system

Source: Modified from Haas et al. (2011).

The *FIS* is an RES-E policy implemented to support the price of electricity generated from RES-E technologies while Fiscal Incentives (Tax credits, Investment subsidies, Investment grant, and lower interest loans) are policies implemented to support investments in RES-E technologies (Table 3.2). The Quota and tendering systems are implemented to support and guarantee generation of electricity from RES-E technologies. These policies are adopted by different EU countries at different times to enhance development of RES-E (see e.g., Table 3.3 for RES-E policies and years of enactment among EU countries).

Table 3.3: Policies and Year of Adoption by Countries

This table contains Information about the RES-S Support policy types and their respective year of enactment for EU countries from 1990 to 2013

Year	FIT WIND	FIP WIND	FIT solar	FIP solar	Quota and Green Trading Certificate	Tax and Investment Grants	Tender	First Cap Introduced
1990	(DE)		(DE)				(UK)	
1991								
1992			(IT)					
1993	(LU)	(DK)	(LU)	(DK)				
1994	(ES),(GR)	(ES)	(ES),(GR)			(SE)		
1995							(IE)	
1996								
1997						(FI),(NL)	(FR)	
1998	(AT)		(AT)					
1999								
2000					(PL)	(PL)		
2001	(FR),(PT)		(FR),(PT)		(IT)			
2002	(CZ),(HU),(LT)	(CZ)	(CZ),(HU),(LT)	(CZ)	(BE),(UK),(LV)	(HR)		
2003	(BG),(NL)	(EE)	(BG),(NL)		(SE)	(SK)		
2004	(SI)	(SI)	(SI)	(SI)		(CY)		
2005	(SK)	(SK)	(SK)	(SK)		(HU)	(PT)	
2006	(IE)	(CY),(IE)	(IE), (MT)	(CY),(IE)		(MT)		(IT),(PT)
2007								(EE),(NL)
2008					(RO)			(CY),(ES)
2009	(LV)			(LV)			(LV)	(LV)
2010	(UK			(UK				
2011		(FI),(DE)		(FI),(DE)				
2012								
2013	(HR)			(HR)				

Source: Own computation based on information from Huber et al. (2004), Haas et al. (2011), Winkel et al. (2011) and IEA Policies and Measures Database, 2014.All rows represent a policy type where the denotations represent the following countries: AT, Austria; BE, Belgium; BG, Bulgaria; CY, Cyprus; CZ, Czech Republic; DK, Denmark; EE, Estonia; FI, Finland; FR, France; DE, Germany; GR, Greece; HU, Hungary; IE, Ireland; IT, Italy; LV, Latvia; LT, Lithuania; LU, Luxembourg; MT, Malta; NL, Netherlands; PL, Poland; PT, Portugal; RO, Romania; SK, Slovakia; SI, Slovenia; ES, Spain; SE, Sweden; UK, United Kingdom; HR, Croatia; NO, Norway; CH, Switzerland.

Table 3.3 above presents the type of policy being adopted by EU member countries and the date of adoption. These policies are expected to drive the capacity development of RES-E in the EU. We also include policies that cap (Cap) the tariff amount or capacity to control for the impact of cost containment on the capacity development of wind and solar

PV in the EU. These RES-E support policies and their expected impact on capacity development are explained in the sections below.

3.1.2.2 Feed-In-System

Following the various directives and phases of renewable energy support schemes, the *FIS* are the most widely adopted national support schemes by EU member states as published in the National Renewable Energy Action Plans (NREAPs).[19] With regard to RES-E in the EU 27, the most predominantly implemented support scheme is the *FIS* (Ragwitz et al., 2012). Under the *FIS*, there are two different options, *FIT* and the *FIP*. The *FIT* scheme guarantees a fixed price for electricity generated from RES-E. Under the *FIT* contract, RES-E generators receive a fixed and guaranteed price per MWh per unit of time of the electricity they generate from RES-E. Under this scheme, a long term guaranteed fixed price is usually set to assure RES-E generators of a fixed price for their output rather than selling it at the market price. The *FIP* on the other hand, is a support scheme which pays a price on top of the market price of electricity. Under this scheme, electricity generated from renewable energy sources could be sold in the open competitive market at the prevailing market price but thereafter receive a premium on top of the market price.

The number of countries implementing *FIS* in the EU over the past years has been rapidly increasing with however significant differences in design (See Table 3.4 for summary of the differences in policy design among countries in the EU). For instance, the number of nations using the *FIS* between the years 2000 to 2005 increased from 9 to 18, and as at

---

[19] As part of the directives, member states are required to publish their action plans in meeting their share of the mandatory targets with indicative road map concerning renewable energy in electricity generation and consumption as well as heat and transport energy consumption.

the end of 2013, 25 of the EU 27 countries had adopted and implemented the *FIS* policies. Out of the 25 countries using the *FIS* to promote RES-E generation, 20 of them use the *FIT*, 5 use both *FIT* and *FIP* while 5 countries use only *FIP* as their major support instrument to promote certain RES-E technologies such as wind farms and solar PV among others (See Tables 3.3 and 3.4). Germany had *FIT* policy in place as far back as 1990 to support both wind and solar PV developments which has accounted for their growth in capacity development of RES-E (European Wind Energy Association, 2014). Luxemburg also implemented the *FIT* in 1993 while Spain and Greece implemented it in 1994. *FIT* was introduced by Denmark in 1993 and by the Czech Republic in 2002. EU member states such as the UK, Italy and Belgium have recently adopted the *FIS* in addition to their Quotas. Finland also abandoned their investment grant scheme and recently adopted the *FIP* in 2011 (see Table 3.4 below).

The use of *FIP* has been increasing across the EU. Currently, the Czech Republic, Denmark, Estonia, Finland, Germany, Italy, the Netherlands, Slovakia, Slovenia and Spain use *FIP* in combination with other support instruments or as the main support tool for renewable electricity. The United Kingdom has also introduced the *FIT* for small scale generation technologies. EU Member states using the *FIT* have accounted for majority of the newly installed onshore and offshore wind and solar photovoltaics in the EU. Almost 93% of all wind onshore capacity and nearly 100% of all solar PV capacity installed by the end of 2010 in EU was initiated by *FIS* systems according to (Ragwitz et al., 2012). Also, in overall terms countries using *FIT* have had a leading role in developing renewables in the EU: 78% of new RES-E generation added between the period 1999 and 2009 was contributed by these countries (European Wind Energy Association, 2012).

Best practice countries such as Spain, Germany, Denmark and Portugal have demonstrated the positive impact of *FIT* on wind energy development. Germany, for instance, which was one of the first countries to implement *FIT*, increased installed wind energy over the last 15 years: the installed capacity increased from 4442 MW in 1999 to 18415 MW in 2005 to 27214 MW in 2010 according to (Ragwitz et al., 2012). By the end of 2010, wind energy accounted for 9.3% of German electricity production. Spain, which has implemented both *FIT* and *FIP* since 1994 had 14.4% of their electricity supply provided by wind by the end of 2010 while in Portugal 14.8% and in Denmark 24%. The *FIT* also had a strong impact on the wind energy market in Portugal which saw an increase in capacity to 3898 MW by the end of 2013. Also, Greece has seen a strong increase, though starting from a lower installed capacity. In 1999, 112 MW wind capacity were installed in Greece, rising to 1208 MW in 2010. Bulgaria, which introduced a feed-in system for wind installations in 2007, increased their wind power capacity to 375 MW in 2010. In France, the installed capacity of onshore wind increased from 222 MW in 2003 to 5660 MW in 2010 as a result of the implementation of *FIT*.[20] Therefore, in this research we expect a positive impact of the implementation, the experience and the heterogeneity in *FIS* policy design on the capacity developed to wind and solar PV in the EU.

3.1.2.3 Quota/ Green Certificates

Some countries in the EU use the quota and the trading green certificates systems to make sure that at least a fixed amount of electricity is generated from renewable sources. Producers and consumers are usually forced to generate or buy a fixed *Quota* of electricity from renewable sources. In a green certificate system, a certificate is issued to renewable

---

[20] (See European Wind Energy Association, 2012)

electricity producers for every unit of electricity produced. In this regard, holders of green certificates, which generally reflect the societal value of producing from RES-E, have the opportunity to access two different electricity markets. In a country where a green certificate system is practised, electricity generated through renewable energy sources are certified for two different purposes. The first purpose of green certificates is to keep accurate measure of electricity produced from renewable energy sources and also to determine whether the demand for green electricity has been met or if there is demand at all. The second purpose for certifying electricity produced from renewable sources is to enable the establishment of a green certificate market which has an autonomous function from the electricity market as a commodity (Schaeffer et al., 1999). So therefore, holders of green certificates can access the general electricity commodity market where they will face competition like any other electricity produced from different sources or access the green certificates markets.

Quotas are being allowed to be traded by entities who are obliged to have a certain quota of electricity generated from renewable sources. This allows entities the sole free will to either buy quotas from other firms or fulfil their quota obligation themselves (Ringel, 2006). The green certificate trading system is an incentive employed to enhance the increased share of renewable electricity in the electricity market. A certificate is received by electricity producers for each pre-defined unit of energy generated from renewable sources connected to the grid. The demand for green certificates could be seen to be driven by the obligation imposed by the EC and the various governments. Demand for green certificates could be directly or and indirectly forced on consumers, distributers, generators and suppliers among others through a mandated obligation to generate, buy, transmit or deliver not less than a specific amount of green certificates (Dinica, 2006; Meyer, 2007; Ringel, 2006). Green certificates could be seen as a comparatively new, innovative style of tradable quotas. In spite of its recent use, the model has gained popularity in many EU member countries since its introduction in the Netherlands during the late 1980s.

Poland, Italy, Belgium, United Kingdom, Latvia, Sweden, Sweden and Romania are currently using the *Quota* scheme to enhance development of RES-E. In the year 1999 Poland had an installed wind capacity of 4MW and 0 MW capacity of solar; in the year 2000 when *Quota* was introduced in Poland, wind capacity increased to 19 MW, while solar PV remained 0 MW. By the end of 2013, total wind energy capacity in Poland was 3429 MW while solar PV was 1 MW. Intuitively, one can argue that implementing the *Quota* policy aided in the development of wind energy but not with solar PV.

Prior to the implementation of *Quota* by Italy in 2001, installed wind energy capacity and solar PV capacity were 363 MW and 20 MW respectively. By the end of 2013, installed capacities for wind energy and solar PV were 8454 MW and 18420 MW respectively. From our data, we observe a relative growth in wind and solar PV capacities in countries after the adoption of the *Quota* system. Our aim is therefore to statistically examine the extent to which the implementation of the *Quota* system affects capacity development. We use a dummy variable of 1 to represent the existence of *Quota* and 0 otherwise in our regression models. We also use the number of years a particular policy has been in existence to represent the experience of the quota policy. We expect a positive significant relationship between *Quota* and capacity development.

3.1.2.4 Fiscal Support Instruments

Some countries in the EU have been using other financial incentives to enhance the development of RES-E capacity growth. These financial incentives include reduction or free taxes, soft loans, investment subsidies, investments grants, interest free loans, among others referred to as *Tax* in this research. Sweden, Finland, Netherland, Portugal Croatia Slovakia, Cyprus and Malta are countries using tax breaks and other fiscal incentives to promote RES-E capacity growth. Countries and years where there fiscal incentives are present, we represent with a dummy variable of 1 and 0 otherwise. The experience of the policy is also represented by the number of years the policy has been in existence in a particular year. We expect a positive significant relationship between fiscal support instruments and capacity growth.

3.1.2.5 Tender

Tendering is a policy whereby prospective RES-E investors are invited to tender their bids for support in adding capacity. Investors are, however, not allowed to win a tender and be under an *FIS* contract at the same time. We test the effectiveness of this policy by using a binary variable and the number of years of its enactment for each country for a given time. We expect a significant relationship between *Tender* and capacity development. The UK has the most experience of the *Tender* scheme which was implemented as far back as 1990. Ireland also implemented the *Tender* scheme in 1995 and France in 1996. Subsequently, Portugal and Latvia implemented the *Tender* scheme in 2006 and 2009 respectively (See Table 3.3 above). We expect a positive impact of *Tender* policy on capacity development.

3.1.2.6 Cap

Cap is a policy introduced by some countries in EU to curb the amount of tariffs to be received by investors of RES-E technologies. Cap could either be introduced on the unit of production eligible for support or on the total amount of tariff by the government. This implies that, if for instance, a producer of RES-E produces an amount of electricity higher than the amount eligible for support, the remaining power produced would be sold in the market at the prevailing market rate. Also, if the *Cap* on the total amount of tariff is reached, extra RES-E added capacity would not be supported. The first Cap was introduced by Austria, Italy and Portugal in 2006, followed by Estonia and Netherlands in 2007. Cyrus and Spain introduced the *Cap* policy in 2008 with Latvia adopting it in 2009 (See Table 3.3 above). While Netherlands and Austria introduced caps on cost limit, Portugal, Estonia, Latvia, Spain, Ireland and Cyprus introduced caps on capacity of RES-E. We include the Cap variable to determine the impact of cost containment on capacity development. We expect either negative or positive relationship between the *Cap* policy and wind energy and solar PV capacity development.

Table 3.4: Summary of RES-E Policies by Countries

This table presents information regarding the various RES-E policies adopted by EU 28 countries and commentary regarding policy changes, generosity and eligibility among others.

Czech Republic	Feed-in Systems (since 2002), plus by investment grants	Relatively high feed-in tariffs with lifetime guaranteed duration of support. Producer can choose fixed feed-in tariff or premium tariff (green bonus). For biomass cogeneration only green bonus applies. Feed-in tariff levels are announced annually but are at least increased by two percent annually.
Denmark	Premium feed-in tariff for onshore wind, tender scheme for offshore wind, and fixed feed-in tariffs for others	Duration of support varies from 10 to 20 years depending on the technology and scheme applied. The tariff level is generally rather low compared to the formerly high feed-in tariffs. Recently the support scheme got revised and RES generators receive again a higher premium on top of the market price. A net metering approach is taken for solar photovoltaics.
Estonia	Feed-in tariff system	Feed-in tariffs paid for 7–12 years, but not beyond 2015. Single feed-in tariff level for all RES-E technologies. Relatively low feed-in tariffs make new renewable investments very difficult
Finland	Energy tax exemption combined with investment incentives	Mix of tax refund and investment subsidies: Tax refund of 6.9 €/MWh for Wind and of 4.2 €/MWh for other RES-E. Investment subsidies up to 40% for Wind and up to 30 % for other RES-E.
France	Feed-in tariffs plus tenders for large plants	Feed in tariff for RES-E plant < 12 MW guaranteed for 15 years (20 years PV and Hydro). Tenders for plant >12 MW. FITs in more detail: Biomass: 49-61 €/MWh, Biogas: 46-58 €/MWh, Geothermal: 76-79 €/MWh, PV: 152.5-305 €/MWh; Landfill gas: 45-57.2 €/MWh; Wind3: 30.5- 83.8 €/MWh; Hydro: 54.9-61 €/MWh. Investment subsidies for PV, Biomass and Biogas (Biomass and Biogas PBEDL 2000-2006). 2% annual reduction of tariff introduced in 2012.
Germany	Feed-in tariffs	Feed in tariff guaranteed for 20 years. In more detail, Feed in tariff for new installations (2004) are: Hydro: 37-76.7 €/MWh; Wind6 : 55-91 €/MWh; Biomass & Biogas: 84-195 €/MWh; Landfill-, Sewage- & Mine gas: 66.5-96.7 €/MWh; PV & Solar thermal electricity: 457-574 €/MWh; Geothermal: 71.6-150 €/MWh.
Greece	Feed-in tariffs combined with investment incentives	Feed in tariff guaranteed for 10 years (at a level of 70-90% of the consumer electricity price depending on location and type of producer) and a mix of other instruments: a) Up to 40% investment subsidies combined with tax measures; b) Up to 50% investment subsidies depending on RES type.

Hungary	Feed-in tariff (since January 2003, amended 2005) combined with purchase obligation and grants	Fixed feed-in tariffs recently increased and differentiated by RES-E technology. No time limit for support defined by law, so in theory guaranteed for the lifetime of the installation. Plans to develop TGC system; at that time the feed in tariff system will cease to exist
Ireland	Feed-in tariff scheme replaced tendering scheme in 2005	New premium feed-in tariffs for biomass, hydropower and wind started 2006. Tariffs guaranteed to supplier for up to 15 years. Purchase price of electricity from the generator is negotiated between generators and suppliers. However support may not extend beyond 2024, so guaranteed premium tariff payments should started no later than 2009. Tendering scheme – currently with technology bands and price caps for small wind (<3 MW), large Wind (>3 MW), small Hydro (<5 MWp), Biomass, Biomass CHP and Biogas. In addition, tax relief for investments in RES-E.
Italy	Quota obligation system with TGC and Fixed feed-in tariff for PV	Obligation (based on TGCs) on electricity producers and importers. Certificates are issued for RES-E capacity during the first 12 years of operation, except biomass which receives certificates for 100% of electricity production for first 8 years and 60% for next 4 years. Separate fixed feed-in tariff for PV, differentiated by size and building integrated. Guaranteed for 20 years. Increases annually in line with retail price index.
Latvia	Feed in tariff and Quota obligation system (since 2002)	Quota system (without TGC) typically defines small RES-E amounts to be installed. High feed-in tariff scheme for wind and small hydropower plants (less than 2 MW) was phased out from January 2003. Nowadays a favourable feed in system is installed for small-scale RES generators, whereas for mid-scale generators a tendering scheme is installed for most technologies.
Lithuania	Feed-in tariffs	Relatively high fixed feed-in tariffs for RES-E technologies.
Luxembourg	Feed-in tariffs	Feed in tariff guaranteed for 10 years (PV: 20 years) and investment subsidies for Wind, PV, Biomass and small Hydro. feed in tariff for Wind, Biomass and small Hydro: 25 €/MWh, for PV: 450 €/MWh.
Malta	Low VAT rate and very low feed-in tariff for solar	Very little attention to RES support so far. Very low feed-in tariff for PV.
Netherlands	Feed-in tariffs plus Tax exemption	Mixed strategy: Green pricing, tax exemptions and feed in tariff. The tax exemption for green electricity amounts 30 €/MWh and feed in tariff guaranteed for 10 years range from 29 €/MWh (for mixed Biomass and waste streams) to 68 €/MWh for other RES-E (e.g. Wind offshore, PV, Small Hydro).
Poland	Quota obligation system and excise tax incentives	Obligation on electricity suppliers with targets specified from 2005 to 2010. Penalties for non-compliance were defined in 2004, but were not sufficiently enforced until end of 2005. The RES electricity producer is entitled to sell it to the grid at least at the average market price from a previous year (published by the regulatory authority). The price was about 38 D /MWh in 2007. The fulfilment of the national targets can be done either by submitting a relevant quantity of TGC's for redemption or by paying a substitution fee (about 74 D /MWh in 2008).
Portugal	Feed-in tariffs combined with investment incentives	Feed in tariff and investment subsidies of roughly 40% within program for Economic Activities (POE)) for Wind, PV, Biomass, Small Hydro and Wave. Feed in tariff in 2003: Wind: 43-83 €/MWh; Wave: 225 €/MWh; PV: 224-410 €/MWh, Small Hydro: 72 €/MWh. Tariff depends on the quality of site and time of generation.

Romania	Quota obligation with TGCs, subsidy fund (since 2004)	Obligation on electricity suppliers with targets specified from 2005 to 2010. Minimum and maximum certificate prices are defined annually by Romanian Energy Regulatory Authority. Non-compliant suppliers pay maximum price.
Slovakia	feed-in tariffs and tax incentives	Fixed feed-in tariff for RES-E was introduced in 2005. Prices set so that a rate of return on the investment is 12 years when drawing a commercial loan.
Slovenia	Feed-in tariffs and public funds for environmental investments	Renewable electricity producers choose between fixed feed-in tariff and premium feed-in tariff. Tariff levels defined annually by Slovenian Government (but have been unchanged since 2004). Tariff guaranteed for 5 years, then reduced by 5%. After 10 years reduced by 10% (compared to original level). Relatively stable tariffs combined with long-term guaranteed contracts makes system quite attractive to investors.
Spain	Feed-in tariffs	Electricity producers can choose a fixed feed-in tariff or a premium on top of the conventional electricity price. No time limit, but fixed tariffs are reduced after either 15, 20 or 25 years depending on technology. System very transparent. Both are adjusted by the government according to the variation in the average electricity sale price. In more detail (only premium, valid for plant < 50 MW): Wind: 27 €/MWh; PV15: 180-360 €c/kWh, Small Hydro: 29 €/MWh, Biomass: 25-33 €/MWh. Soft loans, tax incentives and regional investment incentives are available.
Sweden	Quota obligation system with TGCs	Obligation (based on TGCs) on electricity consumers. Obligation level defined to 2010. Non-compliance leads to a penalty, which is fixed at 150% of the average certificate price in a year. Investment incentive and a small environmental bonus available for wind energy.
UK	Quota obligation system with TGCs and FIT	Quota obligation (based on TGCs) for all RES-E: Increasing from 3% in 2003 up to 10.4% by 2010 – penalty set at 30.5 £/MWh. In addition to the TGC system, eligible RES-E are exempt from the Climate Change Levy certified by Levy Exemption Certificates, which cannot be separately traded from physical electricity. The current levy rate is 4.3 £/MWh. Investment grants in the frame of different programs (e.g. Clear Skies Scheme, Offshore Wind Capital Grant Scheme, the Energy Crops Scheme, Major PV Demonstration Program and the Scottish Community Renewable Initiative)

Sources: Adapted from Huber et al. (2004) and updated with information from Haas et al. (2011), Winkel et al. (2011), and IEA Policies and Measures Database, 2014.

3.1.3 Socio Economic Factors

In line with previous literature, we control for socio economic factors that could possibly affect the development of wind energy. The socio-economic factors considered in this research include energy consumption per capita, gross domestic product per capita, oil prices, natural gas prices, coal price, electricity prices, percentage of electricity generated from oil sources, percentage of electricity generated from coal sources, percentage of electricity generated from natural gas sources, percentage of electricity generated from nuclear sources, percentage of electricity generated from renewable sources, population growth, and total energy use.

3.1.3.1 Gross Domestic Product per Capita (GDP)

Following Menz and Vachon (2006); Carley (2009); Marques et al. (2010); Marques and Fuinhas (2011b); Marques et al. (2011); and Jenner et al. (2013), we control for GDP per capita in this research. We expect that countries with higher income and high GDP per capita should be able to afford developed infrastructure, and skills in promoting alternative clean sources of energy. Marques et al. (2010) find a positive impact of high GDP on the capacity development of RES-E. They argue that the positive relationship between GDP and RES-E capacity development is based on the fact that, higher income countries have the potential to afford extra regulatory cost which is aimed at promoting RES-E development. In other words, they have enough resources to promote the use of energy from clean sources. There is, however, a split in the literature regarding measures of wealth such as GDP per capita on the development of renewable energy. Carley (2009) and Jenner et al. (2013) find a positive relationship between GDP per capita and renewable energy development while Marques and Fuinhas (2011b) find a negative relationship. Other researchers such as Yin and Powers (2010); Shrimali and Kniefel (2011) and Dong (2012) find no significant relationship between GDP per capita and renewable energy development. Hence we include GDP per capita to examine this further and expect positive, negative or no significant relationship with capacity development. The source of this variable is the World Bank Statistics Database (2015) expressed in constant 2005 US$.

3.1.3.2 Electricty Consumption Per Capita

Following Carley (2009) and Marques et al. (2010), we control for energy consumption per capita which is usually used to determine the energy needs of a country as well as an indicator of development. Electricity consumption could come from all sources of energy including the traditional and clean energy source. A country could either decide to increase its electricity production through clean sources or traditional sources to meet the rising consumption per capita. We test the hypothesis that as a country electricity consumption per capita increases, RES-E capacity will increase. We therefore expect a positive significant impact of high electricity consumption per capita on wind energy and solar PV capacity development if the increment is coming from wind energy or solar PV, and a negative impact if traditional sources are rather increased to fulfil the rising electricity consumption of the country. The source of data for this variable is the World Bank expressed in kwh per capita.

3.1.3.3 Total Electricity Production

The source of this variable is the World Bank and it is expressed in kwh. We control for the total electricity generation from all sources. This variable is expected to impact positively on the development of wind energy. This variable is included to control for the electricity market size of countries in our sample.

3.1.3.4 Generation from Coal, Oil, Natural Gas,Renewables & Nuclear

As supported by economic theory, some researchers are of the view that lobbying and political activities play a vital role in the development of traditional energy generation sources (Huang et al., 2007; Marques et al., 2010; Jenner et al., 2013). These lobbying activities, generally noticed in Government policies and other influential agencies, are expected to derail the capacity development of RES-E. In fact, Marques et al. (2010b) went further to argue that a strong barrier to the capacity development of renewable energy sources is the stakeholders of the industries which are involved in traditional generation sources due to their vital role in the general economic growth of a country.[21] We therefore test this hypothesis and expect a negative relationship between electricity generated from traditional sources and the development of wind farms. Electricity production from coal, oil, natural gas and nuclear sources are measured as a percentage of total generation. Electricity production from renewable sources, excluding hydroelectric, includes geothermal, solar, tides, wind, biomass, and biofuels expressed as a percentage of total electricity production. The sources for this data are the World Bank and Eurostat and it is expressed as a percentage of total electricity generation.

---

[21] Traditional energy generation sources contribute significantly to investment, employment and other economic macro and micro economic factors. This offers them a higher possibility to lobby for the derailment of renewable energy sources at the expense of traditional sources.

3.1.3.5 Oil, Electricity, Natural Gas and Coal Prices

Due to the expensive initial cost involved in the adoption of wind, solar PV and other RES-E technologies, electricity generated from such sources is relatively much more expensive as compared to the energy from traditional sources. The expensive nature of clean energy has also been attributed to additional environmental cost, which energy from the traditional sources does not bear (Menz & Vachon, 2006). This results in the less competitive nature of clean energy prices in the short term (Marques et al., 2010). The economic literature is split on the impact of underlining prices of energy from the traditional sources of generation on renewable energy capacity development (Bird et al., 2005; Van der Linden et al., 2005; Van Ruijven & Van Vuuren, 2009; Marques & Fuinhas, 2011b; Dombrovski, 2015). Previous studies control for the effect of the prices of coal, natural gas and nuclear power on the capacity development of RES-E.

We include these variables due to the fact that higher prices for conventional energy sources could render electricity generated from such sources very expensive, and hence electricity generated from wind and other renewable sources becomes competitive and economically viable. This could lead to increment in the adoption of wind, solar PV and other clean energy technologies rather than generating from the traditional sources. Therefore, in this regard, traditional or conventional sources would be substituted for wind or other clean sources. For this reason, we expect to establish that a higher price in conventional sources should lead to higher capacity development in wind energy and solar PV.

There is also the possibility of non-significant or negative impact of higher prices of conventional energy source on wind energy capacity development. In the case of non-significance, this could be as a result of minute increment in prices of conventional sources which would still be cheaper as compared to energy from RES-E sources. Negative impact could also be as a result of the lack of strong environmental policies in countries that would entice investors and consumers to opt for RES-E technologies even with the rising prices of conventional energy sources. There have been diverse findings regarding the impact of prices of conventional sources on clean energy development.

For instance, Marques and Fuinhas (2011b) find a positive and significant relationship between oil price, natural gas price and coal price on renewable energy capacity development among EU countries and negative impact on non EU countries. Their sample size was however between 1990 and 2006 which did not cover the period where energy prices were very volatile (during the financial crisis 2007-2009). So therefore, the recent volatile nature of prices of oil and other conventional energy sources have not been captured in their research. We will correct this by expanding the sample size to cover the financial crisis period during which renewable energy development was also affected. See Appendix AC3 Figure 2 for the price movement of coal, natural gas, oil and electricity in 27 EU countries from 1992 to 2013. The source of data for the whole sale electricity and natural gas prices from 1992 to 2007 was the IEA OECD Factbook, 2014, and from 2007 to 2013 was from Eurostat measured in Euro/ kWh and Euro/GJ respectively. Annual data prior to 2007 was not available on Eurostat. The source of data for coal and crude oil prices was the IEA OECD Factbook, 2014. The average prices for total OECD was used for non OECD countries.

3.1.3.6 Population Growth

We control for the impact of population growth (Popul.Growth) on the capacity development of wind energy. We expect a positive relationship between population growth and wind energy development. We believe that rising population growth would lead to high demand for energy consumption which could lead to capacity growth in RES-E generation. The source of the population variable is the World Bank expressed as a percentage.

3.1.4 Political Factors

Due to the nature of renewable energy technologies, political factors play a very vital role in their capacity development. All the support schemes considered in this research are as a result of political decisions implemented by governments to support renewable energy capacity development. Carley (2009) recognises political influence as the most significant contributor to renewable energy development. Following Gan et al. (2007), Marques et al. (2010) and Jenner et al. (2013) we control for the dependence on energy import by countries.

3.1.4.1 Dependence on Energy Imports

Energy security is very vital and most of the time some countries rely on energy imports to meet their energy demands. Energy import dependence in this thesis represents the rate at which a nation depends on energy imports to meet its energy demand. This indicator is calculated by dividing net imports by the sum of gross inland energy consumption plus maritime bunkers. The literature suggests a positive relationship between high energy dependence and capacity development of renewable energy, see (Gan et al., 2007;

Marques et al., 2010).This implies that high dependence on energy importation leads to the substitution of imports of energy to renewable energy development. However, contrary to the theory regarding the positive relationship between energy import dependence and RES-E development, Chien and Hu (2008) report no significant relationship between renewable energy development and high energy imports. So therefore, while we expect to confirm the growing theory of the positive impact of high energy imports on the capacity development of RES-E, there is also a possibility of non-significant relationship. The source of data for this variable is Eurostat-Statistical Office of the European Commission, 2014, and it is measured in a form of a percentage positive or negative.

3.1.5 Environmental Factors

Each country has unique environmental factors which can possibly affect the capacity development of their RES-E generation. We control for the technical potential of wind by using the geographic area as a proxy variable. We also control for the carbon emissions tons per capita of each country following (Menz & Vachon, 2006; Carley, 2009; Marques et al., 2010; Marques & Fuinhas, 2011a, b).

3.1.5.1 Wind Technical Potential

For the purposes of estimating the effect of policies on wind energy capacity development, we control for technical wind potential of member states in our analysis. The technical potential in this regard is the amount of wind pressure with the possibility of increasing energy efficiency and reducing greenhouse gas emissions with the implementation of wind farms. This is because wind energy and other renewable sources are unique and vary according to region. High quality windy areas may attract significant wind energy capacity development as compared to lower windy areas. The effectiveness of wind farms is subject to the availability of quality wind in a given area (Menz & Vachon, 2006). There is limited information regarding the technical potential of wind energy in Europe to cover the wide time period in this research.

So therefore, following Marques et al. (2010) we control for a wind technical potential variable based on the geographic dimension of a country. This wind technical variable also captures the available production technologies in a given country. We therefore, rationally expect a higher geographic area to be associated with higher wind energy capacity development. The theory suggests that areas with higher availability of wind should have high wind energy capacity development and vice versa. As noted by Carley, (2009) and Marques et al. (2010), this variable in measuring the technical potential of wind energy is highly debatable. While Carley (2009) report a negative relationship between wind technical potential, Marques et al. (2010) report a positive and significant relationship. The source of data for the technical potential variable expressed in square kilometre square is the UN statistics Division, Demographic Year Book, 2014.

3.1.5.2 Carbon Emissions (tons per Capita]

The global concern regarding the consequence of greenhouse gases on the atmosphere has resulted in the control and commitment to reduce carbon emissions at the national levels. Due to binding commitments in the EU, one would expect higher emitting carbon nations to resort to rapid adoption of renewable technologies. We therefore include this variable with the expectation that higher carbon emissions would lead to high wind energy development. This assertion has been supported by the literature, which argues that RES-E investments are rapidly adopted when carbon emissions are high (Van Ruijven & Van

Vuuren, 2009). However, higher carbon emission countries that are less concerned about global warming and the effects of carbon emissions are likely not to invest in wind and other clean sources but rather continue with the traditional sources of generation. This could lead to less development of wind energy and hence a negative relationship between emissions and wind energy capacity development. We therefore test the hypothesis that high CO2 emissions will lead to high development of RES-E technologies. The source of the CO2 variable, expressed in tons per capita is the World Bank.

3.2 Overview of Empirical Framework

There have been various econometric methods applied to examine the impact of policy measures on RES-E capacity development (Menz & Vachon, 2006; Carley, 2009; Marques and Fuinhas, 2011b). The challenge, however, in determining the impact of policy invectives on capacity development is the possibility of spatial and temporal effects overlapping (Polzin et al., 2015). Due to the characteristics and nature of RES-E policy making, the best econometric method to adopt in assessing its impact on capacity development according to the literature is the panel data approach (Menz and Vachon, 2006; Carley, 2009; Yin and Powers, 2010; Marques and Fuinhas, 2011b; Polzin et al., 2015). Therefore in chapters 4 and 5 of this thesis, we use an ex post approach to empirically examine the effectiveness of RES-E policies on capacity development.

Panel data contains information of different observations across different time periods and hence makes it possible to make causal relationship inferences from results (Baltagi, 2008). Due to the possibility that the available data might not contain all information that could drive or derail capacity development of RES-E, there is the need to control for factors that might not be captured due to the information in the data and hence, for that matter, we control for unit heterogeneity by using fixed effects estimations for our analysis in Chapters 4 and 5.

In Chapter 4 we analyse the impact of the enactment and the experience of various wind energy support policies on capacity development, while in chapter 5 we examine the effectiveness of *FIS* policies on capacity development of wind and solar PV. Our measure of wind energy capacity development is annual cumulative wind capacity (CC) and annual added wind capacity (AC) in chapter 4, and AC in chapter 5.These measures are explained and justified in the respective chapters. For a technology type *i* (wind or solar PV) adopted in country *i* during year *t*, the model given in equation 3.1 is the baseline model we use for our analysis in chapters 4 and 5

$$Y_{ijt} = \beta_0 + \beta_1 X_{ijt} + \beta_7 H_{ijt} + \varepsilon_{ijt} \quad (3.1)$$

where *Y* represents the dependent variables (CC or AC), *X* represents either dummy variable for the existence of policy, the dummy variable for the experience of policy or our new indicator capturing the strength of *FIS* policy. H represents a series of social, enviromental and economic variables expected to have an impact on the development of wind and or solar PV, while ε represents the error term. The exogeneity assumption for OLS does not usually hold for panel dataset especially for our data since there is the possibility of the presence of unobserved country effects and unit heterogeneity which if not controlled would yield inconsistent estimates. Therefore, there is the need for additional treatment of the error term to yield consistent estimates in the presence of unobserved unit heterogeneity (Wooldridge, 2002). In this case for *t*= 1,2,3,4…,T, … $E(\varepsilon_{ijt} / X_{ijt}; H_{ijt}) \neq 0$ violating the homogeneity assumption and hence results in inconsistent estimates as the error term is correlated with independent variables in each period. Therefore we estimate our model using the fixed effects estimator which allows for the control of unobserved and time variant and invariant specific country effects such as market instabilities, wind energy potential, planning regime differences among countries, wind energy capacity development before the time analysed among others. Estimating our model using the fixed effects results in an error term given by $\varepsilon_{it} = u_i + u_t + \mu_{it}$ where u_i represents the country specific effects, u_t represents time specific effects while μ_{it} represents the independent identical random error terms. In this estimation, which is the extra treatment of the error term allows for the control for time invariant country specific effects mentioned above. We further test for the superiority of the fixed effects model to determine the existence of unit heterogeneity by using the Hausman test statistics (Hausman, 1978). For robustness checks, we conduct the OLS random effects and PCSE estimations using our dataset. The estimation processes are explained in the respective chapters while the results are presented in the Appendix.

In summary, based on prior research, our analysis in Chapter 4 and 5 proceeds as follows; 1) Observation of the nature and quality of our data. 2) We perform some diagnostic test including tests for heteroscedasticity, multicollinearity, panel autocorrelation, normality of the data and the superiority of the regression model for our analysis. 3) When standard assumptions about errors are violated, such as being independent and identically distributed, we make adjustments and select the best model to improve the accuracy and reliability of our estimators. 4) We report and compare the results of other models for robustness checks.

3.2.1 Lag Structure

Due to the nature of our data and a common assumption in longitudinal analysis that the effect of independent variables on dependent variables is immediate and with a certain degree of delay (see, e.g., Polzin et al. (2015), we include this relation in our model with the use of a lag structure. We use the respective time values of the dependent variables and compare the results with different time values of the independent variables to determine the effect of policies on capacity development. To determine whether the implementation of a policy could immediately trigger capacity addition or could take up to a year to trigger capacity addition, we include a lag structure from zero to one year. This means that capacity development during year *t* could be as a result of implemented polices during year *t, or* during year *t-1,* .With this lag structure, the time dependent effects of RES-E policies on capacity development are captured (Wooldridge, 2010; Polzin et al., 2015).

Prior to the implementation of RES-E policy, there is a communication of the intended policy and hence investors could be ready before the implementation of the policy, thereby speeding up the addition of capacities and onward connection onto the national grid. Therefore, using the independent variables at time *t*, we capture the pent- up demand prior to the implementation of a policy by assuming that capacity addition is contemporaneous to policy implementation. However, due to the nature of RES-E technologies such as wind turbines and solar PV, capacity addition could be delayed (Polzin et al., 2015). Wind farms and solar PV, for instance, take time to be built and connected to the national grid and hence a policy implemented during year *t* could result in additional capacity during year *t+1*. Hence, we make our analysis based on the results from the model with one year lag structure and compare the results with the model without the lag structure.

3.2.2 Specification Test

Following Marques and Fuinhas, (2011b) and Polzin et al. (2015) we begin our analysis by initially performing several diagnostic specification tests to examine the quality of our data and the possible violation of classical linear regression model assumptions. We test for serial correlation, cross sectional dependence and groupwise heteroscedasticity. We also test for the normality of the data as well as multicollinearity.

Classical linear regression models usually assume a normal distribution of the errors to ensure that the estimates function as a maximum likelihood estimator (Baltagi, 2008). While skewness measures the rate at which a distribution is not symmetric about its mean value, kurtosis measures the tails of the distribution (Brooks, 2014). A normal distribution is not skewed and is symmetric about its mean while one tail will be longer than the other in a skewed distribution. From our policy data, we observe that while countries such as Germany adopted *FIS* policies during the early 90s with higher installed capacity, most of the countries implemented RES-E policies in the late 90s, and hence we expect our data to be skewed. Therefore to test for the deviation from normality, the Bera-Jarque test Jarque and Bera, (1980) was conducted using Stata. This test allows for the determination of whether mutually, the coefficient of skewness and kurtosis of the errors are zero. In other words, it tests the null hypothesis that the distribution of the series is symmetric about its mean. The test results and interpretation are presented in chapters 4 and 5 respectively.

Violation of the homoscedastic assumption of OLS (variance of the errors being constant) is known as heteroscedasticity, which we test by using the Breusch-Pagan test in Stata (Breusch and Pagan, 1979). When the homoscedasticity assumption is violated OLS estimates could still be unbiased and consistent but the desirable efficiency property would be lost; thus, the minimum variance among the group of unbiased estimators would be lost (Brooks, 2014). The presence of heteroscedasticity could lead to misleading inferences if the standard errors are wrong. The Breusch-Pagan Test results for all models are presented in Chapter 4, Table 4.3 and Chapter 5, Tables 5.1 and 5.2 respectively. The results indicate evidence of the presence of heteroscedasticity and therefore the need for additional treatment to remedy this concern. The interpretation of the results and the process of treating this concern are presented in the respective chapters.

It is usually assumed in classical regression models the error terms are not correlated with one another. In other words, the covariance between the error terms over time is zero (Brooks, 2014). Violation of this assumption would mean that the error terms are correlated across time, known as serially correlated or autocorrelated. Ignoring the presence of autocorrelation could still lead to unbiased estimates; however, they would be inefficient to make inferences. Similar to heteroscedasticity, the desirable properties would be lost and hence misleading inferences could be made when standard errors are wrong. We test this by using the Wooldridge test in Stata which indicates the presence of autocorrelation in all model specifications (Wooldridge, 2010). Test results for all models are presented in Chapter 4, Table 4.3 and Chapter 5, Table 5.1 and 5.2 respectively, as well as their interpretation and treatment.

There is also an assumption when using OLS that explanatory variables are not correlated and hence the need to test for this, since we expect some of our explanatory variables to be correlated. We compute Variance Inflation Factors (VIF) for the correlation of explanatory variables and observe that energy use, electricity consumption per capita and electricity production had high factors in all model specifications. Energy use and electricity production were dropped, which reduced the mean VIF to acceptable levels according to the rule of thumb. Results of the VIF test are presented in Chapter 4 Table 4.2 with explanation and the test process. According to Kennedy (2008) the rule of thumb for the VIF test states that factors above 10 indicate unfavourable collinearity and therefore there is less concern for multicollinearity after dropping energy use and electricity production (See Table 4.2 in Chapter 4). Since the problem of multicollinearity is mostly associated with data rather than the model Brooks (2014), simple transformation such as taking natural log of the variables, as done in this research could also remedy the concern (Maddala and Lahiri, 2009). We also provide a correlation matrix with the log transformed variables used in Chapter 4 and Chapter 5 presented in Appendix, AC4 Table 4 and AC5 Table 11 respectively. The results indicate little concern of multicollinearity.

4 The Effectiveness of Renewable Energy Policies in the European Union: Evidence from Wind Energy

4.1 Introduction

In the last decades, global energy markets have been threatened with two major issues which are progressively dominating the global energy agenda, namely: i) the liberalisation of the electricity markets, and ii) the fulfilment of environmental targets - carbon reduction, or percentage of renewable energy installed capacity as compared with traditional energy sources (Schaeffer et al., 1999). For instance, the Kyoto Protocol was a global coordinated effort to accomplish environmental targets, while the EU has also set targets for the usage of renewable energy for 2020 and 2030.

The fulfilment of environmental targets has increasingly been debated and has been a global concern vis-a-vis the consequences of harmful emissions in the atmosphere, resulting in governments taking measures to reduce these emissions. Human activities, such as electricity generation through fossil sources, have been identified as the major contributor of these harmful emissions into the atmosphere. Upon several deliberations by global leaders, it has been agreed that proper coordination and support are needed to reduce the level of harmful emissions into the atmosphere by way of reducing electricity production from fossil fuels, which is a significant part of the political agenda of the EU.[22]

---

[22] UNFCCC report 2007.

However, there are some market barriers and failures affecting the deployment of RES-E technologies and hence the need for government intervention (Painuly, 2001).Wind energy and other RES-E require a high initial investment, which puts them at a disadvantage as compared to the traditional fossil fuel sources. The liberalisation of electricity markets in the EU was also aimed at obtaining lower consumer prices through stronger market competition. A basic problem in this connection is that sustainable energy development requires a planning horizon of 40 to 50 years while the time horizon of commercial markets is much shorter (Meyer, 2007). The expected economic lifetime for a wind farm has been estimated between 20 to 25 years (Crawford, 2009).

According to Meyer (2007), most often, ill-considered commercial investments prevent the introduction of supply systems which are more environmentally friendly, ensure higher energy supply, as well as being less costly in the long run. He posits that wind energy and other RES-E of supply are examples of favourable alternate sources in the long run. One can, therefore, foresee conflicts between the interest of the EU in increasing renewable energy sources - demonstrated by the announcement of a commitment to derive 20% of energy from renewable sources by 2020, and the manner in which concerns for liberalization ripple out and affect the RES-E policy frameworks of individual member countries (Meyer, 2007).

Due to the re-structuring of the energy and electricity markets in the EU, previous implemented support policies were observed to be inefficient Schaeffer et al. (1999) and hence, there was a the need for more advanced and consistent support schemes to be implemented to enable them meet their set targets (Menanteau et al., 2003). This has been reflected in our statistical analysis, whereby the earlier implemented *Tax* and other fiscal incentives did not significantly enhance the development of wind energy in the past. For instance, Aguirre and Ibikunle (2014) are of the view that the initial implemented *Tax* breaks used to encourage RES-E capacity development have a negative impact on capacity development due to the uncertainty underlining their duration and continued existence.

Consequently, governments in the EU developed different support schemes and policies to encourage investments in RES-E technologies (Haas et al., 2011; Meyer, 2003). The implementation of these policies is concurrent with the rapid growth of RES-E capacity especially wind energy which has attracted the attention of academics and practitioners in recent years, and is seen as one of the main alternative energy source to reduce carbon emissions (Green and Vasilakos, 2011). The controversy relates, however, to which of these policies enhance more adequately the RES-E capacity development. Most of the earlier research on the effectiveness of RES-E policies is of a quantitative nature and case studies primarily focused on the U.S., during a time where there was no mandatory reduction of carbon emissions. Only a few recent studies have attempted to examine the effectiveness of the RES-E policies in the EU.

In this chapter, we study the effectiveness of RES-E support policies in the EU and identify which of the support policies has been very effective (if there is any) in promoting the development of wind energy across the continent. We analyse a data sample which collates information on 27 EU countries and examine both the overall and per country effectiveness of policies on the development of wind energy.

We consider different policy designs and policy enactment dates. Our analysis controls for both the existence and experience of the RES-E policies on the development of wind energy. In this comparison, the main criteria of success are the speed and scale at which wind energy penetrated the (national) energy markets, particularly the increased installed production capacity of wind energy. The promotion and penetration of wind energy power depends on several policy related factors, and these form the basic structure of the comparative evaluation of such policies. We measure the effectiveness of the *FIT*, *FIP*, *Quota*, *Tax*, *Tender*, and the *Cap* policy by examining the rate at which wind energy capacity increases or decreases as a consequence of a given policy being in place. Our results show that the *FIT* and the *Quota* are the most effective RES-E policies in the EU based on experience and existence in the case of *Quota*. *Tender* also has a week significant relationship with wind energy.

4.2 Literature Review

Several approaches have been used to study the effectiveness of RES-E policies including the use of qualitative methods (Espey (2001), Harmelink et al. (2006), Rabe (2006), and Wiser et al. (2007), and case studies (Langniss & Wiser, 2003; Reiche & Bechberger, 2004). Consistent among them is the success rate of some of the national and sub-regional RES-E policies on the capacity development.

For instance, Meyer (2003) examines the potentials and the problems regarding an increase in the RES-E generation through support systems in liberalised energy markets. He considers the *FIT* system, *Quota*[23] and *Tender* support schemes and concludes that the *FIT* scheme has surpassed other incentive schemes in promoting wind energy capacity development.

These results are consistent with those of Meyer (2007) who provides a comparative study on the renewable energy policies of Spain, Sweden and Denmark, more specifically, their

---

[23] This is also known as renewable portfolio standard (RPS) in the USA.

commitment to the wind energy capacity development. He argues that long term stability of a given support scheme when applied to the wind energy, are the most popular and effective policies and conclude that amongst the policies in place the *FIT* is the most effective one. He observes, however, that from time to time, in all countries, energy policies are likely to change, which introduces regulatory uncertainty and may delay investments. While the work of Meyer (2007) is of a qualitative nature, we provide an ex post quantitative approach by using statistical methods to determine the long term stability of policies on capacity development.

Huber et al. (2004) study different elements underlying the various support schemes adopted in the EU 15 and find that there is no clear favourite RES-E support scheme - each support scheme has merits and demerits. They suggest that the initial design, components and structure of RES-E policies are the most essential parts that need to be examined carefully to attract investors to develop new technologies rather than favouring already existing technologies. They conclude that well-designed *FIT*s implemented among the EU15 countries are the most efficient RES-E schemes as compared to other implemented policies. They emphasise the importance of a well-designed RES-E policies to reduce the revenue uncertainty and attract investors.

Van der Linden et al. (2005) conducted an international experiment of RES-E support policy schemes in the USA and Europe and conclude that *Quota* is an effective and efficient RES-E incentive scheme since it offers an appropriate level of financial assistance to the end user which promotes renewable energy power investments particularly in Europe. Their study is, however, based on samples which cover a very limited time period; and at the time the studies were conducted there was still little experience regarding the use of the *Quota* scheme.

Gan et al. (2007) also made a comparative study on the renewable energy policies for some EU countries and the US and their impact on installed capacity growth. Their results reveal that countries with clear, coherent and consistence RES-E policies and goals, such as Germany, attained better results in the promotion of renewable energy, whereas countries such as the Netherland, Sweden and the US progressed at a slower pace due to inconsistencies in the incentive schemes in place and regulatory uncertainty on the future support schemes. They conclude that the *FIT* and the *Quota* are the most effective policies in promoting renewable energy technologies.

Furthermore, Dinica (2006) analyses support schemes for the promotion of RES-E from the investors perspective where she emphasizes on the fact that the profitability risk associated with the support schemes do have an impact on the investor's investment behaviour. Also, she concludes by laying much emphasis on the importance of policy design, which should provide investors with high confidence regarding their rate of profitability and at the same time guarantee low risk of investment. She shows that commended *FIT* could result in lower renewable energy diffusion when designed poorly. Lemming (2003) analyses financial risk in a *Quota* market from the perspective of both existing and potential investors in green electricity generation. The framework for the study was based on a consumer-Based TGC system with market where wind farms are the only source of green energy. A negative correlation is reported between the TGC prices and wind farm energy production variation. This negative correlation tends to reduce the short term financial risk. Therefore, there is a positive effect of variations in prices of TGC on financial risk as compared to the *FIT* systems.

Kydes (2007) and Palmer and Burtraw (2005) analyse the effectiveness of RES-E policies. The former article studies the variations in the renewable energy policies in the US and their effect on energy targets, and find that RPS affect significantly the energy targets set at both short and long terms. The latter studies the effect of renewable portfolio standards on the US energy markets and concludes that RES-E deployments as well as carbon emissions reduction targets are highly affected by RPS policies (even though the state level RPS positively affect RES-E development, they also slightly increase the cost of electricity prices).

There are few empirical studies on the effectiveness of RES-E policies, perhaps due to the lack of information available, or the differences in renewable energy schemes in place across countries, or the long time frame over which energy goals are usually set (See Carley, 2009). One exception is Menz and Vachon (2006), who study the effectiveness of renewable energy policies on the wind farm investments in the USA, using a dataset which comprises information on wind power capacity, wind quality and incentive policy regimes for 39 US states for the time period of 1998 to 2003.[24] Their findings reveal that the state share of wind energy deployment is highly affected by policies in place which aim to promote wind energy. Also, they find that RPS and the Mandatory Green Power Option (MGPO) have a positive and statistically significant effect on the wind energy distribution among states. Financial incentives and the voluntary green power choice, however, exhibit less effect on wind energy capacity development. We note the fact that the generalisation of their results is limited due to the limitations with the small sample size.

Carley (2009) tests the effect of *RPS* incentive schemes on the percentage of electricity generated through RES-E in the US, using OLS, fixed effects and fixed effects vector

---

[24] The researchers initially considered all 50 states in the US but later dropped 11 states due to lack of data and low wind energy potential among those states.

decomposition model and time series variables, using a dataset comprising information on 48 US states for the time period of 1998 to 2006. Consistent with Menz and Vachon (2006), the findings, reveal that the percentage of the RES-E power installed capacity compared with the total energy power installed capacity increases with the number of regional states committed with RPS policies. Yin and Powers (2010) also examine, for the US market at a state-level, the effectiveness of the *RPS* policies on the growth of RES-E, controlling for the state and year and develop a new measure which captures important features of the design of the *RPS* policies. Their results suggest that the developments in the RES-E capacity installed are significantly affected by both the specifics of the design and the implementation of *RPS* policies.

Shrimali and Kniefel (2011) use a panel dataset which comprises information on over 50 US states for the time period of 1991-2007. Using a fixed effects model they estimate the impact of the *RPS* policy on the development of wind energy, solar photovoltaic and geothermal and conclude that the *RPS* policy when focusing on either the output sale or the increment in the capacity installed are positively associated with investments in geothermal and solar energy and negatively associated with investments in the wind and biomass capacity. They also find that statistically there is no significant relationship between investments in renewable energy and the GDP, GDP per capita, and natural gas price. The above results apply, however, to *RPS* policies in the US only - where there is no mandatory carbon emission reduction scheme.

Dong (2012) analyses the impact of the *FIT* and *RPS*, using a panel dataset which comprises information on 53 countries for the time period of 2005-2009. Their results suggest that the use of *FIT* incentive schemes led to about 1,800MW more of wind capacity installed than the use of the *RPS* incentive scheme. They also find that high energy power demand and oil dependence are positively correlated with investments in wind energy and affect the pace of investments in wind energy. They also report that there is a high positive correlation between wind energy capacity development and electricity market factors. The short time frame of their data sample could affect the testing of multicollinearity when lags of electricity net is included. Their research also focused on two RES-E policies (*FIT* and *RPS*), thereby ignoring other policy incentives implemented in countries within their sample, which could possibly have an effect on the development of wind energy. The issue of endogeneity is not addressed in their paper, therefore limiting the ability to generalise their findings. We address these limitations with a large data sample and the inclusion of all policies implemented among member countries in our sample, as well as using a lag structure to capture the time effect of adding capacity. These researchers also fail to consider the experience of various adopted policies on the capacity development of RES-E. It is expected that, a policy of which there is long experience could be more effective in enhancing the capacity development than a fairly new policy. A well tried policy could be amended for enhancement of results as a result of experience from practising and learning. The previous research also fail to consider the time effect of how long it takes to add capacity based on the existence of a policy which is considered in this research.

Using 38 countries worldwide and applying the fixed effects vector decomposition model Aguirre and Ibikunle (2014) examine the determinants of RES-E growth and posit that some government supported RES-E policies such as *Tax* breaks derails investment in RES-E technologies. Polzin et al. (2015) also examine the impact of public policy on RES-E investments by institutional investors using OECD countries and suggest that *FIT* policy is a strong driver of RES-E investments since it has direct impact on the risk and return structure of such projects. Neither Aguirre and Ibikunle (2014) nor Polzin et al. (2015) consider the impact of policy experience on deployment of RES-E technologies.

Determining the effectiveness of RES-E policies and other drivers of RES-E capacity development is an ongoing debate, with very few applications to the EU market, with the exceptions being (Marques et al. 2010; Marques et al. 2011; Jenner et al. 2013; Dombrovski 2015). Specifically, Marques et al. (2010) analyse the effectiveness of RES-E policies using a panel dataset collected from the time period of 1990-2006 and a regression model based on fixed effects vector decomposition. Their results suggest that the EU directives, such as the Directive 2001/77/EC, are in the right direction, and oil, coal and natural gas prices as well as the level of CO2 emissions limits investments in renewable energy technologies in Europe.

Marques et al. (2011) also examine the drivers of renewable energy development in the EU using quantile regressions. They assert that environmental issues such as global warming are not yet affecting investments in RES-E. Neither Marques et al. (2010) nor Marques and Fuinhas (2011b) consider country specific policies aimed at driving RES-E development in their research. They ignore the impact of specific policy framework of countries on the development of RES-E. They also did not consider the determinants of specific RES-E technology development. Romano and Scandurra (2011) also study the determinants of renewable energy investments using a sample which comprises information on 29 countries for the time period of 1980 to 2008, grouping the countries as low and high carbon emission economies. Their results show that GDP, technological efficiency and nuclear power generation significantly explain the dynamics of investments in renewable energy markets.

Jenner et al. (2013) test the effectiveness of the *FIT* policy using a fixed effects regression model, based on a dataset with information on 26 EU countries for the time period of 1992-2008. They use a new indicator, return on investment, which captures the strength of the *FIT* policy considering the policy tariff size, digression rate, duration of contract, electricity prices and the cost of production from renewable. Their results show that *FIT* policies have a significant impact on the solar photovoltaic development, but no effect on the wind energy development if implemented alone.[25]

Bolkesjø et al. (2014) use an econometric model based on a behavioural model similar to that of Jenner et al. (2013) and technology, policy and country specific data for RES-E capacities from 1990 to 2012 of the five largest electricity consuming countries in Europe (UK, France, Germany, Spain and Italy) and posit that *FIT* has positively and significantly affected capacity development of onshore wind and solar photovoltaic. Their findings of a positive impact of *FIT* on capacity development of onshore wind is contrary to that of Jenner et al. (2013) who find no significant relationship. While their analysis covers only five countries in the EU, the analysis of Jenner et al. (2013) does not cover data for current years. Both analyses neglect the impact of policy experience on the deployment of RES-E technologies, which is analysed in this chapter. Dombrovski (2015) also analyse the impact of support policies on capacity development in EU and posit that the *FIT*, *Tender* and *Quota* policies are drivers of wind energy capacity development. Dombrovski (2015) is the first to distinguish between *FIT* and *FIP* and test its impact on capacity development in the EU, yet, they ignore the impact of policy experience.

---

[25] They observe that the *FIT* is only effective in promoting wind energy capacity when combined with the Tender scheme.

Therefore, there is a need for deeper interrogation of the design of RES-E policies which is part of the motivation for this chapter. Table 4.1 below summarises the available literature on the evaluation of RES-E support policies and their main findings.

Table 4.1: Summary of Relevant Literature

Class of Study	Authors	Sample	Dependent variable	RES_E Technology	Policy Variables	Key Findings
	Bolinger and Wiser (2001)	USA	Renewable growth	Total Renewable	14 Different state clean energy funds	Much finance is needed to support capacity development
	Berry and Jaccard (2001)	9 USA states,3 EU countries and Australia	Renewable percentage	Total renewable	RPS	The find significant relationship between RPS and development
	Lemming (2003)	EU	RES-E development	RES-E development	Quota, FIT	They observe a negative correlation between Quota and wind energy production which turns to reduce short term financial risk as compared to FIT
	Meyer (2003)	Spain, Sweden and Denmark	Renewable energy growth	Renewable energy	FIT, RPS, Taxes	They find FIT to be the most effective policy

Surveys and case studies	Huber et al. (2004)	EU 15	Renewable percentage	Total renewable	All RES-E policies in EU15	They did not find any superior policy. They concluded that the design and structure of policies are most important
	Petersik (2004)	US	Renewable percentage	Total renewable	Different types of RPS design policies	They find that RPS had not made large impact on capacity development
	Wiser et al. (2007)	US States	Renewable percentage	Total renewable	RPS	They find that RPS has driven capacity development among states
	Van der Linden et al. (2005)	USA and selected countries in Europe	Renewable growth	Total renewable	Various policies	Quota/RPS is the most effective policy in driving renewable energy growth
	Dinica (2006)	Selected countries	Renewable percentage	Total renewable	FIT, Quota	Concluded that investment risk associated with support schemes do have an impact investors behaviour. They found that

						FIT when designed poorly would not be effective
	Meyer (2007)	Selected countries from EU	Renewable energy growth	Renewable energy	FIT, RPS, Tax	They find FIT to be the most effective policy
	Gan et al. (2007)	US Germany, Netherlands and Sweden	Renewable energy growth	Renewable energy	FIT, Quota, Tax,	Reported consistency and well-structured such as FIT and Quota are the most effective policies in driving capacity
	Butler and Nuehoff (2008)	UK and Germany	Wind development	Wind development	Quota, Auction and FIT	They posit that FIT reduces cost to investors and drive capacity development
Econometrics	Menz and Vachon (2006)	39 U.S States	Annual cumulative capacity	Wind	Dummy: RPS,GDR,MGPO,PBF,RC	They found RPS and mandatory Green power option as the most effective policies

	Carley (2009)	48 US States	Annual cumulative Generation and % of RES-E Generation	Total renewables	Dummy: RPS	They reported RPS to be effective in driving percentage of energy generated through renewable sources
	Yin and Powers (2010)	50 US states	Percentage of RES-E Generation	Percentage of generation from renewable	Dummy: RPS, MGPO, PBF, NM. Strength of RPS through INCRQMTSHARE	They conclude that design and structure of RPS drives capacity development
	Marques et al. (2010)		% of RESE capacity. % of RES-E of total primary Energy supply	Percentage of generation from renewable	Dummy: EU membership	They conclude that EU Directive 2001/77/EC drives RES-E development
	Shrimali and Kniefel (2011)	50 US states	Percentage of RES-E capacity	Wind, geothermal, biomass and solar	Dummy: RPS,GPP,MGPO and PBF	They conclude that RPS are drive solar and geothermal investments and negatively related with wind and biomass capacity development

	Delmas and Montes-Sancho (2011)	650 Utilities	Annual Cumulative Capacity	Total renewable source of energy	Probabilities: RPS, MGPO,GDR,	They find that RPS has a negative impact on capacity development while MGPO has a positive relationship on capacity development
	Marques et al. (2011)	24 European countries	% of RESE capacity. % of RES-E of total primary Energy supply	Percentage of generation from renewable	No RES-E Policy	They posit that some socio economic factors affect development of RES-E
	Jenner et al. (2011)	26 EU countries	Solar PV, Onshore Wind, Geothermal and Biomass	Solar PV, Onshore Wind, Geothermal and Biomass	Binary controls for enactment of Tax, tendering scheme, and FIT. SFIT	The found a positive relationship between FIT and wind and no impact on solar PV
	Groba et al. (2011)	26 EU countries	Cumulative annual capacity and annual added capacity	Onshore wind and solar PV	FIT_Dummy, Tax-dummy, Tender, dummy, RPS strength (indicator),ROI nominal units indicator	They conclude that global warming is not yet driving investments in RE energy

	Pop et el.(2011)	26 OECD countries	Capacity per capita, renewable energy investment per capita and percentage of total RES-E electricity capacity	Total renewable	FIT_Dummy, Tax-dummy, Tender, dummy, and other controls	They find a small impact of technological advances on the capacity development of RES-E
	Gan and Smith (2011)	26 OECD countries	per capita supply of renewable energy and bioenergy	Total renewable energy and Bioenergy	RES-E policies, Renewable enrgy R&D, Carbon emissions policies and other controls	They find some country specific factors and GDP as drivers of RES-E
	Dong (2012)	53 Countries	Annual cumulative capacity/Added capacity	Wind	Dummy: FIT, RPS	They report a negative relationship between RPS and capacity development and a positive impact of FIT on capacity development
	Jenner et al. (2013)	26 EU countries	Added capacity	Onshore Wind and solar PV	Dummy: FIT, RPS, TEN, TI, EU2001. Strength of RPS and FIT through variables ROI and INCRQMTSHARE	Wind and solar capacity development are positively related to the return on investment provided by the FIT policy.

	Bayer et al. (2013)		Added capacity	Wind ,Hydro and Solar capacities	Counts of projects registered under CDM,RES-E installed capacity	They find a significant link between Innovation and renewable energy capacity
	Aguirre and Ibikunle (2014)	38 countries worldwide	Renewable growth	Total Share of renewable	Direct Investment, FIT, Fiscal and Financial support, Grants subsidies, Green certificate, Loans, Negotiated agreements, Markets Based Instruments, Information and Education, Regulatory instruments and Voluntary instruments	They report that voluntary approaches and fiscal and financial instruments have negative impact on capacity development while negotiated agreements have a positive impact
	Bolkesjø et al. (2014)	Spain, France, Italy, Germany and UK	Cumulative capacity	Onshore wind, Solar PV and Bioenergy	FIT, RPS and Tender	They find that return on investment from FIT policy drives wind and solar PV capacity development. They also report that RPS drives bioenergy capacity development

						while tender also drives onshore wind capacity development but not solar PV and Bioenergy
	Polzin et al. (2015)	OECD countries	Added capacity	Multiple renewable sources, Wind, Solar and Biomass	FIT, Grants and soft Loans, axe based systems	They find that FIT has been effective in driving RES-E capacity development while grants and soft loans are effective in the short term.

Note: PBF represents Public Benefits Funds, RC represents Retail Choice, GDR represents Generation Disclosure Requirement, and INCRQMTSHARE represents Incremental Share.

4.3 Objectives

The RES-E support policies are expected to accelerate investments in renewable energy technologies and progress. Yet, EU countries have in place very different incentive schemes to encourage investments in renewable energy generation sources, which include in some instances, combinations of different support schemes to achieve the intended target of RES-E capacity development (see Tables 3.3 and 3.4 in Chapter 3). The question is whether those support schemes and policies have indeed increased wind energy capacity beyond what would have been the case if they were not available.

We study wind energy capacity development because it is currently the most relevant renewable energy in terms of capacity installed with rapid growth in the EU and globally (Butler & Neuhoff, 2008; Carley, 2009; Bayer et al., 2013). Incrementally, wind energy is becoming more competitive in terms of both the initial investment cost and production cost (Awerbuch, 2003; Jenner et al., 2013). Several factors could be associated with the growth disparity of wind energy development among the EU countries, such as natural factors, socio economic factors among others (Van der Linden et al., 2005; Marques and Fuinhas, 2011). Nevertheless, the support schemes and incentive policies in place do play a major role (Menz and Vachon, 2006; Carley, 2009; Marques and Fuinhas, 2011b; Bolkesjø et al., 2014). Our aim is to examine the effectiveness of each of the incentive policies that are in place in the EU countries, over the time period of 1992 to 2013.

Majority of the past studies examining the effectiveness of RES-E policies are of qualitative nature and usually applied to the US context. The few studies which consider empirical examination but focussed on US data include Menz and Vachon, (2006), Carley, (2009), Lyon and Yin, (2010), and Yin and Powers, (2010), with limited data sample, as seen in (Menz and Vachon, 2006). Recent studies with empirical examination focused on European data include (Marques et al., 2011; Marques and Fuinhas, 2011a, b; Shrimali and Kniefel, 2011; Jenner et al., 2013; Dombrovski, 2015). However, while Marques et al. (2010) and Marques and Fuinhas (2011b) did not include country specific support policies in their analysis, Jenner et al. (2013), Bolkesjø et al. (2014) and Dombrovski (2015) consider country specific policies, yet ignore the impact of policy experience on the development of wind energy.

Therefore, in this chapter, drawing lessons from the above literature, we analyse the effectiveness of RES-E policies in terms of their existence and in terms of their experience.[26] We place much emphasis on the continuous existence of a particular policy and the number of years the policy has been in place in our analysis, controlling for the policy discontinuities using dummy variables. For instance, if a particular policy was discontinued along the years, the dummy variable takes the value of (0) while the experience of the policy also becomes (0) from the year of discontinuation. Aside from very few exceptions such as Menz and Vachon (2006), who investigate the effect of policy experience on development of wind energy using one year data in the US, the literature on the impact of policy experience on RES-E capacity development is very scarce.

We contribute to the literature by focusing on a region which has mandatory RES-E policies in place to contribute to their commitment in reducing carbon emissions and also by considering the RES-E policies which are current and or discontinued and testing their

---

[26] We consider the number of years a particular policy has been in existence. If for instance, a policy was implemented in 1997 it would be 10 years in 2007 provided the policy is still in place.

impact on the development of wind energy in the region. Furthermore, we take into account both the existence and experience "years in place" of each renewable energy scheme, which is currently scarce in the current literature.

We employ econometric analysis by using country specific and technology specific data from the EU for the period 1992 to 2013 to analyse the impact of RES-E support schemes on the capacity development of wind energy. A period where RES-E support schemes had gained much experience and its impact on capacity development could be measured with limited biasness. This period also covers the timeframe when oil prices were at the highest, which could have an impact on the capacity development of wind energy. To the best of our knowledge, no empirical study in the literature uses a data sample which goes beyond 2012. We use the fixed effects panel model estimation for our analysis. For robustness of our results, we also use pooled OLS, random effects, and PCSE for comparison. We also perform a series of specification test for reliability of our results.

We also model our econometric model to include a one year lag structure of explanatory variables to capture the time effect of adding capacity due to the enactment of a policy. With the exception of Dombrovski (2015) and Polzin et al. (2015), to the best of our knowledge, no other econometric study considers the time it takes to add capacity after the implementation of a policy. All studies assume a contemporaneous effect of policy implementation on RES-E deployment.

4.4 Data Sample and Methodology

In order to econometrically test for the effectiveness of various national RES-E support policies in the EU, we conduct analysis using policy existence, policy experience and wind power capacity for 27 EU countries. Malta was excluded from the sample due to the lack of availability of data. The time period covered by this analysis is 1992 to the end of 2013, a time during which many countries restructured their electricity markets and adopted new policies to promote the use of wind energy and other RES-E technologies in order to meet their targets. We also test for the impact of political, socio economic and environmental factors on capacity development of wind energy using a panel data approach so as to control for specific unobserved country factors that could affect wind energy development and policy implementation.

4.4.1 Data Sample

We collect country level data from different policy documents to form a national policy database for all the countries in our sample between 1992 and 2013. Our choice of variables for this research is guided by the existing literature. We also compile yearly country level data of wind capacity among all the countries in our sample for the same time period. The variables used are explained above in chapter 3 and briefly listed below. The source of our policy existence and experience data is the IEA Policies and Measures Database (IEA/IRENA, 2014) supplemented with information from Huber et al. (2004) and Haas et al. (2011) to get a complete policy database for all countries and years in our sample. The source of our wind capacity data (CC and AC) is (Eurostat statistical office of the European Commission, 2014).

4.4.1.1 Dependent Variables

The choice of dependent variable for the measurement of RES-E development varies among researchers in the literature. While some researchers consider actual generation or total energy supply for the measurement of RES-E development others measure RES-E development as either added capacity Menz and Vachon, (2006), Jenner et al. (2013), Dombrovski (2015), cumulative capacity Carley (2009), Bolkesjø et al., (2014) and Polzin et al. (2015) or percentage of RES-E to total electricity generation (Marques et al., 2010, 2011; Marques and Fuinhas, 2011b).

In this chapter we use two dependent variables to capture the effectiveness of RES-E policies on wind energy capacity development. The dependent variables, CC and AC are both absolute values rather than percentage growth. While the former is the absolute annual cumulative capacity in MW, the latter is the absolute annual added capacity in MW. The choice of a dependent variables depends on the aim of the research. The main aim of our research is to determine how much capacity of wind has been added as a result of the existence or experience of a policy. Therefore, our focus is on the additional capacity added as a result of a policy rather than the cumulative capacity from previous years. However, we use cumulative capacity as a robustness check and also to avoid the omission of negative capacity values, since our variables are log transformed. Cumulative capacity is not used as the main dependent variable but purposely for robustness checks because we do not expect the enactment of a policy during the current year to have an impact on previous year's capacity development.

Also, absolute added capacity was chosen instead of growth rate to avoid explosive growth rate from countries with little wind capacity in a particular year and growing at a higher percentage in the next years. For instance, the total wind energy capacity of Bulgaria in the years 2004 and 2005 was 1 MW and 8MW respectively indicating a 700% increment. So therefore, using percentage increment or growth rate as a dependent variable could lead to high rates when in actual sense the increment in absolute terms is minimal, hence introducing additional statistical variability which is irrelevant to our analysis (see for instance Jenner et al. 2013).

Also, using absolute added capacity reduces the variability that would have otherwise been introduced if ratio of RES-E to total capacity was used. RES-E percentage share is very sensitive to electricity production from fossil fuel sources. For instance, the total electricity capacity of a country could increase as a result of reducing gas prices due to shale gas reserves and which would impliedly reduce the importation of coal. When this happens, despite the fact that wind capacity could be growing in terms of percentage, it could be relatively declining as a percentage to total electricity. Also, when other conventional facilities are shut down due to environmental concern as happened in 2011 when Germany shut down eight nuclear stations, the total electricity capacity decreases, which automatically increases the percentage of RES-E even when additional capacity is not added. Therefore, using a ratio as a dependent variable could sometimes be misleading in such instances, hence our choice of absolute added capacity as a dependent variable. The dependent variables are logged based on specification tests.

4.4.2 Independent Variables

4.4.2.1 Country Specific Policies

For the purposes of this study, we consider the *FIT*, *FIP*, *Quota, Tax, Tender* and *Cap* as the major polices implemented by EU countries to promote wind energy and other RES-E technologies. For all these policy variables, we consider their date of implementation and create dichotomous variables for them. For instance, to test for the effect of the policy existence on the outcome variable, we use a dummy variable which takes the value of "1" if the policy is in existence in a given year. If the policy is not in existence in a given year, the dummy variable takes a value of "0". We also test for the effect of the number of years a particular policy has been in existence on all the outcome variables. In addition to the policy specific variables, we control for other socio economic, political and environmental variables.

4.4.2.2 Control Variables

In line with previous literature, we control for a mixture of socio economic, environmental and political factors which could impact on capacity development of wind energy. These variables include electricity consumption per capita (*Elect.Consumption*), Gross Domestic Product per capita (*GDP*), percentage of electricity production from oil sources (*Oil Share*), percentage of electricity production from coal (*Coal Share*), percentage of electricity production from natural gas (*Natural Gas Share*), percentage of electricity production from all renewables excluding hydroelectric (*Renewable Share*) and rate of population growth (Popul.Growth), oil price (*Oil Price*), natural gas price (Natural Gas Price), coal prices (Coal Prices) and percentage of energy import dependence (*Energy Import*) and wind energy potential (*Potential*). We take the natural logarithm of the control variables based on specification tests results. All variables, notations, descriptions and their sources are presented in Appendix, AC5 Table 12 and explained in Chapter 3.

4.4.3 Panel Model Specification

Panel data analysis is meaningful in several different ways. Panel data analysis could still provide meaningful research outcomes when the data is balanced, unbalanced, or even when there is missing information. Using panel data makes possible the expansion of sample size as well as gaining of extra degrees of freedom, which is particularly important when a large number of regressors are used (Wooldridge, 2010). Two of the major estimation techniques applied in panel data analysis are the fixed effects estimation and the random effects estimation. While the fixed effects estimations controls for specific unit heterogeneity, potential endogenous variables are instrumented by the random effects models (Baltagi, 2008). Therefore, estimating with the fixed effects assumes that the coefficient of the slope is constant for all countries. However, while the intercepts are assumed not to vary across time, they vary across individual countries indicating heterogeneity among countries (Wooldridge, 2010). On the other hand, the random effects model assumes that the variations across countries are rather random and uncorrelated with the independent variable. Thus, the coefficients for the slope are assumed constant across all units, while the intercept remains a random variable. This implies that in a random effects model, $\alpha = \alpha_1 + \varepsilon_i$ where the mean value for the intercept of all countries is represented by α while ε_i represents the random error which captures the individual variations in the intercept of each country in the sample.

Therefore, using a random effects model for panel data such as ours where unit heterogeneity is expected to be fixed across countries, would yield inconsistent estimates; hence, the fixed effects estimator might be the best model. Therefore, we test the impact of the existence and the experience of a given policy on wind energy capacity development (CC and AC), using the country fixed effects regression model below where t refers to time and i to country.

The base form of the model is given below in Equations 4.1 and 4.2 respectively

$$LnCC_{it} = \beta_0 + \beta_1 FIT_{it} + \beta_2 FIP_{it} + \beta_3 Quota_{it} + \beta_4 Tax_{it} + \beta_5 Tender_{it} + \beta_6 Cap_{it} + \beta_7 H_{it} + \beta_8 k_{it} + \varepsilon_{it} \quad (4.1)$$

$$LnAC_{it} = \beta_0 + \beta_1 FIT_{it} + \beta_2 FIP_{it} + \beta_3 Quota_{it} + \beta_4 Tax_{it} + \beta_5 Tender_{it} + \beta_6 Cap_{it} + \beta_7 H_{it} + \beta_8 k_{it} + \varepsilon_{it} \quad (4.2)$$

The model estimation with the lag effect is presented in equations 4.3 and 4.4 respectively,

$$LnCC_{it} = \beta_0 + \beta_1 FIT_{it-1} + \beta_2 FIP_{it-1} + \beta_3 Quota_{it-1} + \beta_4 Tax_{it-1} + \beta_5 Tender_{it-1} + \beta_6 Cap_{it-1} + \beta_7 H_{it-1} + \beta_8 k_{it-1} + \varepsilon_{it-1} \quad (4.3)$$

$$LnAC_{it} = \beta_0 + \beta_1 FIT_{it-1} + \beta_2 FIP_{it-1} + \beta_3 Quota_{it-1} + \beta_4 Tax_{it-1} + \beta_5 Tender_{it-1} + \beta_6 Cap_{it-1} + \beta_7 H_{it-1} + \beta_8 k_{it-1} + \varepsilon_{it-1} \quad (4.4)$$

where $LnCC$ represents the natural log of the cumulative annual wind energy capacity while $LnAC$ represents the natural log of absolute growth or annual added wind energy capacity installed in a particular country at a given time. *FIT, FIP, Quota, Tax, Tender* and Cap represents the existence (dummy variable) or experience (number of years) of each of the policies in a given country at a given time. H represents the natural log of suit of socio economic, environmental and political factors explained in Chapter 3 which could possibly impact on the development of wind energy capacity (*Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Oil Price, and Ln Elect. Price, Ln Coal Price, Ln Energy Import, Ln Potential*) and K represents unobserved country specific time invariant effects such as wind technical potential, planning regimes and capacity prior to our sample period).[27] ε is an independent identically distributed random error term. *t-1* represents the one year lag effect of the independent variables on the dependent variables.

While the baseline models (Equations 4.1 and 4.2) aim to capture the effect of pent-up demand before a policy is implemented, we include a one year lag structure in models 4.3 and 4.4 to capture the effect of the time it takes to add capacity due to the implementation of a policy as explained in Chapter 3, Section 3.2.1. Regarding the possible endogeneity problem related to the "renewable share variable" used in our regression model specification, given that growth of wind energy is directly related to renewable energy growth, the lag of renewable energy share in Equations 4.3 and 4.4 is not endogenous, hence, mitigates the reverse causality problem (see, e.g., Kennedy, 2008). Therefore, our results with the lagged independent variables provide unbiased and consistent results.

Also, the use of CC is purposely for robustness checks, because, we do not expect the enactment of a policy during a particular year to have an impact on capacity development during the previous years, as noted in Section 4.4.1. Nevertheless, it is interesting to see the results and use as a robustness check, hence, we report the results from the CC model. All analyses and inferences in this chapter are based on the results from our fixed effects model with AC as dependent variable and a one year lag of independent variables presented in Table 4.5 below.

Our fixed effects specification model provides consistent and unbiased estimates if omitted country level time invariant variables are correlated with the independent or

---

[27] We initially included a variable for "energy use" in the regression model which was highly correlated with energy consumption per capita and electricity consumption per capita. Energy use and energy consumption per capita were subsequently dropped.

dependent variable. Unobserved country fixed effects such as RES-E planning regimes of countries in our sample, technical potential of wind (windiness), the total capacity of wind energy prior to our analysis period, land area as well as other time invariant environmental factors could be correlated with both wind energy capacity development and the enactment of a policy and hence the need to employ a model which controls for these country specific fixed effects (Carley, 2009; Shrimali & Kniefel, 2011; Boomsma et al., 2012; Jenner et al., 2013; Polzin et al., 2015).

To establish the relationship between the existence and experience of RES-E enacted country specific policies on the development of wind energy capacity, we use a variety of panel data analysis. Initially, we use an OLS model to estimate the association between policy existence and policy experience on wind energy capacity development using our two measures of wind capacity development (*Ln CC* and *Ln AC*). We use both cumulative capacity and added capacity in order to differentiate the effect of policy existence and experience on historical development of wind and the development in recent years for robustness check, (see for instance, Dong, 2012). Analysing our results based on OLS could lead to inconsistent and biased results due to its inability to control for country level time unobserved factors which will lead to omitted variable bias (Carley, 2009; Jenner et al., 2013). When standard errors are heteroscedastic within the sample as evidenced in this case according to the results presented in Table 4.3 below, the omission of correlated time invariant variables would lead to biased estimates. We therefore conduct the Breusch and Pagan Lagrangian Multiplier (LM) test for random effects, Breusch and Pagan (1980) by using the xttest0 command in Stata. This tests the hypothesis that there is no difference in the estimation from OLS and the random effects. The test results indicate the superiority of the random effects model over OLS at the 1% confidence level for all model specification (see Table 4.3 below).

We note, however, that these country specific effects could be expected to be random or fixed across the sample. If the effects are random, it is assumed that the time invariant variables are not correlated with other independent variables. The random effects model would result in more reliable coefficients in the case that these unobserved time-invariant variables are uncorrelated. However, with our sample, one would expect the unobserved time invariant variables to be correlated with the policy incentive dummy variables and in that case, the random effects estimation would yield inconsistent estimates (Carley, 2009). Using the random effects in this case will result in overconfidence of results. Therefore, a fixed effects estimation would be the appropriate model to use when we expect unobserved omitted time invariant factors to be correlated with both policy variables and wind energy capacity development (Carley, 2009; Marques et al., 2010). Unobserved country unit heterogeneity is controlled for by the fixed effects model so as to eliminate bias of coefficients time variant and invariant factors.

To confirm the superiority of the fixed effects model over the random effects model, we conduct the Hausman test Hausman (1978), to determine whether the fixed effects or random effects would produce efficient and consistent estimates and whether there is the presence of unit heterogeneity.[28] From the results of our Hausman test presented in Table 4.3 below, we reject the null hypothesis of no unit heterogeneity indicating the need to apply the fixed effects estimation to control for unobserved variations between countries. The p values of the test statistics for all regression equations are less than 0.05 indicating

---

[28] The Hausman test compares two estimators known as $\hat{Q}_1$ and $\hat{Q}_2$ consistent with each other under the tested assumption. Estimator $\hat{Q}_2$ being efficient and consistent under the tested assumption is the null hypothesis (H0). Hence, there should not be systematic differences between both estimators. The efficiency assumption would be violated if the data is clustered and hence the Hausman test could not be properly applied in determining the appropriate model. The results of our Hausman test indicate the superiority of the fixed effects model in making our analysis.

significance at the 1% confidence level.[29] Hence, our analyses are based on the results from the fixed effects regression models. We however provide results from the OLS and random effects models for robustness purposes.

Furthermore, from the results of our specification test presented in Table 4.3 below, the presence of heteroscedasticity and autocorrelation in our data sample presents a concern which has to be robustly analysed. Even though this concern has been dealt with in our fixed effects model with the use of the robust command as suggested by Hoechle (2007), for further robustness and comparison of different estimation, we follow Parks (1967) and use a two-step process to address serial correlation and heteroscedasticity in our sample. We remove possible serial correlation by estimating auto correlation from OLS residuals in the first step. We remove heteroscedasticity and contemporaneous correlation in the second step by using PCSE as proposed by (Beck and Katz, 1995). Coefficients of OLS estimates are used by the PCSE to compute standard errors devoid of contemporaneous correlation and heteroscedasticity. Coefficients of the PCSE specification are over estimated without controlling for country fixed effects. Result for this estimate with a one year lag structure is reported in Appendix, AC4 Table 2. The xtpcse command in Stata was used for this regression.

4.4.4 Analysis of Specification Test

Prior to our analysis, we a perform series of diagnostics test to examine the reliability and validity of our data and estimators. We conduct the Bera-Jarque test, Jarque and Bera (1980) for normality using the sktest command in Stata, of which results for all models

---

[29] The Rho for the fixed effects regression results was high (.99936128) indicating the fraction of variance explained by the independent variables.

indicate that the data deviates from normality and hence should be transformed. The independent and joint significance of the test is significant at the 1% confidence level. The data was then transformed by taking natural log of the variables as suggested by Brooks (2014), which resulted in the data getting close to normality with a 10% significance level for both kurtosis and the joint test and no significance for the skewness.

Table: 4.2: Variance Inflation Factors

VIF with policy existence variables						VIF with policy experience variables					
Before			After			Before			After		
Variable	VIF	1/VIF	Variable	VIF	1/VIF	Variable	VIF	1/VIF	Variable	VIF	1/VIF
Energy Use	26	0.04	Elect.Consumption	7.81	0.13	Energy Use	27	0.04	Elect.Consumption	7.7	0.1
Elect.Consumption	16	0.06	CO2	6.34	0.16	Elect.Consumption	16	0.06	LnCO2	6.3	0.2
Elec.Production	14	0.07	Natural Gas Share	5.94	0.17	Elec.Production	13	0.08	Natural Gas Price	6	0.2
Potential	12	0.09	GDP	5.87	0.17	LnCO2	12	0.09	GDP	5.7	0.2
LnCO2	11	0.09	Oil Price	4.41	0.23	Potential	11	0.09	Oil Price	4.5	0.2
GDP	8.9	0.11	Coal Price	4.27	0.23	GDP	8.3	0.12	Coal Price	4.4	0.2
Natural Gas Price	6.6	0.15	FIP_Dummy	3.26	0.31	Natural Gas Price	6.7	0.15	Coal Share	3.3	0.3
Oil Price	5.2	0.19	Coal Share	3.26	0.31	Oil Price	5.2	0.19	Potential	3.3	0.3
Coal Price	4.4	0.23	Potential	3.13	0.32	Coal Price	4.6	0.22	Oil Share	2.9	0.3
Nuclear Share	4	0.25	Oil Share	2.88	0.35	Coal Share	4.1	0.24	Renewable Share	2.6	0.4
Coal Share	4	0.25	FITFIP	2.74	0.36	Nuclear Share	3.8	0.26	Elect.Price	2.5	0.4
Oil Share	3.5	0.29	Renewable Share	2.37	0.42	Oil Share	3.5	0.29	FIT_Years	2.4	0.4
FIP_Dummy	3.3	0.3	Elect.Price	2.11	0.47	Elect.Price	3	0.33	Quota_Years	2.2	0.5
FITFIP	2.8	0.36	FIT_Dummy	2.03	0.49	Renewable Share	2.6	0.39	Energy Import	2	0.5
Elect.Price	2.7	0.37	Energy Import	2.01	0.5	FIT_Years	2.5	0.4	Nuclear Share	1.8	0.5
Renewable Share	2.4	0.42	Nuclear Share	1.87	0.53	Quota_Years	2.2	0.45	Natural Gas Share	1.8	0.6
FIT_Dummy	2.2	0.47	Natural Gas Share	1.83	0.55	Energy Import	2	0.5	FIP_Years	1.7	0.6
Energy Import	2	0.5	CAP_Dummy	1.75	0.57	Natural Gas Share	1.8	0.55	Tax_Years	1.6	0.6
Natural Gas Share	1.9	0.54	Quota_Dummy	1.74	0.57	FIP_Years	1.8	0.57	CAP_Years	1.5	0.7
Quota_Dummy	1.8	0.57	Tax_Dummy	1.48	0.68	Tax_Years	1.6	0.62	Popul.Growth	1.4	0.7
CAP_Dummy	1.8	0.57	Popul.Growth	1.37	0.73	CAP_Years	1.5	0.67	Tender_Years	1.3	0.8
Tax_Dummy	1.5	0.67	Tender_Dummy	1.33	0.75	Popul.Growth	1.4	0.72			
Popul.Growth	1.4	0.71				Tender_Years	1.3	0.77			
Tender_Dummy	1.3	0.75									
Mean VIF	5.90		Mean VIF	3.17		Mean VIF	5.9		Mean VIF	3.2	

For multicollinearity, using existence and experience variables, we conduct the VIF test using the VIF command in Stata of which results indicate a mean VIF of 5.90 and 5.94 respectively (see Table 4.2 above). The highest factor was the energy use variable with a VIF of 26 and 27 using the existence and experience variables respectively. VIF for electricity production was also high at 13.65 and 13.26 using existence and experience respectively. Due to the inclusion of energy consumption and electricity production from other sources in our model, we drop energy use and electricity production variables after which we observe a mean VIF of 3.17 and 3.2 using existence and experience variables (see Table 4.2 above). The highest VIF in the model becomes less than 10 which is the rule of thumb in VIF estimation (Baltagi, 2008).

Table 4.3: Specification Test Statistics

	Existence on LNCC and LNAC		Experience on LNCC and LNAC	
Test	LNCC	LNAC	LNCC	LNAC
Wooldridge Test (autocorrelation)	159.597***	15.699***	174.830***	14.044***
Breusch-Pagan Test (heteroscedasticity)	100.92***	79.27***	94.38***	83.93***
LM Test	330.97***	79.29***	365.46***	78.92***
Hausman Test	67.95***	90.65***	129.32***	177.98***

We also employ the Breusch-Pagan test, Breusch and Pagan (1979) to test for the presence of heteroscedasticity using the hettest command in Stata. Using CC and AC, and the existence and experience of policy, the Breusch–Pagan test result indicates the presence of heteroscedasticity at the 1% significance level, presented in Table 4.3 above. This implies that the independent variables have a common variance which needs to be addressed to prevent inefficient estimates. We further test for the presence of serial correlation by using the Wooldridge test, Wooldridge (2002) with the xtserial command in Stata. For all test results, the P values are less than 0.01 indicating the presence of serial correlation. Even though our estimates would be unbiased and consistent, the presence of serial correlation makes it inefficient (Brooks, 2014). However, efficient and consistent standard errors would be produced in the presence of serial correlation if there is appropriate adjusted standard errors (Drukker, 2003; Baltagi, 2008). To obtain efficient estimates, there is the need to address the presence of serial correlation and heteroscedasticity, and therefore, we use Hoechle modified Driscoll-Kraay heteroscedasticity, autocorrelation and spatial autocorrelation robust standard errors in Stata (Hoechle, 2007).

4.5 Results

Table 4.4: Descriptive Statistics

This is a summary statistic table where, the number of Observations, Mean, Standard Deviation, Minimum and Maximum values are provided for the relevant regression model variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
CC	594	1404.384	4178.626	0	34660
AC	594	197.4545	483.9258	-240	3356
FIT_Dummy	594	0.3468013	0.476353	0	1
FIP_Dummy	594	0.1212121	0.3266487	0	1
FITFIP	594	0.0606061	0.2525358	0	2
Quota_Dummy	594	0.1447811	0.3521766	0	1
Tax_Dummy	594	0.1666667	0.3729921	0	1
Tender_Dummy	594	0.0690236	0.2537079	0	1
CAP_Dummy	594	0.0909091	0.2877221	0	1
FIT_Years	594	2.59596	4.632721	0	23
FIP_Years	594	0.5622896	1.913913	0	12
Quota_Years	594	0.9225589	2.632793	0	14
Tax_Years	594	1.257576	3.371738	0	17
Tender_Years	594	0.3451178	1.514545	0	13
Cap_Years	594	0.3619529	1.308411	0	8
GDP	594	24272.47	16756.37	2460.654	86127.24
Elect.Consumption	594	6196.756	3603.961	1935.561	17212.95
Coal Share	594	30.62511	26.62496	0	97.33103
Natural Gas Share	594	1.06E+07	6.68E+07	0	5.93E+08
Nuclear Share	594	20.57517	24.22304	0	87.98622
Oil Share	594	9.32348	19.55767	0	100
Renewable Share	594	4.28701	6.303238	0	48.62688
Population Growth	594	0.2007021	0.8253948	-3.820174	3.732596
CO2	594	8.291522	3.644724	2.636157	27.14212
Potential	594	162425.3	158893.1	2590	549190
Oil Price	594	89.4082	15.7421	27.9	140.1
Electricity price	594	74.32273	28.61197	24.25	224.95
Natural Gas Price	594	106.364	47.88678	18.7	342.3
Coal Price	594	95.77542	33.2181	32.2	276.7
Energy Import	594	45.87417	25.97881	-49.8	102.5

Table 4.4 above contains descriptive statistics of the variables used in this chapter. A preliminary analysis of the descriptive statistics is vital to determine possible biasness of results due to possible extreme variability in variables. For the purposes of this study, the mean and standard deviations of our results are as expected for all variables due to the possible large variability among countries in our panel. As expected, we have larger mean

values for variables such as CC, *Potential*, *GDP* and *Elect.Consumption*. The high values of Potential lead to high coefficients in the fixed effects regression models.

We run the regression without *Potential* and noticed the significance of our results did not change and so we report the results of the regression with *Potential*. We also expected to observe negative values for variables such as AC, *Popul.Growth* and *Energy Import* which have all been observed. Due to the energy balances of countries, we expected energy import dependence of certain countries to be negative. The negative AC of wind energy were expected due to the possibility of technical problems that could lead to farm shut down. Since our objective is to determine the growth of wind energy, we ignore the negative values and represent them by "0".

Table 4.5: Fixed Effects and Random Effects Results for the Existence and Experience of Policies on Ln CC and Ln AC with Time Lag Lag

This Table reports the results for the, random effects and fixed effects regression equations (4.3) and (4.4) with one year lag effect for the determinants of the wind energy capacity growth due to the existence and experience of RES-E policies. In the second column are the independent variables while the second row are the models used. The dependent variable in all equations is the natural log of cumulative Annual wind Energy Capacity (Ln CC) and natural log of Annual Added Capacity (Ln AC). FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy respectively are dummy variables representing the existence of feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other fiscal benefits, Tender and the first introduction of Cap respectively with a year lag .FIT_Years, FIP_Years, Quota_Years, Tax_Years, Tender_Years and CAP_Years respectively are policy experience variables representing the number of years feed-in-tariffs, feed-in-premium, Quota and Green Trading Certificate, Taxes and other fiscal benefits, Tender and Cap has been in place with a one year lag. Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Elect. Price, Ln Coal Price, Ln Energy Import, represents the natural logs of Gross domestic product per capita, Electricity consumption per capita, percentage of Electricity production from coal, percentage of Electricity production from Natural gas, percentage of Electricity production from Nuclear, percentage of Electricity production from renewable, Population Growth, Carbon emissions, Wind technical potential, Oil price, Electricity price, Natural gas price, Coal price and Energy import dependence respectively with a one year lag. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significance level, respectively. R-Squared represents the explanatory power of the regression model.

VARIABLES	Existence on LnCC		Experience on LnAC		Existence on LnAC		Experience on LnAC	
	RE	FE	RE	FE	RE	FE	RE	FE
L.FIT_Dummy	1.170*	0.816			1.381*	1.001		
	(0.436)	(0.385)			(0.383)	(0.325)		
L.FIP_Dummy	0.581	0.165			0.395	-0.034		
	(0.492)	(0.476)			(0.601)	(0.551)		
L.Quota_Dummy	1.227**	0.890*			1.646**	1.234*		
	(0.429)	(0.393)			(0.509)	(0.480)		
L.Tax_Dummy	-0.121	-0.438			-0.144	-0.506*		
	(0.375)	(0.324)			(0.297)	(0.232)		
L.Tender_Dummy	0.495	-0 006			0.714*	0.308*		
	(0.417)	(0.311)			(0.299)	(0.146)		
L.CAP_Dummy	0.472	0.085			-0.007	-0.310		
	(0.390)	(0.404)			(0.341)	(0.394)		
L.FITFIP	-1.489*	-1.077			-1.396*	-1.026		
	(0.702)	(0.622)			(0.660)	(0.610)		
L.FIT_Years			0.162***	0.145*			0.135***	0.090*
			(0.050)	(0.054)			(0.040)	(0.043)
L.FIP_Years			-0.103	-0.103			-0.098	-0.104
			(0.092)	(0.078)			(0.055)	(0.061)
L.Quota_Years			0.257***	0.262***			0.320***	0.306***
			(0.056)	(0.054)			(0.055)	(0.057)
L.Tax_Years			0.032	0.005			0.035	0.004
			(0.046)	(0.036)			(0.037)	(0.027)

L.Tender_Years			0.048	-0.039			0.075*	-0.026
			(0.044)	(0.035)			(0.034)	(0.033)
L.CAP_Years			0.159*	0.084			0.077	0.002
			(0.074)	(0.070)			(0.044)	(0.050)
L.LnGDP	1.395**	0.678	1.550***	1.040	1.043**	0.242	1.279***	0.461
	(0.441)	(1.000)	(0.453)	(0.973)	(0.396)	(0.975)	(0.385)	(1.018)
L.lnElec.Consumption	2.691*	7.141***	3.542*	7.286***	0.739	4.690**	0.995	5.391***
	(1.366)	(1.672)	(1.435)	(1.316)	(0.897)	(1.557)	(1.003)	(1.367)
L.LnCoal Share	0.435*	0.242	0.485**	0.322	0.437***	0.366**	0.476***	0.396**
	(0.221)	(0.211)	(0.168)	(0.195)	(0.126)	(0.124)	(0.118)	(0.137)
L.LnNatural Gas Share	-0.020	-0.142	-0.080	-0.262	0.050	0.103	0.035	0.052
	(0.112)	(0 146)	(0.102)	(0.130)	(0.090)	(0.144)	(0.093)	(0.143)
L.LnNuclear Share	-0.300*	-0.142	-0.276*	-0.139	-0.078	0.189	-0.090	0.119
	(0.117)	(0.169)	(0.118)	(0.147)	(0.108)	(0.158)	(0.112)	(0.153)
L.LnOil Share	-0.090	0.033	-0.071	0.062	0.080	0.163	0.070	0.149
	(0.143)	(0.154)	(0.117)	(0.125)	(0.132)	(0.143)	(0.124)	(0.140)
L.LnRenewable Share	0.288**	0.244*	0.177*	0.154	0.217*	0.157	0.126	0.084
	(0.096)	(0.094)	(0.085)	(0.089)	(0.102)	(0.096)	(0.094)	(0.092)
L.LnPopul Growth	0.128	0.063	0.120	0.058	0.188	0.115	0.166	0.080
	(0.077)	(0.060)	(0.076)	(0.059)	(0.102)	(0.082)	(0.088)	(0.069)
L.LnCO2	-2.545**	-3.340**	-2.721**	-2.617*	-0.842	-1.469	-1.144	-1.066
	(0.922)	(1.202)	(0.905)	(0.975)	(0.694)	(1.074)	(0.795)	(1.064)
L.LnPotential	0.762	-31.874	0.622	-37.286	0.774**	-21.457	0.687*	-22.599
	(0.396)	(28.187)	(0.456)	(26.146)	(0.260)	(24.731)	(0.277)	(27.591)
L.LnOil Price	0.528	0.739	0.460	0.628	0.382	0.853	0.319	0.865
	(0.617)	(0.601)	(0.560)	(0.561)	(0.546)	(0.512)	(0.492)	(0.445)
L.LnElect.Price	-0.270	-0.334	-0.829	-0.797	-0.068	-0.231	-0.771	-0.878*
	(0.376)	(0.355)	(0.536)	(0.395)	(0.337)	(0.316)	(0.516)	(0.405)
L.LnNatural Gas Price	0.484	-0.009	0.077	-0.480	-0.179	-0.783	-0.415	-1.108*
	(0.491)	(0.421)	(0.451)	(0.426)	(0.539)	(0.485)	(0.511)	(0.502)
L.LnCoal Price	1.057	1.467*	1.815*	2.076**	1.017	1.528*	1.584	1.955*
	(0.584)	(0.546)	(0.751)	(0.646)	(0.707)	(0.720)	(0.849)	(0.837)
L.LnEnergy Import	-0.051	0.088	0.143	0.376*	-0.297*	-0.278	-0.179	0.018
	(0.190)	(0.152)	(0.180)	(0.164)	(0.150)	(0.138)	(0.150)	(0.193)
Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	567	567	567	567	567	567	567	567
R-squared	0.546	0.798	0.576	0.813	0.546	0.550	0.526	0.563
Number of Countries	27	27	27	27	27	27	27	27

4.5.1 Preliminary Analysis of Results and Robustness

In Table 4.5 above, we present the results of our fixed effects and random effects model analysis of the effectiveness of support policies in driving wind energy capacity development in the EU with a one year lag structure using the models given in Equations 4.3 and 4.4. All analyses in this chapter are based on the results in Table 4.5 above. For robustness checks and comparison of our results, we present the results from the random effects and fixed effects models without the lag structure for the models given in Equations 4.1 and 4.2 for the impact of the existence and experience of wind energy support policies on capacity development (*Ln CC* and *Ln AC*) respectively in Appendix, AC4 Table 1, while the OLS estimate is presented in Appendix AC4 Table 3.

Our results from the random effects model in Table 4.5 and the results from the PCSE model in AC4 Table 2 indicate that the existence of *FIT* policy has a positive and significant impact on CC and AC at the 10 % significance level. However, the results from the fixed effects models indicate no significant impact of the existence of *FIT* on CC and AC. For the existence of *Quota*, the random effects model results in Table 4.5 and the PCSE model results in AC4 Table 2 show a significant impact on CC and AC at the 5% confidence levels. Our fixed effects model results in Table 4.5, however, reveal a 10% significant impact of *Quota* existence on CC and AC. More specifically, from the random effects and PCSE model results, for every five point change, on average, countries with *Quota* will increase their CC by 123% and 169%, respectively and AC by 165% and 186% respectively, more than countries without the policy. On the other hand, according to the fixed effects model, for every 10 point change, on average, countries with *Quota* will increase their CC and AC by 89% and 123% respectively.

Similarly, for the impact of the experience of policy on capacity development, our results from the random effects model in Table 4.5 and the PCSE model in AC4 Table 2 show that the experience of *FIT* policy exerts a positive and significant influence on CC and AC at the 1% significance level while that of the fixed effects model indicate a significant impact at the 10% significance level. For every point change in policy experience, the random effects model shows that on average, there will be an increment in CC and AC by 16.2% and 13.5% respectively while the PCSE model shows increment of 23% and 17% respectively for the same point change in policy experience. However, the results from the fixed effects model show that, for every 10% change in policy experience, on average, there will be a 14.5% and 9% change in CC and AC respectively.

Across all models, the random effects, PCSE and fixed effects, the results show that the experience of *Quota* is significantly related with CC and AC at the 1% confidence level. However, the coefficients of the random effects and PCSE models are higher than the coefficient of the fixed effects model. More specifically, when there is a one point change in policy experience, on average, CC and AC of countries will increase respectively for random effects, 26% and 32%, for PCSE, 29% and 32% and 25% and 30% for fixed effects.

According to the fixed effects and random effects models, the existence of *Tender* shows a significant impact on AC at the 10% confidence level but with no impact on CC. This outcome is expected since the already existent technologies are not eligible for *Tender* invitation. The PCSE model, on the other hand, shows no significant impact of the existence of *Tender* on CC and AC. More specifically, for every 10 point change, on average countries with the *Tender* policy will increase AC by 71% and 31% according to the random effects and fixed effects models respectively. The experience of *Tender* shows no significant impact on capacity development of wind energy according to all our models. Across all models, the existence and experience of *FIP*, *Tax* and *Cap* do not appear to have any significant impact on both wind energy capacity development. We expand on these outcomes further in the next section, emphasising the results from the fixed effects models.

The results presented in AC4 Table 1 are the random effects and fixed effects estimates for the impact of policy without a one year lag structure, which exhibit similar characteristics to the results presented in Table 4.5 above. There is not much difference with the level of significance in the results from all our model specifications. However, it can be noted that the results from the random effects model and PCSE model shows higher coefficients as compared to results from the fixed effects models. The results of the Hausman test presented in Table 4.3 indicate the presence of unit heterogeneity and hence suggest that the fixed effects is the appropriate estimation model. We note from the results of the random effects and PCSE that without controlling for country fixed characteristics (unit heterogeneity), the impact of a policy on capacity development of wind energy in a given country would be overstated, leading to over confidence in results.

We also observe that the model explanatory power R-squared is higher with the fixed effects estimates as compared to the random effects estimates in all model estimations. The fixed effects model, therefore, has more explanatory power than the random effects model for our data sample.

Several control variables are also significant determinants of wind energy capacity development in the EU. Control variables such as *Elect.Consumption, Coal Share, Renewable Share and Coal Prices* are significant determinants of wind energy capacity development and are explained in detail in the discussion section of this chapter.CO2 has a negative relationship with capacity development.

4.6 Summary of Key Findings

In summary, we observe the following outcomes from our analysis;

i. *FIT* existence has no significant relationship with CC and AC.

ii. The number of years *FIT* policy has been in place has a positive impact on CC and AC.

iii. The existence and experience of *FIP* policy have no significant impact on CC and AC.

iv. Quota existence has a positive significant relationship with CC and AC.

v. The number of years Quota policy has been in place has a positive impact on both CC and AC.

vi. The existence of *Tax*, *CAP* and Tender has no significant impact on both CC and AC (with the exception of Tender with a week significant impact on AC).

vii. The experience of *Tax*, *CAP* and Tender has no significant impact CC and AC.

viii. Income effect measured by GDP per capita has no statistical significant impact on wind energy capacity growth.

ix. Electricity consumption per capita (Elect.Consumption) has a positive and significant impact on wind energy capacity development in the EU.

x. Electricity production from coal (Coal Share) has a positive and significant causality with wind energy capacity development.

xi. Electricity production from renewable (Renewable Share) as expected has a positive and significant causality with wind energy capacity development.

xii. Carbon emission measured by (CO2) has a negative and significant impact on wind energy capacity development.

xiii. Parameter measuring the technical potential of wind (land size) has no significant impact on capacity development.

xiv. The price of coal has a significant and positive impact on wind energy capacity development.

4.7 Discussion

4.7.1 Effect of Policy Existence

The results from this analysis further confirm the mixed findings regarding the effectiveness of RES-E policies around the globe. The outcome of our analysis further confirms the contradictory findings regarding the effectiveness of the much talked about *FIT* policy in the contribution to RES-E capacity development in the EU. Policy makers often want to find out whether their implemented RES-E policies have actually driven installed capacity beyond which it would have increased in the absence of such policies. We find that existence of an active *FIT* policy when assumed that the effect is immediate does not have any significant impact on the cumulative annual wind energy capacity and the annual added capacity in the EU. Also, accordingly, considering the fact that a policy implemented at time t could result in capacity addition during time $t+1$, we find a non-significant impact of *FIT* on capacity development.

Our results indicate that the mere existence of an *FIT* policy does not drive wind energy capacity development. The essence of a wind *FIT* support scheme is primarily to give investors a guaranteed amount of money for every kwh of electricity produced per unit of time from RES-E technology and supplied to the national grid, so as to motivate them invest in the technology. This policy, to some extent, mitigates significantly the risk involved in having to sell electricity from wind in the open market and hence supposed to be a motivation enough to encourage investments in wind energy. However, our results indicate that the mere existence of the policy does not drive wind capacity development. This could be as a result of wind energy being recently observed to be competitive and able to compete in the open market due to reduction in production cost, or as a result of the dummy variable not being able to capture the full effect of the policy (Jenner et al., 2013).

Our finding is consistent with the literature, such as that of Jenner et al. (2013) who use fixed effects panel models to control for country specific effects and conclude that the mere existence of an *FIT* policy does not drive wind energy capacity development unless when combined with the tendering scheme. Dong (2012) also reports a positive but insignificant relationship between *FIT* and wind energy capacity development. Polzin et al. (2015) on the other hand, posit that existence of *FIT* policy significantly impacts positively on wind energy capacity development. These conflicting findings about *FIT* effectiveness could be as a result of differences in data sampling as well as the inability of the dummy variable to capture the heterogeneity in the design of the policy. This is, one of the motivations for examining the impact of policy experience on capacity development.

On the other hand, the existence of *FIP* which is similar to *FIT* has a negative but insignificant impact on wind capacity development. Under the *FIP* policy, government pays a premium on top of the market price of electricity to contract holders generating electricity from wind sources. Generators of wind energy need to sell their output in the open market where prices are not fixed before a premium is paid on top of the market price. The existence of the *FIP* policy has been observed to have a negative, though insignificant, influence on the capacity development of wind energy. Both *CC* and *AC* capacity have a negative but insignificant relationship with the *FIP* policy. We expected either a negative or positive impact of *FIP* on capacity development of wind energy. Our results however confirm that risk averse renewable energy investors do not see the *FIP* as an appropriate incentive to lure them to invest in wind energy.

Investors on an *FIP* contract are exposed to market risk of electricity prices and have to compete with other cheaper sources of electricity generation. Our analysis indicates that RES-E investors have not responded positively to the recently growing *FIP* policy. Governments are recently adopting this policy to reduce the pressure on their budgets and to persuade investors to compete in the open market for the sale of their electricity generated from wind sources. This policy does not guarantee investors a fixed amount of money for their output and hence exposes the expected revenue from RES-E investment to further uncertainty due to market price volatility. While the premium is fixed for some countries, in other countries the premium depends on the market price of electricity. It has been observed that in recent times, some countries in the EU have either scrapped *FIT* for *FIP* or reduced the *FIT* tariffs and implement both policies.

We find robust evidence of a significant impact of the existence of *Quota* on wind energy capacity development in Europe. We reject the null hypothesis that existence of *Quota* does not positively encourage wind energy development. The mere existence of the *Quota* policy has a statistically significant relationship with both cumulative annual wind capacity and annual added capacity in the EU. This finding is contrary to that of Carley (2009) who explains that *RPS* policies have not effectively encouraged capacity development of renewable sources of generation over the years but have effectively increased the percentage of renewable energy generation in the total electricity generation portfolio among states in the US. Jenner et al. (2013) also report no significant impact of the existence of *Quota* on capacity development of wind in the EU. Our result is, however, consistent with the findings of Menz and Vachon (2006), Dong, (2012) and Dombrovski (2015) who find a positive and significant impact of *RPS/Quota* on wind energy development.

Our results also reveal a non-insignificant relationship between *Tax* and capacity development of wind. Some countries offer tax reductions and other soft loans for RES-E investors so as to encourage investment in renewable technologies. Our results however, confirm that such a policy has not been very effective in promoting wind energy growth in the EU. In the case that the only promotional policy in place is *Tax* breaks, wind energy investors therefore are only left with the option of selling their output in the market, which is plagued with price uncertainty. Our results are in line with the findings of Menz and Vachon (2006) who also find a non-significant relationship between *Tax* and wind energy development. However, our results are inconsistent with the findings of Aguirre and Ibikunle (2014) who report a negative and significant relationship between *Tax* and renewable deployment. These different outcomes could be due to differences in data sampling, while our data comprises 27 EU countries, their data includes 38 countries globally, with the majority using *Tax* incentives to encourage RES-E deployment. The impact of *Tax* could also be technology specific and hence the non-significant impact on wind energy deployment in the EU.

We also observe a significant relationship between the existence of an active *Tender* policy and added capacity of wind energy in the EU. This implies that selective tendering for wind energy investments has a positive significant impact on capacity development.

The UK has used this policy to increase their RES-E capacity over the years. Investors are usually asked to *Tender* for support to invest in RES-E technology. This is consistent with the findings of (Dombrovski, 2015).

The cap policy has also not been very significant in promoting the development of wind energy capacity in EU. We expected a negative impact of *Cap* on capacity development since it limits either the capacity to be added or the tariff to be received by an investor. Our results is consistent with Jenner et al. (2013) who find no significant impact of the existence of *Cap* on the capacity development of wind energy in the EU.

4.7.2 Effect of Policy Experience

For a further test of the effectiveness of RES-E policies, we consider the effect of the number of years a policy has been in existence on the capacity development of wind energy. In this case, we test the hypothesis that a policy which has been in existence for a longer time has good experience and will have a significant impact on capacity development. As expected, we find a positive and significant impact of the experience of *FIT* policy on both CC and AC of wind energy. This means that countries with high experience of *FIT* policy would increase their CC and AC by about 14.5% and 9% respectively, on average more than countries with lesser *FIT* policy experience. We expected a positive impact of experience of the policy on capacity development due to the learning effect. Higher experience of a policy could be expected to give investors some kind of certainty on their investments. The more years the policy is in existence, the more likely policy makers would improve their design to achieve the intended purpose of increasing RES-E development. Since the *FIT* policy has a direct impact on the return on investment, a well experienced policy should be properly designed to mitigate or reduce the risk associated with returns and hence should have a positive impact on capacity development. Our finding is consistent with Polzin et al. (2015) who are of the view that the longer and certain *FIT* policy is in place, the more effective it will be in driving capacity development.

However, we observe that the impact of the experience of *FIT* policy on CC is highly significant with a higher percentage than the impact on AC. A possible explanation for the reason why the experience of *FIT* policy has a high significant impact on annual cumulative capacity of wind energy than annual added capacity, could be as a result of other policy design factors driving the previous years installed capacity.

The experience of *FIP*, on the other hand, exerts a negative and insignificant impact on CC and AC of wind energy. This implies that the longer an *FIP* policy stays in place, the lesser annual added capacity of wind energy. The longer *FIP* policy stays in place, the more the uncertainty of the wind energy investor's revenue, since they have to sell their output in the open market before a premium is paid on top. This policy exposes investors to market uncertainty on their expected revenue and hence their negative response to the policy. The experience of *FIP* does not have any significant impact on CC. This is because, the already added wind energy capacity in previous years cannot enter into *FIP* contracts, therefore, no causal relationship between them.

As expected, the experience of *Quota* policy has a significant and a positive impact on wind energy capacity development. Our results indicate that higher experience of the *Quota* policy leads to about 26% and 31% more in annual cumulative wind energy capacity and annual added capacity respectively (see Table 4.5 above). Our analysis significantly improves the existing divergent literature on the effectiveness of Quota in promoting RES-E capacity development. While some researchers believe that Quota have not necessarily enhanced capacity development Carley (2009) and Jenner et al. (2013), others believe the policy has been very effective in promoting RES-E development (Menz & Vachon, 2006; Bolkesjø et al., 2014).

Our findings therefore confirm the latter. Best practices are attained through the process of learning, and much experience of a Quota policy would possibly lead to realistic quotas with strong enforceability laws to actually attract power generators to adopt wind energy technologies to complement their generation portfolio. Our analysis, therefore, indicates that both the mere existence and the experience of *Quota* are strong drivers of capacity development of wind energy in the EU.

The number of years Tax policy is in existence also has a positive but insignificant impact on both CC and AC of wind energy. Due to the expensive nature of wind technologies, *Tax* breaks and other incentives alone could not make up for the difference between the cost of electricity generated from traditional sources and the cost of electricity generated from wind sources, and hence, investors are not motivated to revert to wind sources based on the existence of *Tax* breaks alone. The experiences of both *Tender* and *Cap* have no significant impact on wind capacity development.

4.7.3 Socio Economic Factors

Consistent with the existing literature, we find mixed effects of socio economic and other environmental factors on wind energy capacity development in the EU. The literature is split on the effect of GDP on the development of renewable energy technologies. We find a positive but non-significant association between GDP per capita and cumulative annual wind capacity, and a negative and insignificant effect on annual added capacity. This implies that wealthier countries in the past and currently have not supported the capacity development of wind energy.

A possible explanation for this, could be as a result of the decreasing cost of production of energy from wind sources, which makes richer countries reluctant in supporting the technology. Richer countries could also be able to bear the environmental cost of generating energy from traditional sources which could perhaps be the reason for not supporting wind energy. For instance, richer countries might prefer to generate energy from their already installed traditional sources and pay the penalties for emitting high carbon, rather than invest in wind energy.

Our finding is consistent with Carley (2009) and Dong (2012) who find no significant relationship between GDP and wind energy. On the contrary, Jenner et al. (2013) also report a positive and significant impact of GDP on wind energy development but negative impact of GDP on solar PV development. These mixed findings of the impact of GDP on capacity development suggest that it is technology dependent, and hence, richer countries might support other RES-E technologies rather than wind energy, hence, the need for more rigorous studies to determine which types of RES-E technologies are largely supported by wealthy countries (Jenner et al., 2013). Other researchers such as Menz and Vachon (2006) and Huang et al. (2007) confirmed the positive effect of GDP (wealth) on the development of wind technologies. Furthermore, Marques et al., (2010) find a negative effect of GDP on wind development for non EU members and a positive effect for EU members.

According to economic theory and the existing literature, rising input prices for traditional electricity generation sources are likely to lead to substitution for other sources of generation such as wind energy (Marques and Fuinhas, 2011b). The hypothesis that prices for fossil sources of energy will cause a substitution to the adoption of wind sources has been tested in this research. Consistent with the literature, we observe varied results for the effect of input prices of traditional sources of generation on wind energy capacity development. In the case of oil prices, all our models reveal that, increment in prices is not a significant factor to cause a shift from traditional generation sources to wind energy.

This is consistent with the findings of Sadorsky (2009) and Marques and Fuinhas (2011b), who report insignificant statistical relationship between prices of oil and RES-E growth among EU member states. Their sample, however, predates the era of high oil prices in 1998 when a barrel was around $150. Our analyses are robust and correct for this bias by covering the period of higher oil and other energy input prices. We therefore reject the hypothesis that change in oil prices causes a shift to renewable energy sources of generation. This outcome further defies the substitution effect theory in economic literature regarding the prices of oil and wind energy capacity development. Rising oil prices are usually a result of high cost of extraction when there are less oil reserves, with difficult accessibility, such as deep water. These higher prices for oil, are usually expected to enable a shift from oil sources of energy generation to RES-E, but this is not the case for wind energy according to our results in Table 4.5. A possible explanation for this could be as a result of the lower quantity of oil used in generating energy in the EU. This could also mean that oil price hikes would stimulate the use of coal or other sources of energy generation rather than wind sources, particularly, when there are existing plants available for use with other sources.

On the other hand, rising prices of coal causes a shift from traditional generation sources to wind energy. Countries in the EU do make a switch to wind energy source when coal prices go up. This shift is expected since wind energy is gradually becoming competitive and higher prices of coal will make wind energy investments more competitive and attractive (Jenner et al., 2013). This may also be as result of the large use of coal in generating energy in the EU as compared to oil. Generation from oil is relatively expensive as compared to coal and for that reason coal as an input is largely used in the EU to generate electricity. When coal prices goes up, all other things being equal, cost of production from coal sources of energy goes up, hence causing a rise in electricity prices. If electricity prices go up as a result of rising coal prices, environmentally friendly countries would resort to wind energy rather than generate from coal, which would increase electricity prices and at the same time pollutes the environment. The substitution effect in economic theory is therefore upheld with rising coal prices, due to the high volume of coal used in generating electricity in the EU.

To determine the effect of lobbyists of traditional generation technologies on wind energy development, we test for the effect of electricity produced from coal, natural gas, nuclear and oil sources on the capacity development of wind energy. We find no significant impact of lobbyists of natural gas, nuclear and oil sources of electricity generators on the capacity development of wind energy in the EU. The percentage of electricity generated from natural gas, nuclear and oil sources does not have any significant causal relationship with the capacity development of wind energy. However, we find robust evidence of significant positive impact of the percentage of electricity generated through coal sources on the added capacity of wind energy.

The literature is split on the effect of lobbyists on the development of renewable energy. For example, Groba et al. (2011) and Jenner et al. (2013) report a negative and significant relationship between electricity produced from traditional fossil based sources and wind energy capacity development and posit that larger generation from traditional sources delays investments in renewable sources. It is expected that, since the major concerns of politicians and policy makers are the immediate state of life and wealth rather than long term, favouring energy generated from traditional fossil sources would lead to perhaps increased energy consumption at the lowest cost as compared to energy from wind sources, and hence, of energy generated from these sources should delay investments in RES-E, which are rather expensive.

The finding of this research, has, however, proved otherwise for the case of natural gas, oil and nuclear, but confirms the status quo for coal. Previous researchers used data for the early years of policy implementation and perhaps the reason for the contrary results regarding the effect of lobbyist on wind energy capacity development. In the past, when the renewable energy industry was in the early stages, there could have been strong lobbyist effect of oil and natural gas on the capacity development as noticed in earlier research. Yet, in recent years, there have been stronger and well defined social and political measures put in place to encourage investment in renewable sources, and for that reason, lobbyist for traditional generation sources could have less impact on the capacity development of renewable sources.

As expected, the percentage of electricity generated from all renewable sources has a positive impact on wind energy capacity development. The higher the percentage of energy generated from RES-E, the higher the development of wind energy capacity, ceteris paribus. Energy consumption per capita is positively and significantly related to wind energy development. Consistently, we find that rising energy consumption is complemented by energy from wind sources. This is because rising energy consumption speeds up investments in wind energy. This outcome was expected due to the possibility of countries investing in wind sources rather than importing or adopting traditional generation sources to supplement their demanding energy needs. Investing in wind sources of electricity does not only supplement demanding energy needs, but also helps reduce the impact of hazardous gases through the generation of electricity from traditional fossil sources.

We also analyse the impact of natural and environmental factors on the development of wind energy. Adding to the mixed literature regarding the effects of high carbon emissions on renewable energy developments, we find that CO2 impact negatively on wind energy development. Higher CO2 do not motivate investments in wind energy technologies but rather retard its development. This effect is highly significant with cumulative capacity but insignificant with added capacity according to our results. One explanation for this, is the lack of concern regarding the impact of harmful emissions on the atmosphere. In a continent such us the EU where there is a mandatory limit to the amount of harmful gases a country can emit, one would expect high carbon emissions to hasten investment in wind energy and other renewable sources, but that is rather not the case.

This could also be possible when countries prefer to pay penalties for emitting rather than shifting to renewable energy sources. This demonstrates weaker commitment to environmental concerns as a result of higher emissions. Another possible reason for this effect is that, perhaps, there is already the existence of huge investments made in traditional sources of energy generation and hence the reluctance to shift to wind sources. Our result is consistent with the findings of Marques et al. (2010); Romano and Scandura, (2011) and Dombrovski (2015) who posit that higher carbon emissions does not hasten investments in renewable energy technologies.

We also find a negative and insignificant relationship between wind technical potential and the capacity growth of wind energy. This is similar to studies such as Carley (2009) who finds a negative impact of the wind technical potential on the capacity development of wind energy. This finding is however, contrary to studies such as Marques et al. (2010) and Menz and Vachon (2006) who find a positive and significant impact of potential on capacity development.

4.8 Conclusion

From Chapter 2 we observe that, in the absence of government support policies investments in RES-E technologies might be unprofitable. Yet, there is some significant growth in RES-E investments. Due to the likely unprofitable nature of such technologies without government support, countries in the EU have enacted many different policies to encourage investments in RES-E technologies. In this chapter, we contribute to the existing literature by examining the effectiveness of those enacted policies on the capacity development of wind energy in EU. We provide an in-depth econometric analysis of the effectiveness of RES-E policies by utilizing a country and time fixed effects model with a large panel data sample and a lag effect structure. For robustness of our results we conduct our analysis using OLS, random effects, fixed effects and PCSE models for comparison. We control for country level characteristics in our fixed effects models.

We find that, while some enacted policies play a vital role in the capacity development of wind energy, others have an unintended or no effect on the capacity development of wind energy. The diverse policy implications emanating from our results demonstrate the availability of different types of policies ranging from control based, through command based to incentive based measures implemented by policy makers to promote RES-E development. These policies, in addition to creating green power market electricity for producers, also encourage capacity increment by way of implementing new measures for traditional electricity capacity and sales. These policies are more relevant to the EU due to their mandatory carbon emissions targets. Our analysis allows us to further examine the experience of RES-E policies on capacity development of wind energy.

We find that the *FIT* which has been widely enacted across the EU is one of the most effective policies in promoting wind energy capacity development. We show that while the existence of an active *FIT* policy does not significantly drive the cumulative added capacity and annual added capacity of wind energy, a well experienced *FIT* has a positive and significant impact on the cumulative wind capacity and the annual added capacity. This result is expected as one of the main concerns for RES-E investors is uncertainty of their cash flow and profitability and the assumption that a well experienced *FIT* could be properly designed to mitigate that uncertainty. The *FIT* policy mitigates the uncertainty of the price of electricity generated through wind farms as it assures a price guarantee. However, a poorly designed *FIT* policy might not lead to increment in capacity. *FIT* policy has a direct impact on the risk/return of investors, and a well experienced and properly designed *FIT* policy would be expected to provide a long term reliable revenue certainty and hence enhance wind energy deployment.

One of the reasons why the dummy variable representation of *FIT* does not have a significant impact on capacity development could be as a result of its inability to capture the heterogeneity in policy design. Therefore, this study could be extended to develop a variable to capture the heterogeneity in the design of the *FIT* policy since it is the most adopted RES-E policy in the EU. The experience of *FIP*, on the other hand has a negative but insignificant impact on the wind energy capacity development. This implies that shifting from *FIT* to *FIP* policy could derail the capacity growth of wind energy and hence the need to properly structure and design *FIP* policies to mitigate most of the risks associated with the revenue to wind energy investors under an *FIP* contract.

Therefore, as a policy implication, *FIT* is preferred to *FIP* and hence the need to properly design and maintain *FIT* policies to encourage capacity development of wind. This finding further suggests the enactment of a properly deigned long term *FIT* policies with a clear targets to be achieved. Switching from *FIT* to *FIP* policies as well as changes to prices of electricity from wind farm on existing policy holders should be discouraged.

According to our analysis, the *Quota* is one of the most effective policies in promoting the capacity development of wind energy in the EU. Both the existence and a good experience of *Quota* significantly drives rapid development in wind energy capacity (both cumulative capacity and annual added capacity). The quota to generate a certain percentage of electricity through renewable sources allow firms either to adopt wind farms or buy electricity generated through renewable sources such as wind farm operators, albeit increasing the wind energy capacity. The *Tender* policy also has a weak significant impact on wind energy investments. The existence and experience of *Tax and Cap* have no significant impact on capacity development. This implies that the existence of Tax incentives alone to drive capacity development rather derails investments in wind energy.

Our results further indicate that, while carbon emissions levels impact on wind energy development, energy dependence have no impact. This suggest that countries in our sample are more concerned about the environment than energy security. The EU is at the forefront of reducing carbon emissions and hence this outcome is not surprising. Energy consumption is also positively linked to wind energy development, implying that when energy consumption of countries in our sample goes up, they resort to wind energy development to supplement the demand. There are series of limitations to our analyses in this chapter. These limitations and suggestions for future research are discussed in Chapter 6 of this thesis.

5 The Effect of Feed-in-System Incentive Policies on the Development of Wind and Solar Photovoltaic Energy Capacity: Evidence from the European Union Countries

5.1 Introduction

In an effort to meet their indicative targets and increase electricity generation from renewable sources, EU countries have adopted and implemented different support policies and legislations to make RES-E investments more attractive (see Tables 3.3 and 3.4 in Chapter 3). These regulations and support schemes are motivated by various reasons including climate concerns, making good use of natural resources and concerns regarding fossil fuel use for electricity generation among others (Carley, 2009).

The most adopted policy types implemented in the EU are the *FIS* (*FIT* or *FIP*) and the Quota. *Quota* is a command type of policy which is quantity driven and allows utility companies to choose from any renewable source to meet their *Quotas*. *FIS* on the other hand, is a type of policy that contracts producers of electricity from renewable sources with guarantee of a certain price they will receive for each MWh of electricity generated per unit of time and supplied to the national grid. The *FIS* provides incentive on a technology specific basis so as to make every RES-E source attractive due to initial investment and production cost differences. *FIS* varies considerably in terms of design and structure across countries in the EU, and can be implemented through the use of either a fixed (*FIT*) or premium (*FIP*) tariff. In the case of *FIT*, producers receive a guaranteed amount on every MW per unit of time of electricity generated through renewable sources and supplied to the national grid for a specified duration. If the policy is *FIP*, a premium is paid on top of the market price of electricity for a specified duration.

These differences in design structures coupled with market factors play a major role in the strength of the policy in terms of the incentive it provides for investors. For instance, certain countries provide a high tariff amount with limited number of years while others provide a smaller amount of tariff for a longer time period (See Table 3.4 in Chapter 3). From 1990 to 2013, 24 EU countries have implemented *FIS* schemes to promote wind and or solar PV capacity development, which is concurrent with the capacity development of wind energy and solar PV in the EU. There are, however, significant variations in capacity development across countries. These variations could be attributed to the differences in design and structure of various *FIS* policies as well as market conditions among countries in the EU. Despite the enormous progress in renewable energy capacity developments in the EU, the variations in development among countries have aroused some concerns regarding whether the *FIS* incentive policies in place are effective and have been the reason for capacity development.

Previous literature has examined the impact of socio-economic factors, ecological factors, macroeconomic factors and the incentive policies on the capacity development of wind energy and solar energy, (Menz & Vachon, 2006; del Río & Gual, 2007; del Río González, 2008; Marques & Fuinhas, 2011b). Most of this existing empirical literature on the effectiveness of renewable energy support policies relies on dichotomous variables which take the value of "1" if a policy is in place and "0" otherwise. Yet, such methodology ignores policy design features (such as duration of contract, tariff size and type, digression rate of tariffs among others) and market characteristics (e.g., electricity price, interest rates and production cost) that may cause variation in the strength of a policy in a given country at a given time (Jenner et al., 2013). From our analysis in chapter 2, we observe that the profitability from RES-E investment affects the decision and timing of investment. Yet, using dummy variable to capture the impact of policy on capacity development does not capture the profitability of the investment and hence its impact might not be realised. In this chapter, we focus on *FIS* incentive policy by considering the characteristics of policy and its interaction with market factors.

We examine the stringency of the *FIS* policy by taking into consideration the interaction between policy design features (contract amount, duration of contract, digression rate if applicable, contract type) and market conditions (cost of production, market electricity price, countries interest rate), and with a country-year fixed effects model, we measure how capacity development is reactive to the stringency of the *FIS* policy across countries in the EU. More specifically, we develop a new indicator, Present Value of the net revenue per MWh (*PvRev*) of electricity generated through wind or solar PV sources which was installed in a given country during a particular year. We then use a country - year fixed effects model to test for the impact of the new indicator on capacity development of wind and solar PV among 27 EU countries. Since revenue and profitability are the key motivations for investors in investment evaluation, we expect a higher incentive/revenue provided by *FIS* contract to have a positive influence on wind energy and solar PV development.

Jenner et al. (2013) were the first to examine the effectiveness of the *FIT* policy using fixed effects panel data regression model which considers information on the renewable energy policies from 26 EU countries, using a performance indicator of *FIT* policies, return on investment (ROI) as an independent variable. Their performance indicator captures different aspects of *FIT* policies such as tariff size, digression rate, electricity wholesale price, contract duration and electricity generation cost. Yet, the ROI variable of Jenner et al. (2013) neglects the time value of money and also does not distinguish the effects of both the fixed tariff and the premium tariff. The use of a new indicator, *PvRev*, captures the performance differences between the *FIT* and the *FIP* policies, and takes into account the time value of money. This new indicator also captures the heterogeneity in the design of similar policies across countries in the EU.

Building on the work of Jenner et al. (2013) and using the five largest electricity consuming countries in the EU, Bolkesjø et al. (2014) examine the impact of *FIT* on capacity development. Similar to Jenner et al (2013), they measure the strength of *FIT* using an investment model which calculates the return on investment under an *FIT* scheme by capturing the specific design and components of the policy and its interaction with market factors. However, their analysis does not take into consideration the relative values of the tariff amount as well as the present value of revenue per MWh per unit of time due to the presence of policy. Since their sample includes only five countries, it could be difficult to generalise their results to the entire EU. Recent year's data was also not included in their study. Similar to Jenner et al. (2013), their analysis ignores the individual impact of the *FIP* and hence limits the ability to comment on the effectiveness of *FIP* when it is the only policy in place to enhance capacity development. Both the studies ignore the impact of the revenue in monetary terms on capacity development. While Jenner et al. (2013) find no significant impact of *FIT* on wind energy development, Bolkesjø et al. (2014) find a positive and significant impact of *FIT* on wind energy development. These contradictory results could be as a result of differences in data sample as well as estimation techniques, which makes the impact of *FIT* on capacity development inconclusive; hence the need for further interrogation of the policy.

Therefore, in this chapter, we contribute to the literature in different ways. Firstly, we focus on a policy type that has gained much popularity in the EU, (i.e. *FIS*), and examine the economic benefits to a producer of electricity who holds a FIS contract for generating electricity from wind or solar PV sources, and determine the impact of the revenue on wind and solar PV capacity development. Secondly, we consider the existence of other RES-E incentive schemes that have not gained much attention in the econometric analysis of RES-E policies in the EU.

Thirdly, we develop an indicator *PvRev* similar to Jenner et al. (2013) and Bolkesjø et al. (2014) which captures the strength of the incentive provided by the existence of various FIS policies and the market conditions. Our analysis allows us to separately estimate the effects of the strength of *FIS, FIT, FIP* and the market revenue on capacity development of wind and solar PV. We also analyse the impact of the relative monetary value of *FIS* policies as announced by governments on the capacity development of wind and solar PV.

We find that the mere existence of *FIS* and *FIT* does not have a significant impact on capacity development of wind and solar PV. Yet, when the dummy representation of the existence of policy is replaced with the revenue indicator, *PvRev*, we find robust evidence of significant impact of the indicator on both wind and solar PV capacity development. We also find robust evidence that, in the absence of *FIS* policies, the revenue from selling electricity in the competitive market drives capacity development of wind energy but has no significant impact on solar PV capacity development in the EU. We conjecture that the strength of the policy captured by our *PvRev* indicator, which is determined by the interaction of the policy design features and market conditions, is a more influential factor of wind and solar capacity development than the mere existence of policies.

5.2 Characteristics of FIS Policies in Europe

The *FIS* is unique in design and can incorporate different incentives among countries to promote investments in RES-E technologies. *FIS* policies differ among countries in the EU in the following ways, of which are captured in our model formulation:

i) **Structure of Tariff**: *FIS* could be designed as either a fixed tariff or a premium tariff paid on top of the market price of electricity produced from renewable sources. While the *FIT* pays a fixed tariff, the *FIP* pays a premium on top of the wholesale market price of electricity. In the EU, 24 countries out of the 27 have adopted *FIS* systems, and out of the 24 countries, 19 have the *FIT* structure, 6 have the *FIP,* while 5 have both *FIT* and *FIP* (See Table 3.3. in Chapter 3). This design structure of the *FIS* is captured in our analysis, where we separately examine their impact on capacity development.

ii) **Tariff Size:** There are differences in the amount of tariffs paid to generators of electricity from renewable sources across countries in the EU. The amount of tariff varies based on location and technology among others. Due to different production cost across technologies, tariff amount is usually technology specific and differs significantly among other technologies. For instance, a higher tariff amount would be needed for solar PV to make it competitive due to the high cost of production (See Table 3.4 in Chapter 3 for summary of tariff amount across technologies).

iii) **Duration of Contract**: The duration of an *FIS* contract varies across policies, technologies and countries. The duration of *FIS* contract in our sample varies from 10 years to the entire life of the project. Some countries provide a higher tariff for a short time while others provide a smaller tariff for longer time period. For instance, while the *FIT* contract duration in France is 18 years, Germany and Spain have 20 years contract duration under *FIT* and *FIP* in the case of Spain. The contact duration under *FIT* in Austria is, however, 13 years (See Table 3.4 in Chapter 3). These variations in the contract term have an impact on the strength of the policy by virtue of revenue to be received. These variations in contract duration are captured in our model estimation of the strength of the *FIS* policy.

iv) **Digression Rate**: Some countries have a built in digression rate into their *FIS* policy design. While some countries embed an annual reduction rate in their *FIS* policies others only reduce tariffs after a specified number of years. Some, however, do not have digression rates in their *FIS* policies. Some countries incorporate a digression rate in the design of their policies due to the possibility of future reduction in production cost resulting in higher profits for investors. The tariff amount reduces after a certain period of time and in some countries, whereas, others introduce a percentage of annual reduction in tariffs. However, some countries do not have digression rate in their policy design. There is a fixed percentage of annual reduction in tariffs. We incorporate the effect of the digression on the revenue in our analysis when applicable (See Table 3.4 in Chapter 3).

5.3 Literature Review

As noted in Chapter 4, there is a growing trend in the literature with regard to the success of renewable energy policies. The general trend in the literature on the evaluation of RES-E support schemes is twofold; that is those who use qualitative and descriptive approaches such as case studies and surveys and those who employ the use of econometric techniques in assessing the effectiveness of RES-E policies.

The literature about the descriptive approaches is vast while that of econometric techniques is currently being explored. Most of the earlier papers focused on America, however, there is a recent emphasis on Europe. Descriptive and qualitative studies have used different approaches and posit that *FIT* and *RPS* have played a significant role in determining the capacity development of RES-E technologies among European countries (del Río & Gual, 2007; Lipp, 2007; del Río González, 2008; Lesser & Su, 2008; Haas et al., 2011).

The second growing trend in the literature is the use of econometric techniques in assessing the role of support policies in the growth of renewable energy. Such studies are mostly focussed on *RPS* policies among states in the US. Econometric studies that evaluate the determinants of RES-E capacity development could also be sub grouped into three streams; i) studies that uses cross sectional analysis with the use of dichotomous variables to represent the enactment of support scheme; ii) Studies which employ panel specifications and control for country fixed factors largely with the use of dummy variables to represent the enactment of support schemes; iii) studies that use panel specifications and control for country fixed characteristics, with the use of more complex variables that capture the differences in policy design and strength.

Researchers categorised under the first group use pooled cross section analysis with the use of dummy variables to determine the effectiveness of RES-E policies on driving the development in capacity (Menz and Vachon, 2006; Adelaja & Hailu, 2008; Alagappan et al., 2011;). The second category of literature improves on the findings of the first category by using fixed effects models and other rigorous econometric techniques in assessing the causality between Res-S support policies and capacity development in order to reduce omitted variables bias (Carley, 2009; Delmas & Montes-Sancho, 2011; Marques &

Fuinhas, 2011b; Shrimali & Kniefel, 2011; Dong, 2012;). The findings of this group of research vary with different outcomes on the causality between policies and capacity development. These diverse findings could be attributed to the techniques employed by this class of researchers in reducing omitted variable bias that could possibly be correlated with capacity development and policy enactment. From our findings, we observe that, once state and country level characteristics and time are controlled for, the results are not consistent, while the earlier findings, which neglected time and country fixed effects in their analysis.

For instance, using a panel data of over 50 US states and a time period of 1991-2007, Shrimali and Kniefel (2011) posit that the impact of RPS on renewable energy development is technology dependent. They report a positive impact of RPS on the development of some renewable energy technologies and a negative impact on others. Carley (2009) on the other hand, using US state level data from 1998-2006 finds no significant impact of the existence of RPS on the percentage of total renewable generation of total production among US states. She reports, however, a positive correlation between *RPS* policy and total renewable energy capacity. Dong (2012) also analyses a panel data of 53 countries and posits that while RPS retards capacity development, *FIT* is very significant in promoting capacity development. The diversity of the findings regarding the effectiveness RES-E policies highlights the importance of incorporating the different characteristics of policy design in assessing its effectiveness and investors responsiveness.

Marques et al. (2010), Marques and Fuinhas (2011a) and Marques and Fuinhas (2011b) were the first to use econometric methods to examine the determinants of RES-E capacity development among European countries. Using a dataset of 24 EU countries from 1990 to 1996, Marques et al. (2010), assess the drivers of renewable energy generation by using total percentage share of electricity generated from renewables as the dependent variable. Even though this study did not evaluate any specific RES-E policy type, they find that energy dependence, energy consumption and EU Directive 2001/77/EC which mandated EU countries to certain RES-E targets are all positive drivers of renewable energy in the continent. They find, however, a negative relationship between the fossil fuel industry and renewable energy capacity development, implying that lobbyists for fossil fuel sources of generation have a negative influence on RES-E development. This means that, according to their results, the more fossil fuel dependent electricity generation technologies increase, the less the share of renewable sources of electricity generation. They did not, however, consider respective policies adopted by countries purposely to increase RES-E capacity in their analysis.

More recently, Aguirre and Ibikunle (2014) examine the determinants of RES-E growth using a broader sample size of 38 countries worldwide and applying fixed effects vector decomposition model and suggest that poorly designed support policies retard RES-E capacity growth. Polzin et al. (2015) also examine the impact of public policy on RES-E investments by institutional investors using OECD countries and suggest that *FIT* policy is a strong driver of RES-E investments since it has direct impact on the risk and return structure of such projects. Neither Aguirre and Ibikunle (2014) nor Polzin et al. (2015) consider the heterogeneity and strength in the specific design of *FIT* policies, which could result in different effect on capacity development which is the focus of this chapter.

The final category of researchers control for fixed characteristics of states by incorporating the market conditions, design and structure of policy and testing its impact on capacity development (Yin and Powers 2010; Jenner et al., 2013; Bolkesjø et al., 2014). Yin and Powers (2010) were the first to incorporate policy design heterogeneity in econometric analysis of RES-E policy among states in the US. They developed a new indicator to measure the stringency of *RPS* policies by capturing different policy structure features (that is coverage, existing capacity, new capacity, incremental requirements among others). They apply this new indicator in a fixed effects panel model and conclude that RPS has driven capacity development among states in the US. They compare their results to another set of analysis comprising the same dataset but ignoring policy design features and conclude that, the effect of *RPS* vanishes without controlling for specific state design of policies. The findings of Yin and Powers (2010) further demonstrate the importance of capturing the design features and market conditions and the degree at which capacity development respond. They also note that the ability of RPS to drive capacity development among states could be significantly weakened by a design feature allowing free trade of renewable energy credit.

Building on the work of Yin and Powers (2010),and applying it to the European context, Jenner et al. (2013) develop a new ROI indicator to capture the strength of an *FIT* policy and measure its impact on capacity development of wind and solar PV by controlling for country and time fixed effects. They find that both the enactment and strength of *FIT* policy drive wind capacity development in the EU. They observe, however, that capacity growth of wind reacts more sharply to the strength of the return than to the mere existence of policy. On the contrary, they find no significant impact of the mere existence of *FIT* alone on solar PV development, but observe a significant causal relationship between their ROI indicator and solar PV capacity development.

To further examine the importance of policy design factors and market conditions on the development of RES-E technologies, Bolkesjø et al. (2014) use an econometric model based on behavioural model similar to that of Jenner et al. (2013) and a technology, policy and country specific data for RES-E capacities from 1990 to 2012 of the five largest electricity consuming countries in Europe (UK, France, Germany, Spain and Italy) and posit that *FIT* has positively significantly affected capacity development of onshore wind and solar photovoltaic. Their findings of the positive impact of *FIT* on capacity development of onshore wind is contrary to that of Jenner et al. (2013) who find no significant relationship. While their analysis covers only five countries in the EU, the analysis of Jenner et al. (2013) did not cover data for current years. Both papers fail to analyse the impact of *FIT* and *FIP* separately, although they are rather different as the latter introduces some kind of uncertainty. Therefore, there is the need for deeper interrogation of the design of *FIS* policies which is the motivation of this chapter.

5.4 Stringency of the Feed-In-Systems Policy

There is an increasing body of literature using a behavioural approach to examine the impact of support policies on capacity development. Notable among them is Masini and Menichetti (2012) who study the impact of behavioural factors in the renewable energy investment process by using a conceptual model with a hand collected dataset of European investors. They posit that the specific design of policies such as the contract size and duration is considered by investors prior to investing in an RES-E technology. They are also of the view that RES-E investors' perception of risk affects their responsiveness to support policies, and hence, the *FIT* policies are preferred to other RES-E policies. Consistent in the behavioural literature is the responsiveness of investors to policy design features such as duration, tariff size, rates of digression (Menanteau et al., 2003; Held et al., 2006; Masini and Menichetti, 2012; Wüstenhagen and Menichetti, 2012). Since these studies are ex ante and quantitative in nature, by way of asking investors of factors affecting their investment decisions, we follow Jenner et al. (2013) and Bolkesjø et al. (2014) by quantifying and testing policy impact on actual added capacity.

FIS policies vary significantly among countries in the EU and as such, the investment incentive provided by the policy varies accordingly, *ceteris paribus*. Policy factors that account for this variation include tariff size (amount of tariff paid to a generator), tariff type (*FIT* or *FIP*), duration of tariff and reduction of tariff over time. The interaction of these policy factors with market conditions such as electricity production cost, market electricity prices and the interest rates of a particular country at a given time results in variations in incentives provided to investors of renewable energy sources across countries in the EU (Jenner et al., 2013; Bolkesjø et al., 2014). With motivation from, and following Jenner et al. (2013) and Bolkesjø et al. (2014), we consider the above factors in developing a new indicator for the present value of the net revenue (*PvRev*) per MWh an electricity producer will receive for generating from wind or solar PV under *FIS* contract. Equation 5.1 represents the total net revenue for a capacity of technology *i* installed in country *j* – during year t:

$$NREV_{ijt} = P_{ijt}^{FIS} \times S_{ijt}^{FIS} \times CT_{ijt} + P_{ijt}^{mkt} \times S_{ijt} \times (TL_{ijt} - CT_{ijt}) - TOC_{ijt} \tag{5.1}$$

where $NREV_{ijt}$ is the expected net revenue for total installed capacity of technology *i* in country *j* during year t; P_{ij}^{FIS} is the electricity price per MWh per unit of time according to the *FIS* contract of technology i installed in country j during year t .[30,31] S_{ijt}^{FIS} is the total expected annual output of electricity to be produced by technology i in installed in country j during year t and sold at P_{ij}^{FIS} ; P_{ijt}^{mkt} is the average market price per MWh of the electricity produced by technology i installed in country j during year t; S_{ijt} is the electricity per MWh produced by technology i during year t and sold at P_{ijt}^{mkt} ; CT_{ijt} is the total duration of *FIS* contract (in years) held by an investor for adding capacity of technology i in country j at time t. TL_{ijt} is the total lifetime of technology i installed in country j. TOC_{ijt} is the life time operating cost for total capacity of technology i installed in country j during year t. $P_{ijt}^{FIS} \times S_{ijt}^{FIS} \times CT_{ijt}$ becomes the net revenue if the contract duration is the same as total life of the technology i.e., ($CT_{ijt} = TL_{ijt}$). However, in the absence of *FIS* policy in a particular country during a particular year, the duration of tariff becomes 0 i.e. ($CT_{ijt} = 0$) and hence the market becomes the only source of revenue where investors would sell their electricity produced. Equation 5.1 above represents a typical cash flow statement where tax, depreciating and the initial cost of the technology is captured in the levelised cost of production (*TOC)*.

$$TOC_{ijt} = ACEP_{ijt} \times S_{ijt} \tag{5.2}$$

TOC_{ijt} is the total annual operating cost of production for generating electricity from technology i built in year t. $ACEP_{ijt}$ is the average cost of electricity production in euro

---

[30] If the contract is *FIP*, this would be the market price of electricity plus the bonus paid on top. If the contract is *FIT*, this would be the total amount paid Euro per MWh per unit of time of electricity sold to the national grid.

[31] This *FIS* rate considers digression rates if possible. The policy amount reduces depending on the design and characteristics. We reduce the *FIS* as stated by the policy. Some *FIS* policies reduce the rate over the years to prevent investors from overly benefitting from reduced cost of production among others.

per MWh per unit of time of wind or solar built in year t. After assessing the total net revenue for investing in capacity of technology i, we compute the present values of all the annual revenues as shown in Equation 5.3 below. This gives us absolute terms of present value of the expected revenue from capacity of technology i in country j during year t. In this model, we assume full capacity utilisation. Equation 5.3 below represents the annual present value of the expected net revenue from adding a capacity of technology i in country j during time t.

$$PV\_NREV_{ijt} = \left(\frac{P_{ijt}^{FIS} S_{ijt}^{FIS} - TOC_{ijt}}{(1+r)^{n}}\right) \Leftrightarrow \left(\frac{P_{ijt}^{mkt} S_{ijt} - TOC_{ijt}}{(1+r)^{n}}\right) \tag{5.3}$$

PV_NREV_{ijt} is the present value of the annual expected revenue. The first part of the right hand side of the equation represents the present value of the annual revenue for installed capacity of technology i at time t in country j operating under *FIS* contract. The second part of the right hand side of the equation represents the present value of the annual revenue for installed capacity of technology i in country j at time t of which the output is sold in the open competitive electricity market. r represents the rate of return in country j while n represents the particular year from where the revenue is discounted. The distinction between t and n is that, while t represents the year the technology was adopted, n represents the subsequent years or age of the technology from years 1-25.[32] .

---

[32] We use the country borrowing rate with a premium of 10 percent on top. We put a premium of 10% due to the highly expensive nature of borrowing for capital intensive projects such as RES-E projects. For robustness check, we used different rates of return and noticed that no significant changes were observed.

$$NPV\_NREV_{ijt} = \overbrace{\sum^{T_1}\left(\frac{P^{FIS}_{ijt}S^{FIS}_{ijt} - TOC_{ijt}}{(1+r)^n}\right)}^{\substack{\textbf{Annual}\\ \textbf{revenue}\\ \textbf{according}\\ \textbf{to the FIS}}} + \overbrace{\sum^{T_2}\left(\frac{P^{mkt}_{ijt}S_{ijt} - TOC_{ijt}}{(1+r)^n}\right)}^{\substack{\textbf{Annual}\\ \textbf{revenue}\\ \textbf{from the}\\ \textbf{energy sold}\\ \textbf{in market}}} \tag{5.4}$$

In Equation 5.4 above, NPV_NREV_{ijt} represents the net present value of the net revenue for adding a capacity of technology i in country j at time t for the whole life of the technology. T_1 represents the years in which the technology is operating under *FIS* contract while T_2 represents the rest of the life of the technology when the contract duration had expired or when there is no *FIS* contract at all. The first part of the right hand side of the equation is the summation of the PV of all annual revenues for the duration of FIS contract when a capacity of technology i is installed in country j at time t (i.e. NPV).The second part of the equation represents the NPV of the net revenue for a capacity of technology i installed in country j at time t after the end of the *FIS* contract or when there is no *FIS* policy in place.[33]

To determine the present value per MWh per unit of time of electricity generated by technology type i installed in country j during year t, we use Equation 5.5 below.

$$Pv\,\mathrm{Re}\,v_{ijt}MWh = \frac{NPV\_REV_{ijt}}{S_{ijt} \times TL_{ijt}} \tag{5.5}$$

---

[33] *FIS* contracts are designed differently. Some contracts cover the entire life time of the technology while others have a short time period. After the duration of the contract, the revenue of an investor for generating electricity from solar or wind depends on the competitive market price of electricity.

where $Pv\mathrm{Re}v_{ijt}Mwh$ represents the PV of the net revenue per MWh per unit of time generated from technology type *i* installed in country *j* at during year *t*. NPV_NREV_{ijt} represents the NPV of total expected net revenue for investing in capacity of technology *i* in country *j* at time *t*. S_{ijt} represents the annual total generation capacity of technology *i* and TL_{ijt} represents the total life time of technology *i*. $Pv\mathrm{Re}v_{ijt}Mwh$ therefore becomes the incentive received either by selling generated electricity under *FIS* contract in countries where it is available, or selling in the competitive market in countries where there is no active *FIS* contract. This enables us to be able to determine the PV per MWh per unit of time prior to the decision to invest by considering the heterogeneity in the FIS policy design and its interaction with market factors. $Pv\mathrm{Re}v_{ijt}Mwh$ is expected to inform the investment decision and hence we expect a positive relationship with capacity development.

The $Pv\mathrm{Re}v_{ijt}Mwh$ indicator could further be split into four components to segregate the design of the *FIS* (fixed or premium), to segregate the effect of *FIS* policy components from non-policy components and to also consider effectiveness of the relative contribution or monetary value of the *FIS* policy as announced by policy makers and examine its impact on capacity development. Splitting the indicator makes it possible to differentiate between countries with *FIS* policies and those without the policy in the same regression models, and to determine their impact on wind and solar PV capacity development. These four components are explained below in Equations (5.6 - 5.9).

$$Pv\mathrm{Re}v_{ijt}MWh\_1 = \frac{NPV\_REV_{ijt}\_1}{S_{ijt} \times TL} \qquad \text{IF FIS>0} \qquad (5.6)$$

Equation 5.6 above separates countries without *FIS* policies from countries with the policy. $Pv\,\mathrm{Re}\,v_{ijt}MWh\_1$ represents the present value of net revenue per MWh per unit of time of electricity when the only option to sell electricity generated from technology i is under *FIS* contract. Therefore, in countries-years where there is no *FIS* policy, NPV_REV_{ijt} takes the value of "0". This variable makes it possible to separate the policy components from the non-policy components. This variable only captures the policy components of *FIS* in all countries in our sample. Both components of *FIP* and *FIT* are captured by $Pv\,\mathrm{Re}\,v_{ijt}MWh\_1$. A positive impact of $Pv\,\mathrm{Re}\,v_{ijt}MWh\_1$ is expected on capacity development of wind and solar PV.

Our analysis allows us to segregate the specific design of the *FIT* from *FIP* and analyse its impact on capacity development. To differentiate the strength between the *FIT* and *FIP* designs and their impact on capacity development, we further split the $Pv\,\mathrm{Re}\,v_{ijt}MWh\_1$ in to Equations 5.7 and 5.8 below;

$$Pv\,\mathrm{Re}\,v_{ijt}MWh\_2 = \frac{NPV\_REV_{ijt}\_2}{S_{ijt} \times TL} \qquad \text{IF FIS=FIT} \qquad (5.7)$$

Equation 5.7 above represents the present value of net revenue per MWh per unit of time of electricity generated from technology i, installed in country j during year t, when the policy in existence is *FIT*. NPV_REV_{ijt} takes the value of "0" in country-year when there is no *FIT* policy. This variable captures only policy components of *FIT*. This makes it possible to determine the impact of policy components of *FIT* alone on capacity development. We expect a positive impact of this variable on capacity development.

$$Pv\,\mathrm{Re}\,v_{ijt}MWh\_3 = \frac{NPV\_REV_{ijt} \rightarrow 3}{S_{ijt} \times TL} \qquad \text{IF FIS=FIP} \qquad (5.8)$$

Equation 5.8 above represents the present value of net revenue per MWh per unit of time of electricity when generated from technology i in country j during year t, when the policy in existence is *FIP*. NPV_REV_{ijt} takes the value of "0" in country-year when there is no *FIP* policy. This variable only captures the policy components of the *FIP* in the EU. This makes it possible to analyse the separate impact of *FIP* on capacity development of wind and solar PV in the EU. Our expectation is to observe a positive relationship between this variable and capacity development.

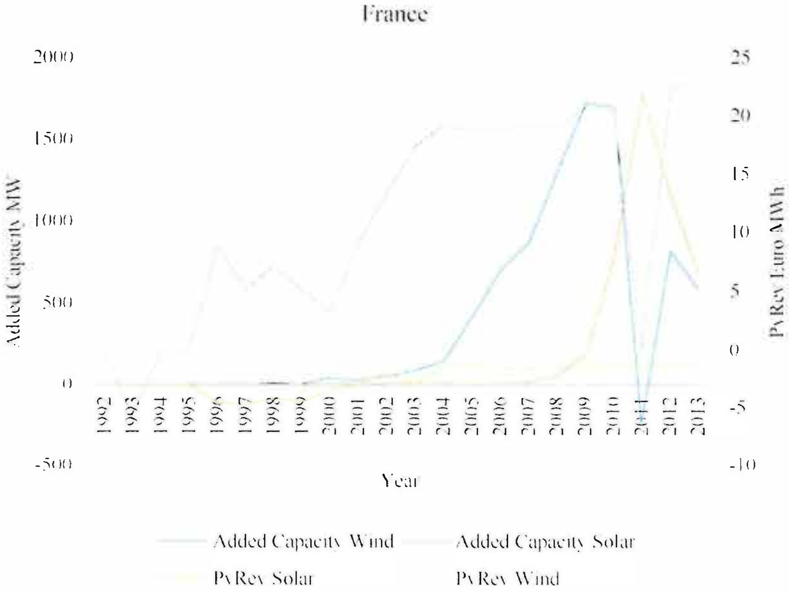
Our analysis also allows us to differentiate the effect of policy components from non-policy components and their impact on capacity development. Therefore, to establish the strength of the indicator when the only available place to sell the output of electricity generated through renewable sources is the market, we develop the indicator in equation 5.9 below;

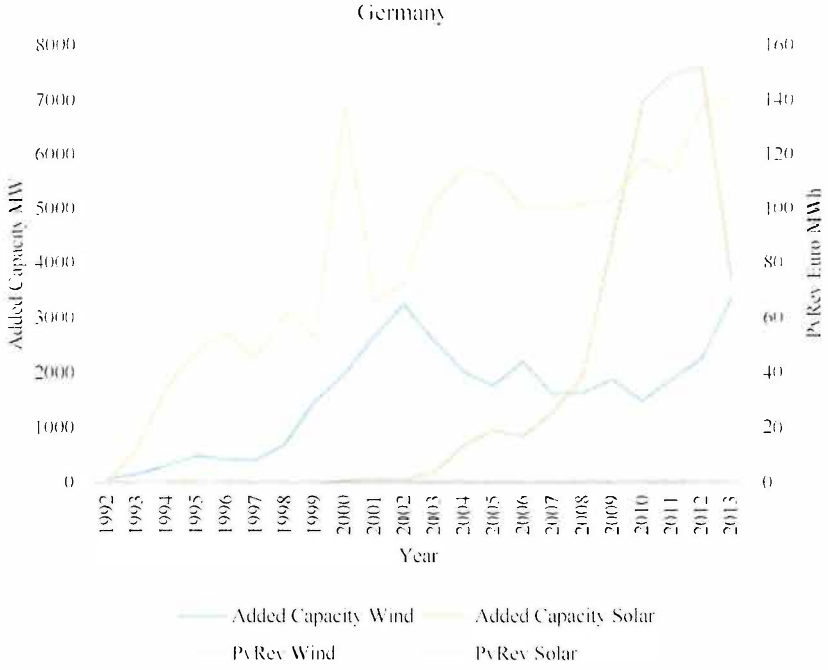
$$Pv\mathrm{Re}v_{ijt}MWh\_4 = \frac{NPV\_REV_{ijt} \to 4}{S_{ijt} \times TL} \qquad \text{IF FIS=0} \quad (5.9)$$

Equation 5.9 above represents the present value of net revenue per MWh of electricity generated from technology i installed in country j during year t, when there is no *FIS* policy in existence. NPV_REV_{ijt} takes the value of "0" in a country-year where there is *FIS* policy. This indicator represents the revenue for selling electricity generated through wind or solar PV in the open competitive market in countries-years where there is no *FIS* policy. We expect market price not to significantly drive capacity development of solar PV due to higher production cost. However, due to the reducing production cost of wind energy, we expect a positive relationship between market prices and capacity development. For simplicity of notation, henceforth we drop $_{ijt}MWh$ from all our indicator variables.

Finally, we also examine the effect of the contribution of *FIT* and *FIP* on capacity development by segregating the stated relative monetary value of the policies and examine its impact on capacity development. This allows us to analyse the impact of the monetary tariff price announced by governments on the capacity development of wind and solar PV. These variables are represented by *FIT_ABS* and *FIP_ABS* respectively. We expect a positive relationship between these variables and capacity development.

Figure 5.1: Computed PvRev Values and Capacity Development for France and Germany





In Figure 5.1 above, we compare our calculated annual *PvRev* values and the annual added capacities of France and Germany. We subsequently did so for all 27 countries in our sample. The rest of the graphs for all other countries are presented in Appendix, AC5 Figure 1. These graphs are presented to show the summary statistics between the value of *PvRev* and the added capacity of respective countries. The motivation for this chapter is to test the degree to which *PvRev* from *FIS* policy drives the capacity development of wind and solar PV and therefore graphs of this kind present a preliminary relationship between *PvRev* and added capacity. We later, in our regression analysis, test for the degree of the relationship between *PvRev* and capacity development after controlling for other factors which are not captured in this graphical relationship. It can be noted from Figure 5.1 that there are times *PvRev* is negative, yet investment has been made in solar PV in France, where as in Germany, there are no negative values for *PvRev*. In our regression analysis, our aim is to capture this heterogeneity in policy design resulting in different values for *PvRev* and its impact on capacity development.

5.5 Justification of PvRev Components and Data Sources

Our new indicator represents the present value of the expected revenue in Euro per MWh, for adding capacity of wind or solar in country *j* during year *t* for the entire life of the technology. If the investor is under *FIT* contract, the producer receives a fixed amount for every MWh of electricity generated through wind or solar PV sources, until the end of the contract where then his revenue changes to the market price of electricity. If the scheme is *FIP*, a premium is paid on top of the market price for every MWh of electricity generated and supplied to the national grid until the end of the contract where then revenue becomes market price of electricity. If there is no *FIS* policy in place, then this variable represents the present value of the revenue for every MWh of electricity generated through wind or solar PV sources and sold in the open competitive electricity market.

We obtain data for tariff amount, tariff duration, type of tariff and the digression rate of tariff from IEA, Policies and Measures Database 2014, where all tariff amount are given in euro. These components of the policy were complemented and compared to information provided by Huber et al. (2004) and Haas et al. (2011) (See Table 3.4 in Chapter 3). There were no differences in the data provided and so our main source for the above components was the IEA, Policies and Measures Database and the other sources were used to fill the gaps in years and countries where data was absent from the main source. Our aim is to capture the heterogeneity in policy design. Yet, we are aware that we cannot completely capture all the heterogeneity in policy design due to certain other factors. For instance, in some countries, such as France, the amount of tariff paid to investors varies according to location and size of the technology and in some cases ownership of the technology. So therefore, following Jenner et al. (2013) and Bolkesjø et al. (2014), we take the average value of each tariff amount across all variations in a country and year when applicable. It will be interesting to see future research capturing heterogeneity across all variations in terms of tariff amount and size of technology, among others, due to our inability to capture all heterogeneity.

Our computation of *PvRev* is consistent with the literature on ex-ante evaluation of projects where full capacity utilisation is assumed, (see Jenner et al. 2013). Consistent with the literature on traditional methods of evaluation, we assume that the technology would operate under full capacity after adoption so as to capture the investment decision as accurately as possible. It is very difficult to estimate the efficiency of a technology prior to adoption, most especially, for RES-E technologies, where efficiency or output largely depend on natural conditions and other factors that cannot be foreseen. Despite the fact that output could be estimated from historical weather conditions, actual output mostly depend on current weather conditions, which are very volatile as observed in Chapter 1. Also, prior to investment, evaluations are made based on the total capacity of the technology and not actual generation, this is the reason why using full capacity would be a realistic assumption, since our aim is to capture the relationship between the revenue and the decision to invest in wind or solar PV capacity. We obtain our capacity data from the (Eurostat-European Union Statistics Database, 2014).

ACEP is vital in this analysis due to the fact that it makes it possible to compute the total revenue relative to production cost in a given country and at a given time. However, we note that production cost of electricity depends on the source of production or technology. There are significant differences in the production cost of electricity among different technologies and hence larger tariffs may be required to generate the same revenue among different technologies. From our data sample, we can observe that the cost of production of electricity from solar PV is much more expensive than cost of production from wind sources; hence, higher tariffs would be needed for solar photovoltaic to generate the same return/revenue as wind sources. The literature suggests increasing decline in the production cost of RES-E generation (Nemet, 2006).There is a possibility that the continuous decrease in the cost of production of RES-E generation technologies might lead to an increment in return/revenue for investors on *FIS* contract. However, the specific design of *FIS* might mitigate some or all of the increase in revenue relative to declining cost of production (Jenner et al., 2013).

This is because *FIS* policies are sometimes designed with a built in digression rate purposely to account for decreasing cost of production which might result in high revenue to investors who hold the contract at the time. In our analysis, we consider the digression rates of policies in countries and years when applicable, which is captured in the *PvRev* variable. For instance, France introduced a 2% annual reduction in *FIT* policy amount from the year 2012 while Spain reduces tariffs after 15, 20 and 25 years depending on type of technology. There is a 5% reduction in *FIT* policy after the first five years and 10% reduction of the original amount after 10 years in Slovenia (See Table 3.4 in Chapter 4 for summary of digression on *FIT* policies).

There exists some difficulty in accessing reliable data for the cost of production of electricity from RES-E sources among European countries (Jenner et al., 2013; Bolkesjø et al., 2014). Therefore in this thesis, following Jenner et al. (2013), we use the leveslised cost of production data provided by (Schilling & Esmundo 2009). They, however, provide cost data from 1980 to 2005 and therefore we use cost data from the GreenX final report by Huber et al. (2004) to fill the gap from 2006 to 2009. The GreenX final report provides data for policy information and cost data from 2006 to 2009 as well as projections for

2010 and 2020.Cost data from (IEA, 2010) are used to fill the gaps in our data sample. These data sources also used by (Jenner et al., 2013; Bolkesjø et al., 2014).

Under *FIS* contract, the tariff amount paid to electricity producers for generating power from RES-E is certain for the duration of the contract, and for that reason, revenue is guaranteed per generation, for the period of the contract. The market prices of electricity on the other hand, are volatile and uncertain. In our new indicator, we assume a constant price of electricity for the entire duration of the technology. We assume the price of electricity during year t for a technology installed in country j would stay the same for the entire duration of the technology. We make the assumption that investors are not able to predict the future prices of electricity, as it is very difficult to estimate, according to the literature (Karakatsani & Bunn, 2008b, a; Torró, 2009; Liu & Shi, 2013). The literature is split on the future evolution of electricity prices. For instance, Felder (2011) is of the view that electricity prices will reduce drastically with the rapid development of energy from renewable sources, while Reuter et al. (2012) are of the view that electricity price will depend on so many different factors, including the activities of large firms.

Therefore, introducing a measure of fluctuations in electricity prices in our model would largely increase researcher bias in the analysis. Since there has been no precise prediction about the future movement of electricity prices, the assumption of constant prices would be the most reasonable option, as it eliminates unnecessary researcher bias regarding the projection of electricity prices. The same assumption was made and justified by Jenner et al. (2013) as there is no consensus in the current literature with regard to the projection of electricity prices. Thus, in the computation of our new indicator, electricity prices at time t in country j when the capacity of wind or solar was added would stay the same for the entire life of the technology. We obtain data for the whole sale electricity market price from (Eurostat-European Union Statistics Database, 2014).

To control for the risk level of every country in our sample, we use the long term borrowing rate to discount the expected future revenue to time t .Due to the fact that the long term borrowing rate reflects sovereign risk and not business risk and considering the expensive nature in acquiring capital for renewable technologies, we add a premium of 10% on top of the respective interest rates of every country in our sample. Discounting the future revenues to the present allows us to capture the risk level of countries in our sample and to measure how it affects capacity development of wind and solar photovoltaic. This discount rate represents the appreciation of the time value of money considered in the investment. We appreciate the fact that discount rate represents the cost of capital and to some extent depends on the particular market or economy and type of investor.

However, due to the nature of our data, we assume that some kind of capital from the risk averse debt capital market could be available at a lower discount rate while the financial market could also be available at a higher rate and therefore we add a premium on top of the long term borrowing rate. In calculating for the levelised cost of electricity production from renewables, most often discount rates used are 5% and 10% (See e.g., Schilling and Esmnundo, 2009; IEA, 2010; DECE, 2014). Therefore, we add a premium of 10% on the top of long term borrowing rate to reflect the risk profile of EU countries. The source of our long term borrowing rate is DataStream. While we note that a 10% premium might not reflect the risk profile of countries, this rate adds up to the individual long term borrowing rates and could serve as a proxy for risk. We welcome future research that could model the individual risk profile of countries and use it to discount the revenue to the present.

Our *PvRev* indicator represents the true and realistic incentive for investors for adding a capacity of technology i in country j during year t. In investment decision making process, the project with the greatest NPV is usually adopted all other things being equal, and for that reason our indicator which represents the true investment incentive provided by the *FIS* policy can be used to examine the effectiveness of the policy on capacity development. This is also reflected in our analysis in Chapter 2, where the investment decision is affected by the profitability from the investment. This indicator captures the most relevant concerns of investors that clearly result in the variation of returns after investing in a renewable energy technology.

5.6 Further Data Sample and Empirical Methodology

In order to examine the effectiveness of *FIS* policies in the EU, we develop an indicator that captures heterogeneity in policy design and its interaction with market factors to determine the expected incentive provided by the availability of *FIS* policy in a country at a given time. We then test the impact of our indicator on the capacity development to of wind and solar PV using 27 EU countries for the time period 1992 to 2013. We also test for the impact of political, socio economic and environmental factors on capacity development of wind energy using a panel data approach so as to control for specific unobserved fixed country factors that could affect wind energy development and policy implementation.

5.6.1 Data Sample

We collect country level data from different policy documents to form a national policy database for all the countries in our sample between 1992 and 2013, during which 25 countries in the EU have implemented *FIS* policies to encourage development of RES-E technologies including wind and solar PV so as to meet their renewable obligation targets. The source of our policy components data is the IEA Policies and Measures Database, 2014, supplemented with information from Huber et al. (2004) and Haas et al. (2011) to get a complete policy database for all countries and years in our sample.

5.6.2 Dependent Variable

Review of the literature suggests that researchers use different dependent variables to measure RES-E development. Some researchers use actual generation or total energy supply for the measurement of RES-E development while others use either added capacity, cumulative capacity or percentage of RES-E relative to total generation capacity of electricity.

In this chapter, we use added capacity to measure the development of wind and solar photovoltaic in the EU. Our aim is to capture the post investment decisions of RES-E investors; therefore, added capacity as a measure of development is preferable to actual generation. AC is preferable to actual generation due to its ability to measure the expected return/revenue on the investment and the present value of such returns when a *FIS* policy is in place. This is because the decision to invest is based on evaluation using added capacity and not actual generation.

We note that the efficiency of wind and solar PV is very uncertain and therefore using actual generation as a dependent variable helps to determine the actual return on the investment. Yet, our aim, is to determine the impact of the strength of *FIS* policy on the pre-investment decision of electricity producers to adopt wind or solar PV technologies in a given country at a given time. For this reason, added capacity would be the best measure as a dependent variable since output could not be accurately forecasted prior to investment.

Furthermore, added capacity is used as a dependent variable rather than percentage of total renewable energy as a measure of growth, because, unlike the *Quota* scheme which is a policy clearly designed with the aim of increasing the total share of renewable energy with relation to traditional energy sources, the *FIS* policy is only designed implicitly to increase renewable energy capacity of specific sources. For this reason, added capacity would be the best measure to test for the effectiveness and strength of *FIS,* rather than percentage of renewable to total electricity generation.

Also, we use added capacity as a dependent variable rather than cumulative capacity because, we note that in addition, the strength of the *FIS* policy and its interaction with market factors in a given country at a given time (captured by our indicator *PvRev*) allows investors to make decisions whether to invest in new RES-E technology in a given country at a given time. In other words, investors decide to add capacity of wind and solar photovoltaic in a given country at a given time based on the revenue to be received as a result of *FIS* policy at the given time. Therefore, we assume that the *FIS* policy at time t is unlikely to affect capacity development at time $t-1$, albeit using added capacity as a measure of development isolates the effects of policies on capacity development in previous years.

With the exception of Menz and Vachon (2006) Shrimali and Kniefel (2011), Jenner et al. (2013), Bolkesjø et al. (2014) and Dombrovski (2015) who used technology specific capacity data, most researchers such as Carley (2009), Lyon and Yin (2010), Marques et al. (2010), Yin and Powers (2010) and Marques and Fuinhas (2011a,b),) among others use renewable percentage of total electricity or total renewable energy data as dependable variables, hence making it impossible to distinguish among the development of different technologies. Using added capacity and technology specific data allows us to examine the effectiveness of wind and solar PV specific *FIS* policies.

5.6.3 Independent Variables

5.6.3.1 Policy Related Variables

In addition to testing for the impact of the strength of *FIS* using the *PvRev* indicator on the capacity development of wind and solar PV, we also control for the effects of other policy enactments. We use dummy variables to control for the existence of other RES-E policy incentive schemes. The dummy variable takes the value of "1" if there is a specific policy in existence at a given time and "0" otherwise. Other enacted policy support schemes we consider include wind and solar photovoltaic energy tax exemptions, investment grants and soft loans as one variable (*Tax*), *Tender*, *Quota* and *Cap*. We also control for the mere existence of the *FIT* and *FIP* policies with the use of dummy variables as well as interaction between the *FIT* and *FIP* and *FIT* and *TEND*. In addition, we test for the impact of the relative tariff amount on capacity development of wind and solar PV.

5.6.3.2 Control Variables

In line with previous literature, we control for a mixture of socio economic, environmental and political factors which could impact on capacity development of wind energy. These variables include Elect.Consumption, GDP, Oil Price, Gas Price, Coal Prices, Oil Share, Coal Share, Natural Gas Share, Renewable Share, Popul.Growth, Energy Import and Potential.

5.7 Empirical Model Specification

We test the impact of *FIS* policy strength on the capacity development of wind and solar PV in the EU using a panel model with country and time fixed effects specification. The merit of using the fixed effects estimation as opposed to the random effects is explained in Chapter 3 and subsequently in Chapter 4. The base form of our panel model is given in equation 5.10 while the model with the lag structure is given in equation 5.11 below;

$$Ln(AC_{ijt}) = \beta_0 + \beta_1 Pv\mathrm{Re}v_{ijt} MWh + \beta_k H_{ijt} + \beta_g U_{ijt} + k_{ijt} + \varepsilon_{ijt} \qquad (5.10)$$

$$Ln(AC_{ijt}) = \beta_0 + \beta_1 Pv\mathrm{Re}v_{ijt-1} MWh + \beta_k H_{ijt-1} + \beta_g U_{ijt-1} + k_{ijt-1} + \varepsilon_{ijt-1} \qquad (5.11)$$

where AC_{ijt} is the natural log of added capacity of technology *i* (wind or solar PV) installed in country *j* during year *t*. $Pv\mathrm{Re}v$ is our estimated indicator for the expected present value of the revenue from the investment in wind or PV during year *t*. We subsequently substitute the *PvRev* variable with dummy variable representation of *FIS* to test for the impact on capacity development. We also substitute the indicator with *PvRev_1, PvRev_2, PvRev_3, and PvRev_4* in order to segregate the effect of *FIT* and *FIP*, as well as policy components and non-policy components from the indicator. H_{ijt} represents a suit of dummy variables for the enactment of other policy incentive schemes (*Quota, Tax, Tender and Cap),* implemented to encourage RES-E development. υ_{ijt} represents the natural log of various factors (*Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price and Ln Energy Impor*t) that possibly have an impact on RES-E capacity development according to the existing literature. κ_{ijt} represents unobserved country level time fixed effects while ε_{ijt} represents the identically distributed random error term. This estimation allows for the control of time invariant country specific effects such as wind and solar potential, differences in planning regimes, commitment towards RES-E, and capacity of wind and solar PV before our sample period. It also allows for the control of time variant factors such as market uncertainties and learning effects of technology. Following, Polzin et al. (2015), we structure our panel model to include a one year lag procedure to capture the effect of the time it takes to add an additional capacity after the implementation of a policy and to also mitigate the endogeneity concern regarding the renewable share variable.

It is worthy to note that, our results in Chapter 2, indicate the significance of output price volatility, correlation between output quantity and output price and the projects' profitability on the investment decision. Yet, our *PvRev* indicator captures only the project's revenue (profit), ignoring the volatility and the correlation coefficient variables. This is because, in this chapter, our data is aggregated at the national level in order to capture the individual country fixed effects and policy heterogeneity on capacity development and this makes it very difficult to compute the volatility and the correlation coefficient.

Also, our indicator captures the revenue from the investments at the national level by considering installed capacity rather than actual generation. Therefore, we could not compute correlation between output production and output price. On the other hand, in order to compute the correlation coefficient between output price and output quantity we would have to use actual renewable energy generation data, per site. However, since our aim is to study the extent at which the *FIS* policy drives investment decision at the national level, we use energy production capacity data. As a future research, it will be interesting to disaggregate the data per country and examine the effect of support schemes policy on renewable energy investments considering the volatility and the correlation coefficient between the output quantity and the output price on firms' investment decisions, per investment project. This would help to identify whether asymmetric investment decisions among firms were taken as a result of a given policy.

To assess the impact of the strength of *FIS* policy on capacity development of wind and solar PV, we use a variety of panel data analysis. Initially, we use an OLS model to estimate the association between policy and capacity development of wind and solar PV using added capacity as a measure of development. Using the results from OLS to make our analysis could lead to inconsistencies and bias due to its inability to control for country level time unobserved factors (Carley, 2009; Marques et al., 2010; Dong, 2012). When standard errors are heteroscedastic within the sample, the omission of correlated time invariant variables would lead to biased estimates. For this reason we employ the Breusch and Pagan Lagrangian Multiplier (LM) test for random effects, Breusch and Pagan (1980) by using the xttest0 command in Stata. The results of this tests, presented in Tables 5.1 and 5.2 below for wind and solar PV respectively, indicate the superiority of the random effects model over OLS at the 1% confidence level across all models. This also indicates the importance of individual country specific effects in our model.

However, these country specific effects could be either randomly distributed or fixed across the sample. When the effects appear to be random, there is the assumption that other independent variables are not correlated with the time invariant variables. With our sample, one would expect the time invariant variables to be correlated with the policy incentive dummy variables. A fixed effect is, however, the appropriate model to use in the event that factors which are correlated with policy variables are omitted (Carley, 2009; Yin and Powers, 2010; Marques and Fuinhas, 2011b; Aguirre and Ibikunle, 2014; Bolkesjø et al., 2014). The fixed effects model estimation controls for unobserved country heterogeneity so as to eliminate bias of coefficients when these effects are correlated with capacity development and policy implementation. On the other hand, the random effects model would result in more reliable coefficients in the case that these unobserved time-invariant variables are uncorrelated. However, due to the individual country characteristics and the nature of our data, we expect the unobserved time invariant variables to be correlated and therefore we expect the fixed effects model to provide reliable estimates.

To further confirm the presence of unit heterogeneity and the superiority of the fixed effects model over the random effects model, we conduct the Hausman test Hausman (1978) to choose between both models. From the results of our Hausman test presented in Tables 5.1 and 5.2 below indicates the presence of unit heterogeneity and therefore the fixed effects model would provide more efficient estimates. The p-values for all Hausman test results are significant at the 1% confidence level. Hence, our analyses are based on the results from the fixed effects regressions model.

Furthermore, from the results of our specification test presented in Tables 5.1 and 5.2 below, the presence of heteroscedasticity and autocorrelation in our data sample presents a concern which has to be robustly analysed. Even though this concern has been dealt with in our fixed effects model, for further robustness and comparison of different estimation, we follow Parks (1967) and use a two-step process to address serial correlation and heteroscedasticity in our sample. We remove possible serial correlation by estimating auto correlation from OLS residuals in the first step. We remove heteroscedasticity and contemporaneous correlation in the second step by using PCSE as proposed by (Beck and Katz, 1995). Coefficients of OLS estimates are used by the PCSE to compute standard errors devoid of contemporaneous correlation and heteroscedasticity. Coefficients of the PCSE specification are overestimated without controlling for country fixed effects. Results for these estimates without a lag structure and with a one year lag structure are reported in Appendix, AC5 Table 4 and AC5 Table 5 respectively for wind energy, while that of solar PV is reported in AC5 Table 9 and AC5 Table 10 respectively. The xtpcse command in Stata was used for this regression.

5.8 Specification Test

Table 5.1: Specification Test Statistics with Wind Energy

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Wooldridge Test (autocorrelation)	15.939***	14.580***	15.020***	13.097**	13.335***	17.984***	13.474***	16.276***	14.961***
Breusch-Pagan (heteroscedasticity)	72.21***	68.71***	81.49***	150.44***	101.97***	62.56***	93.40***	155.12***	68.87***
LM	73.611***	103.05***	135.53***	42.72***	46.73***	86.41***	133.18***	95.05***	102.50***
Hausman Test	262.93***	102.83**	122***	138.32***	133.41***	134.66**	119.45***	272.39***	212.19***

Table 5.2: Specification Test Statistics with Solar Photovoltaic models

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Wooldridge Test (autocorrelation)	68.184***	73.191***	66.869***	58.758***	58.430***	66.104***	67.096***	49.065***	66.650***
Breusch-Pagan (heteroscedasticity)	293.37***	271.11***	267.09***	356.83***	356.19***	350.00***	290.90***	284.40***	271.91***
LM	64.69***	81.83***	92.26***	37.14***	40.30***	44.01***	104.22***	100.06***	74.37***
Hausman Test	149.71***	123.44***	135.05***	49.51***	51.28***	48.87***	158.91***	162.82***	146.01***

Similar to Chapter 4, we begin our analysis by performing a series of statistical tests to examine the reliability and validity of our data and results. We conduct the Bera-Jarque test, Jarque and Bera (1980) for normality using the sktest command in Stata of which results for all models indicate that the data deviates from normality and hence should be transformed to avoid biased analysis, specification in errors and inconsistencies in the estimates. Both the skewness and kurtosis test independently and jointly were significant at the 1% confidence level. Following Carley (2009), Aguirre and Ibikunle (2014 Bolkesjø et al. (2014) and Polzin et al. (2015), we transform the data by taking natural log of the variables. We conduct the Jack-Bera test after transforming the data which resulted in a significant kurtosis but reduced to the 10% confidence level which is close to normality and insignificant skewness. The significance of the joint test was also reduced to 10% confidence level which can be assumed to be close to normality.

We further test for the presence of heteroscedasticity using the Breusch-Pagan test Breusch and Pagan (1979). We test for the presence of heteroscedasticity using the hettest command in Stata in all our 9 model estimations involving *FIS* effectiveness in driving wind and solar PV capacity development. Our results above indicate that for all model specification there is the presence of heteroscedasticity. This means that our policy data is heteroscedastic and has a common variance which has to be addressed to prevent inefficient estimates. Also, we test for the presence of serial correlation by using the Wooldridge test with the xtserial command in Stata (Wooldridge, 2002). All test results presented in Table 5.1 and 5.2 above strongly suggest the presence of serial correlation. Even though our estimates would be unbiased and consistent, the presence of serial correlation makes estimation inefficient (Brooks, 2014). However, efficient and consistent standard errors would be produced in the presence of serial correlation and heteroscedasticity if there is appropriate adjustment of standard errors (Drukker, 2003; Baltagi 2008). For that reason, to correct the heteroscedasticity and serial correlation problem, we use Hoechle modified Driscoll-Kraay heteroscedasticity, autocorrelation and spatial autocorrelation robust standard errors in Stata (Hoechle, 2007).

5.9 Results

Table 5.3: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Added Capacity Wind	594	197.4545	483.9258	-240	3356
Added Capacity Solar	594	133.9529	742.3365	0	9303
FIS_Dummy Wind	594	0.410774	0.492389	0	1
FIS_Dummy Solar	594	0.343434	0.475255	0	1
FIS_Dummy Wind	594	0.346801	0.476353	0	1
FIS_Dummy Solar	594	0.304714	0.460674	0	1
FIS_Dummy Wind	594	0.121212	0.326649	0	1
FIS_Dummy Solar	594	0.082492	0.275344	0	1
FIT&FIP Wind	594	0.060606	0.252536	0	2
FIT&FIP Solar	594	0.047138	0.227458	0	2
FIT&TEND Wind	594	0.026936	0.162033	0	1
FIT&TEND Solar	594	0.026936	0.162033	0	1
FIT_ABS Wind	594	29.91302	49.80023	0	275
FIT_ABS Solar	594	112.0985	187.1577	0	575
FIP_ABS wind	594	9.071645	26.0383	0	166
FIP_ABS Solar	594	16.91808	67.40139	0	464
PvRev Wind	594	11.18308	20.66477	-15.1691	159.3843
PvRev Solar	594	-2.0149	48.77736	-358.324	140.3267
PvRev_1 Wind	594	9.022559	19.88312	-1.98157	159.3843
PvRev_1 Solar	594	10.99126	30.00311	-83.5639	140.3267
PvRev_2 Wind	594	5.189274	13.23256	-8.37169	122.7217
PvRev_2 Solar	594	10.03024	30.20766	-83.5639	140.3267
PvRev_3 Wind	594	0.261527	0.86276	-0.20535	4.485692
PvRev_3 Solar	594	1.395294	9.651141	0	100.512
PvRev_4 Wind	594	8.346009	14.42219	-15.1691	88.73833
PvRev_4 Solar	594	-24.6009	42.86847	-358.324	16.37275
Quota_Dummy	594	0.144781	0.352177	0	1
Tax_Dummy	594	0.166667	0.372992	0	1
Tender_Dummy	594	0.069024	0.253708	0	1
CAP_Dummy	594	0.090909	0.287722	0	1
GDP	594	24272.47	16756.37	2460.654	86127.24
Elect.Consumption	594	6196.756	3603.961	1935.561	17212.95
Coal Share	594	30.62511	26.62496	0	97.33103
Natural Gas Share	594	1.06E+07	6.68E+07	0	5.93E+08
Nuclear Share	594	20.57517	24.22304	0	87.98622
Oil Share	594	9.32348	19.55767	0	100
Renewable Share	594	4.28701	6.303238	0	48.62688
Population Growth	594	0.200702	0.825395	-3.82017	3.732596
CO2	594	8.291522	3.644724	2.636157	27.14212
Potential	594	162425.3	158893.1	2590	549190
Oil Price	594	89.4082	15.7421	27.9	140.1
Electricity price	594	74.32273	28.61197	24.25	224.95
Natural Gas Price	594	106.364	47.88678	18.7	342.3
Coal Price	594	95.77542	33.2181	32.2	276.7
Energy Import	594	45.87417	25.97881	-49.8	102.5

Table 5.3 above contains descriptive statistics of the variables used in this chapter. A preliminary analysis of the descriptive statistics is vital to determine possible biasness of results due to possible extreme variability in variables. For the purposes of this study, the mean and standard deviations of our results are as expected for all variables due to the possible large variability among countries in our panel. As expected, we observe negative *PvRev* values for both solar PV and wind. The highest *PvRev* values for wind and solar are 159.38 per MWh and 140.32 per MWh respectively. From our dataset, we also observe that in the absence of an *FIS* policy where electricity produced from wind and solar PV is expected to be sold in the competitive market, the minimum revenue, denoted by *PvRev_4* for wind and solar PV are -15.169 and -358.324 Euros per MWh respectively.

As expected, we also observe larger mean values for variables such as Potential, GDP and Elect.Consumption. The high values of Potential lead to high coefficients in the fixed effects regression models. We ran the regression without *Potential* and noticed the significance of our results did not change and so we report the results of the regression with *Potential*. As expected, we observe negative values for variables such as added capacity, *Popul.Growth* and *Energy Import* Dependence. Due to the energy balances of countries, we expected energy import dependence of certain countries to be negative. We also expected negative population growth and negative absolute growth of wind energy due to the possibility of technical problems that could lead to farm shut down, as observed in dataset. Since our objective is to determine the growth of RES-E, we ignore the negative values and represent them by "0".

Table 5.4: Fixed Effects Results for the Impact of *FIS* on Wind Energy Development with Time Lag

This table reports the results for the fixed effects regression equation 5.11 presented in (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of *FIS* policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy while L. represents the one year lag of independent variables. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* during year *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* during time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* during time *t*, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* during time *t*, when there is no *FIS* policy in place and the competitive market is the only source of revenue. *LnFIT_ABS* and *LnFIP_ABS* represents the relative monetary amount paid by governments per kwh of electricity generated from wind sources and supplied to the national grid under *FIT* and *FIP* contract. *FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy* are dummy variables representing the existence of feed-in-systems (*FIT* or *FIP),* Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, *Tender* and *Cap* respectively in a country at a given time. *FIT&FIP* represent the interaction between Fixed Tariff and Premium Tariff. *FIS&TEND* represents the interactions between *FIS* with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy Import Dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(WE1) Model	(WE2) Model	(WE3) Model	(WE4) Model	(WE5) Model	(WE6) Model	(WE7) Model	(WE8) Model	(WE9) Model
L.FIS_Dummy	2.401								
	(1.174)								
L.FIT_Dummy	-1.337								
	(1.161)								
L.FIP_Dummy	-2.338								
	(1.137)								
L.LnFIT_ABS		0.186*							0.197*
		(0.081)							(0.073)
L.LnFIP_ABS			-0.223						-0.235
			(0.111)						(0.120)
L.LnNpvRev				0.348**					
				(0.121)					
L.LnNpvRev_1					0.195**				
					(0.122)				

L.LnNpvRev_2						0.330**			
						(0.114)			
L.LnNpvRev_3							-0.529		
							(0.307)		
L.LnNpvRev_4								0.319*	
								(0.115)	
L.FITFIP	1.006								
	(0.547)								
L.FITTEND	0.113								
	(0.468)								
L.Quota_Dummy	1.251*	1.104*	0.804*	0.688	1.074*	1.131*	0.870*	0.710*	1.006*
	(0.507)	(0.460)	(0.468)	(0.418)	(0.470)	(0.466)	(0.473)	(0.437)	(0.468)
L.Tax_Dummy	-0.495*	-0.440	-0.520*	-0.447	-0.479*	-0.385	-0.549*	-0.438	-0.397
	(0.230)	(0.228)	(0.222)	(0.220)	(0.209)	(0.204)	(0.244)	(0.220)	(0.215)
L.Tender_Dummy	0.295	0.220	0.172	0.306	0.294	0.262	0.136	0.308	0.188
	(0.308)	(0.152)	(0.145)	(0.234)	(0.155)	(0.141)	(0.153)	(0.236)	(0.177)
L.CAP_Dummy	-0.385	-0.354	-0.157	-0.541	-0.549	-0.402	-0.081	-0.507	-0.233
	(0.411)	(0.349)	(0.393)	(0.332)	(0.368)	(0.355)	(0.374)	(0.332)	(0.422)
L.LnGDP	0.225	0.499	0.901	0.555	0.582	0.672	0.548	0.844	0.807
	(0.957)	(0.993)	(1.071)	(0.904)	(1.044)	(0.965)	(1.099)	(0.931)	(0.941)
L.lnElec.Consumption	4.538**	4.821**	4.760**	4.374*	4.805*	4.478**	5.132**	3.917*	4.513**
	(1.585)	(1.667)	(1.591)	(1.640)	(1.759)	(1.610)	(1.728)	(1.699)	(1.490)
L.LnCoal Share	0.380**	0.303*	0.360*	0.328*	0.336*	0.342*	0.317*	0.341*	0.331*
	(0.125)	(0.137)	(0.138)	(0.129)	(0.134)	(0.123)	(0.146)	(0.132)	(0.128)
L.LnNatural Gas Share	0.115	0.079	0.155	0.198	0.155	0.122	0.138	0.198	0.080
	(0.146)	(0.176)	(0.171)	(0.163)	(0.180)	(0.161)	(0.195)	(0.175)	(0.151)
L.LnNuclear Share	0.232	0.218	0.226	0.288	0.251	0.281	0.185	0.312*	0.252
	(0.154)	(0.169)	(0.150)	(0.150)	(0.167)	(0.150)	(0.174)	(0.147)	(0.139)
L.LnOil Share	0.164	0.218	0.134	0.185	0.160	0.194	0.158	0.160	0.217
	(0.147)	(0.160)	(0.131)	(0.142)	(0.152)	(0.145)	(0.144)	(0.139)	(0.150)
L.LnRenewable Share	0.149**	0.163**	0.150**	0.125***	0.141*	0.130**	0.153*	0.111*	0.160*
	(0.096)	(0.094)	(0.093)	(0.080)	(0.098)	(0.096)	(0.096)	(0.082)	(0.092)
L.LnPopul.Growth	0.115	0.124	0.074	0.091	0.099	0.103	0.094	0.089	0.104
	(0.085)	(0.093)	(0.080)	(0.078)	(0.085)	(0.084)	(0.083)	(0.077)	(0.086)

L.LnCO2	-1.290	-1.366	-1.462	-1.439	-1.545	-1.376	-1.612	-1.028	-1.196
	(1.004)	(1.102)	(1.142)	(1.098)	(1.162)	(1.077)	(1.159)	(1.151)	(1.047)
L.LnPotential	-24.023	-18.211	-27.617	-9.540	-15.053	-16.781	-25.220	-12.443	-24.821
	(23.725)	(26.132)	(26.578)	(26.802)	(27.314)	(26.570)	(27.126)	(26.701)	(23.895)
L.LnOil Price	0.683	0.931	0.470	0.540	0.727	0.810	0.789	0.483	0.621
	(0.513)	(0.491)	(0.456)	(0.374)	(0.423)	(0.453)	(0.482)	(0.384)	(0.497)
L.LnNatural Gas Price	-0.737	-0.899	-0.478	-0.744	-0.772	-0.901	-0.677	-0.673	-0.660
	(0.475)	(0.485)	(0.445)	(0.369)	(0.425)	(0.476)	(0.454)	(0.381)	(0.506)
L.LnCoal Price	1.511*	1.262	1.674*	1.129	1.277	1.442	1.486	1.150	1.547*
	(0.700)	(0.732)	(0.783)	(0.586)	(0.719)	(0.764)	(0.763)	(0.612)	(0.749)
L.LnEnergy Import	-0.276	-0.278*	-0.249	-0.318	-0.362*	-0.255	-0.258	-0.308*	-0.195
	(0.147)	(0.134)	(0.129)	(0.158)	(0.131)	(0.138)	(0.135)	(0.143)	(0.135)
Constant	-127.160**	-111.385*	-147.939**	-77.659*	-101.203*	-105.714	-138.838	-87.321	-135.202*
	(77.186)	(84.369)	(86.674)	(85.728)	(87.625)	(85.831)	(88.370)	(86.021)	(76.831)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	567	567	565	567	567	567	567	567	565
R-squared	0.512	0.532	0.529	0.549	0.528	0.529	0.529	0.529	0.532
Number of Countries	27	27	27	27	27	27	27	27	27

Table 5.4 above presents the results of our analysis of the impact of *FIS* on the capacity development of wind energy with a year lag. We observe a non-significant relationship between wind energy and the dummy variable representation of *FIS* policy (regression WE1, Table 5.4). Therefore we cannot reject the null hypothesis of non-significant relationship between the dummy variable representation of *FIS* policy and capacity development of wind energy. However, when the dummy variable is replaced with the monetary contribution of the policy we observe a significant and positive impact of the contribution of *FIT* (*FIT_ABS*) on wind energy capacity development but a non-significant impact of the contribution of *FIP* (*FIP_ABS*) on capacity development of wind energy (regressions WE2 and WE3; Table 5.4).

Specifically, we observe that the contribution or monetary value of *FIT* policy increases wind energy capacity by 18.6% at the 10% confidence level. When the policy variable is replaced with our new present value indicator, *PvRev*, we observe a significant impact on wind energy capacity development. We observe that at the 5% confidence level, the strength of *FIS* would increase wind capacity development by 34.8% on average when there is a five point change in revenue (regression WE4, Table 5.4). This implies that in the case of wind energy, there exists a strong correlation between *PvRev* and capacity growth in general even in countries without *FIS* policy. When *PvRev* is split into, *PvRev_1, PvRev_2, and PvRev_4* (in regressions WE5, WE6, and WE8; Table 5.4), in order to segregate the policy components from non-policy components and to capture the effect of the design of the policies, we observe a positive and significant impact even in countries and years where there is no *FIS* policy (regression WE8). This indicates that wind capacity growth is not only driven by revenue provided by the *FIS* policy but by the market return as well.

We also find that both dummy *FIP* and revenue from *FIP (PvRev_3)*, do not drive wind capacity development (regression WE1 and WE7 respectively). We also observe a significant impact of dummy variable representation of Quota policy on capacity development of wind energy. According to our results in Table 5.4, *Tax* exemptions represented by a dummy variable negatively affect capacity development of wind energy while *Tender* and *Cap* policies have no significant impact.

Table 5.5: Fixed Effects Results for the Impact of *FIS* on Solar Photovoltaic Capacity Development with Time Lag

This table reports the results for the fixed effects regression equation 5.11 presented in (PV1)-(PV9) for the determinants of the Solar PV capacity growth due to the strength of *FIS* policy. In the second column are the independent variables while the first row are the dependent variables. PV represents solar Photovoltaic while L. represents the one year lag of independent variables. The dependent variable is the natural log of annual added solar PV capacity (*Ln AC*). ***Ln PvRev*** is the natural log of the revenue per MWh of electricity generated from a solar PV which was adopted in country *j* during year *t* for the entire life of the wind farm. ***Ln PvRev_1*** is the natural log of the revenue per MWh of electricity generated from a solar PV which was adopted in country *j* during year *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. ***Ln PvRev_2*** is the natural log of the revenue per MWh of electricity generated from a solar PV which was adopted in country *j* during year *t*, when *FIT* policy is the only source of revenue. ***Ln PvRev_3*** is the natural log of the revenue per MWh of electricity generated from a solar PV which was adopted in country *j* during year *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. ***Ln PvRev_4*** is the natural log of the revenue per MWh of electricity generated from a solar PV which was adopted in country *j* during year *t*, when there is no *FIS* policy in place and the competitive market is the only source of revenue. *LnFIT_ABS* and *LnFIP_ABS* represents the relative monetary amount paid by governments per kwh of electricity generated from solar PV and supplied to the national grid under *FIT* and *FIP* contract. *FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and Cap_Dummy* are dummy variables representing the existence of feed-in-systems (*FIT* or *FIP),* Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, *Tender* and *Cap* respectively in a country at a given time. *FIT&FIP* represent the interaction between Fixed Tariff and Premium Tariff. *FIS&TEND* represents the interactions between *FIS* with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy Import Dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(PV1) Model	(PV2) Model	(PV3) Model	(PV4) Model	(PV5) Model	(PV6) Model	(PV7) Model	(PV8) Model	(PV9) Model
L.FIS_Dummy	1.803								
	(2.282)								
L.FIT_Dummy	2.653								
	(2.097)								
L.FIP_Dummy	2.001								
	(2.169)								
L.LnFIT_ABS		0.143							0.136
		(0.091)							(0.088)
L.LnFIP_ABS			0.211						0.201
			(0.132)						(0.130)

L.LnNpvRev				0.660***					
				(0.088)					
L.LnNpvRev__1					0.657***				
					(0.089)				
L.LnNpvRev_2						0.664***			
						(0.100)			
L.LnNpvRev_3							0.725***		
							(0.132)		
L.LnNpvRev_4								0.734	
								(0.165)	
L.FIT&FIP	-0.344								
	(1.091)								
L.FIT&TEND	-0.757								
	(0.686)								
L.Quota_Dummy	0.208	0.026	-0.024	0.464	0.470	0.429	0.035	-0.006	0.124
	(0.451)	(0.469)	(0.480)	(0.391)	(0.390)	(0.415)	(0.450)	(0.446)	(0.463)
L.Tax_Dummy	-0.127	-0.151	-0.229	-0.030	-0.045	0.077	-0.324	-0.386	-0.107
	(0.430)	(0.429)	(0.469)	(0.360)	(0.360)	(0.398)	(0.428)	(0.420)	(0.440)
L.Tender_Dummy	0.011	-0.229	-0.116	-0.153	-0.159	-0.151	-0.222	-0.192	-0.206
	(0.683)	(0.652)	(0.662)	(0.464)	(0.477)	(0.471)	(0.679)	(0.682)	(0.626)
L.CAP_Dummy	0.179	-0.018	-0.265	-0.051	-0.027	0.004	0.059	-0.056	-0.198
	(0.792)	(0.754)	(0.735)	(0.604)	(0.606)	(0.600)	(0.743)	(0.760)	(0.707)
L.LnGDP	-4.217**	-3.833*	-4.000**	-3.185**	-3.292**	-2.922*	-4.128**	-4.200**	-4.050**
	(1.361)	(1.386)	(1.400)	(1.136)	(1.167)	(1.325)	(1.312)	(1.292)	(1.322)
L.lnElec.Consumption	4.874*	4.416	5.035*	3.423	3.648*	3.206	5.503*	5.739*	4.638
	(2.277)	(2.314)	(2.287)	(1.722)	(1.733)	(1.881)	(2.215)	(2.232)	(2.271)
L.LnCoal Share	0.206	0.255	0.237	0.282	0.291	0.269	0.227	0.248	0.208
	(0.187)	(0.182)	(0.193)	(0.164)	(0.168)	(0.175)	(0.185)	(0.182)	(0.184)
L.LnNatural Gas Share	-0.122	-0.078	-0.015	-0.171	-0.177	-0.157	-0.051	-0.077	-0.088
	(0.167)	(0 194)	(0.159)	(0.144)	(0.145)	(0.151)	(0.144)	(0.152)	(0.178)
L.LnNuclear Share	-0.427*	-0.374*	-0.443*	-0.380*	-0.384*	-0.368*	-0.456*	-0.447*	-0.408*
	(0.178)	(0.174)	(0.184)	(0.152)	(0.153)	(0.161)	(0.186)	(0.176)	(0.178)
L.LnOil Share	-0.247	-0.296	-0.335	-0.281	-0.281	-0.260	-0.276	-0.305	-0.274
	(0.221)	(0.221)	(0.221)	(0.205)	(0.208)	(0.213)	(0.221)	(0.223)	(0.214)
L.LnRenewable Share	0.306***	0.306**	0.299**	0.222**	0.223**	0.229**	0.281**	0.280**	0.317***

	(0.081)	(0.083)	(0.085)	(0.074)	(0.074)	(0.076)	(0.080)	(0.080)	(0.084)
L.LnPopul.Growth	0.265*	0.272**	0.250*	0.225*	0.223*	0.237*	0.203	0.219*	0.280**
	(0.096)	(0.090)	(0.093)	(0.093)	(0.094)	(0.092)	(0.100)	(0.096)	(0.093)
L.LnCO2	-5.195**	-5.022**	-5.602**	-4.359**	-4.517**	-4.439**	-5.512**	-5.665**	-5.238**
	(1.520)	(1.511)	(1.542)	(1.240)	(1.255)	(1.275)	(1.512)	(1.534)	(1.543)
L.LnPotential	-29.840	-28.235	-24.907	-21.186	-21.251	-17.453	-34.078	-35.413	-24.254
	(28.238)	(28.422)	(26.912)	(20.859)	(20.909)	(21.277)	(26.928)	(26.994)	(27.744)
L.LnOil Price	0.360	-0.020	0.141	-0.125	-0.111	-0.147	0.287	-0.018	0.273
	(0.761)	(0.769)	(0.696)	(0.472)	(0.473)	(0.504)	(0.693)	(0.723)	(0.717)
L.LnNatural Gas Price	1.084	1.332	1.372	1.047	1.039	1.099	1.170	1.372*	1.177
	(0.737)	(0.663)	(0.712)	(0.567)	(0.567)	(0.558)	(0.661)	(0.664)	(0.723)
L.LnCoal Price	-0.595	-0.168	-0.453	0.149	0.159	0.082	-0.421	-0.173	-0.522
	(0.928)	(0.976)	(0.976)	(0.859)	(0.864)	(0.883)	(0.932)	(0.961)	(0.950)
L.LnEnergy Import	-0.300	-0.278	-0.330	-0.212	-0.213	-0.220	-0.318	-0.294	-0.301
	(0.206)	(0.178)	(0.215)	(0.155)	(0.155)	(0.149)	(0.220)	(0.213)	(0.196)
Constant	-94.441	-90.594**	-81.420*	-65.368**	-66.222*	-53.174*	-115.223*	-121.222	-75.450**
	(92.062)	(92.290)	(87.007)	(68.652)	(68.784)	(70.159)	(86.758)	(87.117)	(90.118)
Effects	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	567	567	567	567	567	567	567	567	567
R-squared	0.411	0.459	0.451	0.451	0.578	0.569	0.462	0.551	0.451
Number of Countries	27	27	27	27	27	27	27	27	27

For solar PV, in Table 5.5 above, we find that dummy variable representation of *FIS* policies (regression PV1) does not drive capacity development. We also find a nonsignificant impact of the monetary contribution of the *FIT* and *FIP* on capacity development of solar (regression PV2 and PV3). This means we cannot reject the null hypothesis that dummy variable representation of *FIS* policy and the relative monetary value of the policy have no significant impact on capacity development of solar PV. However, when the dummy variable and the monetary contribution are replaced with *PvRev* (regression PV4, Table 5.5), we observe a positive relationship with capacity growth. This indicates the sensitivity of solar PV capacity development to changes in the revenue provided by either the policy and or the competitive market. In regression (PV5, Table 5.5) we also observe that *PvRev_1* drives capacity development of solar at the 1% confidence level.

This indicator reflects the impact of the revenue provided by the *FIS* on capacity development. Countries who have active *FIS* (*FIT* and or *FIP*) policy will have an average of 65.7% more additional capacity of solar PV installed than countries-years without the policy when there is a change in *PvRev_1*. We also observe that when we disaggregate the *FIS* into (*FIT* and *FIP*), there is a positive and significant relationship between present value of revenue provided by *FIT* and FIP alone on solar PV capacity development at the 1% confidence level (*PvRev_2, and PvRev_3*, in regression PV6 and PV7 respectively, Table 5.5). In other words, we find that capacity development is very sensitive to the revenue provided by the *FIT* and *FIP* policies alone and would increase capacity of solar PV by 66.4% and 73.4% respectively, when there is a unit change in revenue respectively. We can therefore confirm that solar PV capacity development reacts with a higher coefficient to the *FIP* incentive alone than when combined with *FIT* and return from the market.

We also observe that the present value of the revenue when there is no *FIS* policy is not a significant explanatory factor of solar PV development in the EU (in regressions PV8, Table 5.5). In other words, there is no statistically significant relationship between the capacity development of solar PV and the present value of revenue when electricity produced from solar PV sources is expected to be sold in the open competitive market. This implies that the market return without the presence of *FIS* does not drive the capacity development of solar PV, unlike in the case of wind. We also find that the dummy variable representation of other RES-E policies does not have a significant impact on solar capacity development. Other control variables in Tables 5.4 and 5.5 above are significant determinants of wind and solar PV capacity growth and are discussed in the subsequent sections below.

5.9.1 Further Robustness Analysis

As stated earlier, we estimate the random effects model and PCSE with one year lag structure of the independent variables for robustness checks presented, respectively for wind energy (AC5 Table 3 and AC5 Table 5) and for solar PV (AC5 Table 8 and AC5 Table 10). Also, we estimate the fixed effects, random effects, and PCSE without a time lag, thereby assuming that capacity addition is contemporaneous with policy implementation for robustness checks (See AC5 Table 1, AC5 Table 2 and AC5 Table 4 respectively for wind energy).

With the model with one year time lag, estimating the impact of dummy variable representation of *FIS* on wind energy, we observe that the random effects model and the PCSE model shows a significant relationship at the 5% confidence level while that of the fixed effects shows no significant impact. Similar to the estimates from the fixed effects model, the random effects and PCSE estimates for the impact of dummy variable representation of *FIT* and *FIP* on wind energy capacity development are not significant.

When the dummy variable is substituted with the absolute monetary value of the *FIT* and *FIP*, the random effects and PCSE results strongly support the results from the fixed effects by showing that monetary value of *FIT* has a significant impact on capacity development of wind, while that of *FIP* has no significant impact. However, while the confidence level of significance for the fixed effects model is 10%, those of the random effects and PCSE models are 5% and 1% respectively (AC5 Table 3 and AC5 Table 5 respectively). The coefficients of the estimates from the random effects model is 26.7%, that of the PCSE model is 31.8% and that of fixed effects is 18.6%. Both the coefficients and the confidence levels are higher in the random effects model and PCSE model than the fixed effects model.

Similarly, when we test for the effectiveness of *FIS* policies on wind energy development by using our new indicator *PvRev* with the random effects model and PCSE model, the results show a 1% significance level as compared to 5% significance level using the fixed effects model. The coefficients for the random effects model and PCSE model are again higher than that of the fixed effects model. Estimates from the random effects and PCSE show coefficients of 52% and 66% respectively while that of fixed effects is 35%, indicating that without controlling for country specific fixed effects, the results would be overestimated, (see for instance, Jenner et al., 2013).

When we turn to solar PV, the estimates from the random effects models and PCSE models strongly support the estimates from the fixed effects models in terms of direction of effect of our policy variables (see Table 5.5, AC5 Table 8 and AC5 Table 10 for the fixed effects, random effects and PCSE results with one year lag structure). However, as noted with wind energy, the estimates for all random effects models and that of PCSE are higher than the estimates from fixed effects models. This further reiterates the importance of controlling for unit heterogeneity which might be correlated with the error term. Unit heterogeneity is present in our sample and hence if not controlled could lead to over estimation of results as we can see from the random effects models (Carley, 2009; Jenner et al., 2013; Aguirre and Ibikunle, 2014).

According to our results, there is not much difference in the level of significance from the estimates with the assumption that capacity is contemporaneous to policy implementation. However, similar to the results with one year lag, the random effects and PCSE estimates are overstated and hence would lead to overconfidence in results.

We also observe that the model explanatory power R-squared is higher with the fixed effects estimates as compared to the random effects estimates in all model specifications. The fixed effects model, therefore, has more explanatory power than the random effects model for our data sample. Therefore, our discussion is based on the results from the fixed effects models. Also, in all specifications and regression models, the R-squared increases when the dummy policy variables are switched to the *PvRev* indicator. A possible reason for this is the ability of the *PvRev* indicator to capture additional heterogeneity and market factors which otherwise could not be captured by the dummy variables.

5.10 Summary of Key Findings

i. Dummy variable representation of *FIS* does not have an impact on wind and solar PV capacity development.

ii. Dummy variable representation of *FIT* does not have a significant relationship with both wind and solar PV development.

iii. Present value of revenue (*PvRev*) is very a sensitive and significant explanatory factor of the development of wind and solar PV in the EU.

iv. Present value of revenue when there is *FIS* policy alone (*PvRev_1*) has a strong significant impact on the capacity development of wind and solar PV.

v. Present value of revenue when there is *FIT* policy alone (*PvRev_2*) has a strong and significant impact on the capacity development of wind and solar PV.

vi. Present value of revenue when there is *FIP* policy alone (*PvRev_3*) has a strong significant impact on the capacity development of solar PV, but has no significant impact on wind energy capacity development.

vii. Present value of revenue from the competitive market (*PvRev_4*), in the absence of *FIS* policies, has a significant relationship with wind energy development but no significant impact on solar PV development.

viii. Relative monetary value of *FIT* has a significant impact on development of wind but not solar PV, while that of *FIP* has no impact on wind and solar PV.

ix. Wind energy and solar PV capacity development is more sensitive to policy structure, market conditions, and their interactions than to the mere existence of *FIS* policies alone.

5.11 Discussion

There are mixed findings in the literature regarding the ability of *FIS,* which is the most adopted RES-E support policy in the EU, to drive the capacity development of RES-E, especially for wind and solar PV. RES-E technologies are relatively new and riddled with high initial and production cost. A major question by policy makers and interested parties is whether the *FIS* schemes, which have been widely adopted across EU, have actually driven capacity development or whether public money has just been used to subsidize microscopic capacity which could have been installed based on the market conditions.

With our developed new indicator *PvRev* and our fixed effects panel structured model, we observe that the investment incentive provided by *FIS* has significantly driven wind and solar PV capacity development in the EU. This investment incentive resulting from holding a *FIS* policy contract is uniquely designed by countries and differs in sizes, tariffs amount, tenure and eligibility, duration among countries and technologies across the EU. Yet, most evaluations of the effectiveness of *FIS* policies ignore their unique design and structure. The importance of incorporating the unique design and structure of *FIS* policies in econometric evaluation, to determine the investment incentive they provide per country and per year and their impact on the capacity development, is further highlighted by the outcome of our research. We observe that incorporating the investment incentive provided by the *FIS* in our regression models instead of the binary representation results in a different outcome.

For instance, for wind energy, the dummy variable representation of *FIS* and wind capacity development have no significant causality (regression WE1, Table 5.4). This means that investors of wind energy do not react to the mere existence of *FIS* policy alone.

This finding is consistent with the findings of Jenner et al. (2013) who find no significant relationship between the dummy variable representation of *FIS* and wind energy capacity growth except when combined with Tender. We also find a significant positive impact of the monetary value of *FIT* policy as announced by government on the capacity development of wind energy but no significant impact of *FIP*, as announced on wind energy development (regression WE2 and WE3, Table 5.4). This means that the relative monetary value of the *FIT* drives wind energy capacity while the relative monetary value of *FIP* has no impact. While some countries have a set premium to be paid on top of the market price, the premium of other countries depends on the market price of electricity. The additional uncertainty introduced by the FIP could be a reason for its non-significant impact on capacity development.

However, contrary to Jenner et al. (2013), when the dummy variable representation of *FIS* is changed for *PvRev* (in regression WE4, Table 5.4), we observe a significant and positive response with wind capacity development. This means that wind capacity development reacts to the incentive or resultant present value of the revenue provided by the *FIS* and or the market rather than the mere existence of the policy. Specifically, we find that a five point increase in *PvRev* would result in an average of 34.8% capacity increase in wind energy. This implies that the revenue after investment in wind capacity is very important to investors and significantly affects the decision making process in wind energy investments as noted in Chapter 2. From our data, we notice that *PvRev* which captures the heterogeneity in policy is higher in some countries than others, which Bolkesjø et al. (2014) argues could lead to high rates of investments in wind technologies in countries with a high policy incentive. Also, we find that with or without *FIS* support scheme, investments in wind energy is very sensitive to the present value of their expected revenues. Segregating the effect of policy driven from market driven *PvRev*, we test the effect of *FIS* driven revenue only and find a positive relationship between the revenue indicator and the capacity development of wind (*PvRev*, in regression WE5, Table 5.4). This means that the present value of revenue in a country-years where there is an *FIS* policy alone would have about 19.5% more growth in added capacity than countries-years without the policy, when there is a five point change in the indicator.

Even though there are times that the market price of electricity exceeds the amount of tariff provided by the *FIS*, there still exists a positive and significant relationship between *FIS* and capacity growth. This could be as a result of the guaranteed amount provided by the tariff which mitigates part or most of the market risk associated with electricity price volatility for investors. The design and structure of the *FIS* have a direct impact on the risk and return of RES-E projects since it guarantees a certain amount of money for every MWh generated (Cardenas-Rodriguez et al., 2014; Polzin et al., 2015). The findings of this chapter are therefore in line with previous work such as Bolkesjø et al. (2014); del Río and Bleda (2012) and Polzin et al. (2015) who are of the view that *FIS* policies lower the investment risk associated with RES-E investments due to the guaranteed tariff amount and, therefore, strong and well-designed *FIS* policies drive wind capacity development.

Moreover, we note that our indicator which includes both revenue from *FIS* and market revenue (*PvRev* in regression WE4,Table 5.4) has higher coefficients than when regressed with the revenue from *FIS* policy alone (*PvRev_1,* in regression WE5, Table 5.4). This further reiterates the increasing competitive nature of wind energy in the competitive market and confirms the assertion that revenue from the investment is a significant influence in making decisions by investors, rather than the mere enactment of the policy alone (Jenner et al., 2013).

We go further to ascertain the effect of *FIT* and *FIP* driven revenues alone (*PvRev_2 and PvRev_3,* in *regressions WE6 and WE7* respectively, Table 5.4) on capacity development of wind energy and find that development is very sensitive and responsive to the revenue/return provided by *FIT* alone (*PvRev_2* in regression WE6; Table 5.4), but with no significant relationship with revenue provided by *FIP* policy alone (*PvRev_3* in regression WE7, Table 5.4). Specifically, we find that when there is a five point change in country-year where there is *FIT* policy alone, there will be an annual average increment of 33% more in capacity development of wind. This means that countries with an *FIT* policy in place would increase their capacity on average by 33% more than countries without the policy. This outcome further highlights the importance of considering policy design features when examining the effectiveness of enacted policies on capacity development. Both *FIT* and *FIP* are types of *FIS* policies designed differently; however, *FIT* has driven wind capacity development while *FIP* has not. This could possibly be as a result of the design of the *FIP* policy which only pays a premium on top of the market price of electricity. Investors only receive a premium based on the market price of electricity. This exposes them to market price uncertainty and hence their reluctance in response to the policy.

Our results also show robust evidence of a significant relationship between the market driven revenue *PvRev_4* and capacity development of wind energy (in regression WE8, Table 5.4). Wind energy is a matured technology with reducing cost of production and hence gradually becoming competitive in the market (Eerens and Visser, 2008; Kaldellis and Zafirakis, 2011; Abadie and Chamorro, 2014). In the absence of *FIS* policy, our results indicate that the incentive provided by the market has driven wind capacity development. More specifically, for every 10 point change in revenue provided by the competitive electricity market, wind capacity increases on annual average by 31.9%. We can therefore conjecture that, without *FIS* policy, the market revenue is enough to drive the capacity development of wind energy in the EU at the 10% confidence level. Our finding is consistent with Jenner et al. (2013) who find a positive impact of the return from the competitive market on capacity development of wind energy in the EU.

On the other hand, when we turn to solar PV, we observe that the mere existence of a *FIS* policy represented by dummy variable does not drive capacity development of solar PV in the EU (in regression PV1, Table 5.5). In other words, there is no significant statistical relationship between the enactment of policy alone and capacity development of solar PV. This is consistent with Jenner et al. (2013) who find no significant relationship between the dummy variable representations of *FIS* on capacity development of solar PV. The monetary relative value of both *FIT* and *FIP* has no significant impact on solar PV capacity development according to our results (regression PV2 and PV3; Table 5.5). However, when we replace the dummy variable representation of policy existence with our present value of revenue indicator, *PvRev* we observe a strong significant relationship with capacity growth (in regression PV4, Table 5.5). This implies that revenue provided by solar PV investment is much more important in driving capacity development than mere enactment of the policy alone. Specifically, for every 1 unit upward change in the revenue from investment in solar PV, there is likely to be an annual average of 66% increment in added capacity of solar PV. This is particularly so because, we note in our data the incentive provided by certain countries is not enough to make investment in solar PV very profitable.

To disaggregate the effect of policy components and non-policy components from our indicator, we first isolate the impact of market driven revenue from our indicator and regress the indicator with only *FIS* driven revenue on the added capacity of solar PV *PvRev_1* (in regression PV5, Table 5.5). We further split the *FIS* driven revenue in to *FIT* driven revenue *PvRev_2* (in regression PV6, Table 5.5) and *FIP* driven revenue *PvRev_3* (in regression PV7, Table 5.5). The results further confirm the superiority of the impact of the incentive provided by the *FIS* policy on solar PV capacity development. We find a significant impact at the 1% level of significance between *FIS* and solar PV capacity development. In fact, capacity development of solar photovoltaic is very sensitive to the present value of the revenue provided by *FIS* policies than the mere enactment of policy alone. There is likely to be an upsurge in capacity development of about 65.7% when there is one unit change in countries-years where there is *FIS* policy.

This further confirms the importance of the design and structure of the *FIS* policy with the aim of increasing capacity development. A poorly designed policy is probably unlikely to have any impact on capacity development. Our findings are consistent with Jenner et al. (2013) and Bolkesjø et al. (2014) who report a significant impact on the return of investment under *FIS* policy on the capacity development of solar PV and also reiterate the importance of policy components and market factors.

We also observe that there is a positive and significant relationship between the revenue provided by the *FIT* policy alone and capacity development at the 1% confidence level (in regression PV6, Table 5.5). In other words, we find that capacity development is very sensitive to the revenue provided by the *FIT* policy alone and would increase by 66.4% on average in countries-years when there is a unit change in revenue provided by *FIT*. This result is not surprising since the *FIT* guarantees payment for every kWh of electricity generated through solar PV. Production from solar PV is relatively expensive and hence the tariff amount needs to be high enough to ensure profitability. Our result is consistent with Bolkesjø et al. (2014) and Polzin et al. (2015) who report the ability of *FIT* to drive capacity development of solar PV.

The present value of revenue from *FIP* alone *PvRev_3,* is seen to have a significant impact on capacity development of Solar PV in the EU (regression PV7, Table 5.5). This finding is contrary to that of wind energy, where the revenue from *FIP* has no significant impact on capacity development. This could be due to the fact that the premium paid on top of the market price for solar PV is high enough to yield profitable investments and hence the positive response from investors.

The present value of revenue from the competitive market alone *PvRev_4,* does not drive the capacity development of solar PV in the EU (regressions PV8; Table 5.5). In other words, there is no statistically significant relationship between the capacity development of solar PV and revenue from the competitive market. This could be a reason why the statistical level of response to changes in revenue is higher when there is only *FIT* policy in existence and reduces when revenue from market and revenue from *FIP* are embedded in the indicator. This implies that the market revenue without the presence of revenue from *FIS* does not drive the capacity development of solar PV, unlike that of wind. Solar PV is relatively not yet competitive in the open market, unlike wind, hence the inability of the revenue from the competitive market to make such investments profitable. *PvRev* for wind energy is negative for all countries and years without *FIS* policy and hence investors would be expected not to invest unless there are support schemes. Our analysis is similar to that of Bolkesjø et al. (2014) who posit that investments in PV should be discouraged in the absence of *FIS* support schemes, due to the fact that they find negative returns for sola PV investments in years and countries without *FIS* policy.

The levelized cost of electricity production from wind sources is gradually becoming competitive with traditional fossil sources of power generation and hence could be a reason why the market revenue drives wind capacity in the absence of *FIS* policies, and not solar PV (Eerens & Visser, 2008; Schaeffer et al., 1999; Zweibel, 2010; Kaldellis & Zafirakis, 2011; Jenner et al., 2013). In our sample, the cost of production for wind declined drastically towards the end of the period, making the output from wind sources competitive in the open market.

Our model results indicate that, if country specific fixed effects are not controlled, the relationship between support policies and renewable energy capacity development would be overestimated. Also, if policy heterogeneity is not considered, the relationship between renewable energy capacity development and support policies might not be observed. Different factors and features that motivate RES-E capacity development could be contributory factors to the design and structure of *FIS* policies by countries in the EU. These individual factors could include economic, social, geological and political factors among others.

Also, after substituting the dummy variable with our indicator representing the investment incentive provided by the *FIS*, (WE4 to WE8 in Table 5.4 and PV4 to PV8 in Table 5.5) –as Jenner et al. (2013) and Bolkesjø et al. (2014) did for *FIT* in Europe, Yin and Powers

(2010) for *RPS* in the US, we further establish the link between policy design features, market conditions and capacity development of wind and solar PV. Specifically, we establish a strong link between the stringency of the investment incentive provided by *FIS* and capacity development of wind and solar PV. Our finding is consistent with the findings of Dinica (2006) who asserts that RES-E policies which fail to consider profitability and the level of risk of investments during their design process, may not achieve its intended aim of increasing capacity development. She is of the view that the profitability from investing in RES-E is a crucial driver of capacity development. Our analysis should be a basis for the consideration of future energy support policy designs and structure.

Using dummy variables to represent the existence of other policy incentives, our results also indicate that the only non-*FIS* support policy that drives capacity development is the Quota. This finding is contrary to Masini and Menichetti (2012) and Jenner et al. (2013) who report that, other than *FIT*, no other support policy has driven capacity development. This result is consistent with the analysis in Chapter 3.This is particularly so for wind capacity development. The enactment of Quota represented in the model by dummy variable has been observed to drive wind capacity development but not solar PV.

There are several insignificant impacts of other policies on the capacity development of wind and solar PV, which merit further explanation. We observe that apart from *FIS* and *Quota* which have a direct significant positive impact on capacity development of wind and solar PV (only *FIS*), none of the other support policies considered in this research have accomplished their intended aim. *Tax* and other financial incentives, however, have a negative and significant impact on wind energy capacity but no significant impact on capacity development of solar PV. This finding is consistent with Aguirre and Ibikunle (2014) and could be as a result of insufficient tax breaks necessary to encourage investment in such expensive technologies. This means that countries with only *Tax* breaks as a policy to encourage RES-E investments would have a reduction in capacity of wind energy and no significant impact on solar PV. The negative influence of *Tax* incentives could also be attributed to loss of confidence in the policy due to the uncertain nature of how long the *Tax* breaks would be available, for instance whether such incentives would be available when there is a change in government or a period such as financial crisis when governments would be tight on spending (Aguirre and Ibikunle, 2014).

Cost *Cap* also has no influence on capacity development. This policy has recently being introduced and only eight countries in our sample have adopted this policy. The non-significant impact could be as a result of the small weight of this policy in our sample which could not be captured by the dummy variable. The *Tender* also has an insignificant impact on the capacity development of wind and solar PV capacity in the EU.

We also find an insignificant impact of the interaction between the *FIT* and *Tender* on capacity development of wind of wind and solar photovoltaic (*FIT&Tender*, in regression WE1 and PV1 respectively, Tables 5.4 and 5.5). This implies that interaction between *FIT* and *Tender* does not drive capacity development. Our findings are consistent with Jenner et al. (2013) who find no significant relationship between *FIT&Tender* on solar PV development. On the contrary, they find a significant causal relationship between *FIT&TEND* and wind energy development.

The interaction between *FIT* and *FIP* also has no significant impact on capacity development of wind and solar PV. Our analysis indicates that policy design and structure is more important in analysing the effectiveness of policies on capacity development than the mere existence of policies. This is why the dummy variables might have not been able to capture the diversity in policy design across the countries in our sample. This calls for a deeper evaluation of these other policies considering their design and its resultant incentive on capacity development.

5.12 Socio Economic Factors

Our results allow us to analyse the impact of other social economic factors on the capacity development of wind and solar PV development in EU. Our results indicate a non-significant impact of *GDP* per capita on capacity development of wind (WE1-WE8, Table 5.4). The literature is continuously split on the impact of GDP on capacity development. On the other hand, from Table 5.5, we observe a significant negative relationship between solar PV development and *GDP*. This indicates that wealthier and bigger countries do not support the capacity development of solar PV and wind energy. Electricity generation from solar PV is comparatively expensive and richer countries, even though, they could raise capital to support such investment, does not do so according to our results. Supporting solar PV could further exert pressure on the budgets of richer countries due to the high amount of financial support needed to make investments in solar PV profitable, albeit a reason why richer countries does not support the technology.

For wind energy, one possible explanation for the non-significant relationship with GDP per capita could be as a result of the declining cost of electricity production from wind sources, which makes it competitive in the open market and hence it would be prudent to allow output to compete in the open market. This further affirms the position of Jenner et al. (2013) that *GDP* on capacity development depends on technology type. Wealthier and bigger countries might be able to support some technologies based on certain factors and country characteristics. For instance, countries with less potential of wind would support other technologies with a higher potential than that of wind.

From Table 5.4, we observe a positive relationship between electricity consumption per capita and wind energy capacity development. This implies that, the more electricity consumption increases, every other thing being equal, the more likely such increase in demand is to be met by electricity from wind energy. This could be the case due to the reducing cost of electricity production from wind energy sources, or perhaps the global concern about the impact of traditional electricity generation sources on the atmosphere. We also observe a positive and significant impact of the increase in electricity consumption on solar photovoltaic development

Electricity production from renewables has a significant and positive impact on the capacity development of wind energy in all our model specifications (WE1-WE9). As expected, the more energy is generated from renewable sources, the greater the capacity increment in wind energy. This indicates the growing interest of investments in wind energy. A possible reason could be associated to the declining cost of wind technology, which makes it competitive with traditional sources of generation even without government subsidies. So therefore, most environmentally friendly countries would rather increase their RES-E capacity by wind rather than other expensive RES-E technologies. As expected, capacity growth of solar PV is significantly and positively related to percentage of electricity generated from total renewable sources.

We find no significant relationship between electricity production from natural gas and capacity development of wind and solar PV in Tables 5.4 and 5.5 respectively. We also find no significant link between the percentage of electricity generated from coal sources and solar PV development .This is contrary to the findings of Marques et al. (2010) who report a positive relationship between coal share of electricity generation and renewable energy development. On the other hand, we find a positive and significant relationship between coal share and capacity development of wind energy. We find no substantial association between percentage of electricity generated from oil and the development of wind and solar PV in the EU. This could be as a result of the small number of oil generation technologies in the EU. Nuclear share, however, has a positive and less significant impact on capacity development of wind energy, and a negative and significant impact on capacity development of solar PV.As more countries invest in nuclear plants, capacity development of solar PV is significantly reduced.

We also find a negative and significant relationship between energy import dependence and capacity development of wind energy and non-significant impact on solar PV. This implies that the more countries depend on import to supplement their increasing energy needs, the lesser the capacity of wind energy and solar PV being added. This could possibly be as a result of higher import dependent countries importing energy to meet their increasing demand rather than investing in capacity of wind or solar PV. This could also be perhaps as a result of energy import dependent countries investing in other sources of generation rather than wind or solar PV. Our results also show robust negative significant impact of population growth on solar PV development and no relationship with wind energy capacity development. This implies that rising population growth results in less capacity of solar PV being added. From Tables 5.4 and 5.5, we find no significant relationship between coal price, natural gas price and oil price on the capacity development of solar PV in the EU. We observe, however, a significant positive relationship between coal prices and wind energy. We observe that when coal prices go up, all other things being equal, there is a capacity growth in wind energy.

While carbon emissions have no significant impact on wind capacity development, we observe a significant and negative impact on solar PV development. This means that rising CO2 retards capacity development of solar PV. It appears countries would rather pay the penalty for emitting more CO2 than invest in solar PV capacity. This could be possible, especially when the amount to pay for emitting CO2 is less than the amount needed to support solar PV capacity development.

5.13 Conclusion

From our findings in Chapter 1, we notice that profitability and volatility of the price and output are important aspects of the investment decision of RES-E technologies and without government support schemes, it is most likely investments in such technologies would be minimal or not observed at all. Moreover, in Chapter 4, we observe that without accounting for the profitability as a result of a particular support policy, its effectiveness in driving capacity development might not be observed.

Therefore, in this chapter, we perform a more sophisticated econometric analysis of the most adopted RES-E policy in the EU (i.e. *FIS*). As noted earlier, most previous analysis of RES-E policies ignore the policy design and market conditions that could affect the structure of the policy albeit its ability to provide the incentive necessary to encourage investments in renewable energy sources. Using a panel dataset of 27 EU countries, we employ a fixed effects model to determine the effectiveness of the *FIS* policy on the capacity development of wind and solar PV by controlling for country and time specific effects. Our analysis also introduces a new indicator (*PvRev*) that captures the incentive provided by the policy and the market conditions pertaining to individual countries at a given time. The findings of this chapter reveal that our results would be biased and overestimated without controlling for country level fixed characteristics and the impact of the policy might not be observed if policy heterogeneity is not accounted for.

The dummy variable representation of policy has no effect on capacity development of wind energy and solar PV. However, substituting the dummy variable with our *PvRev indicator*, we observe that for a 5% and 1% changes in *PvRev,* on average, there would be a 35% and 66% increase in capacity of wind energy and solar PV respectively. Our results mean that *FIS* policies have driven wind energy and solar PV among EU countries since 1992.

The findings imply that policy design features and market conditions are more important in driving the capacity development of wind and solar PV development than the mere existence of the policy. More specifically, we provide robust evidence to show that policy design, tariff amount, tariff type, tariff duration, digression rate of tariff, market electricity price, and cost of production and cost of borrowing are more important and sensitive to the RES-E investment decision making than the existence of policy alone. Our findings are expected to provide information for policy makers to carefully consider the design and structure of the policy before enactment, since the existence of a poorly designed policy would be equivalent to having no policy at all. Investors react sharply to the investment incentive provided by the policy and market conditions, and hence *FIS* policies should be carefully designed to be able to provide enough incentive to encourage investments in such technologies since the policy directly impacts on the risk/return of the investment. There are some limitations to our analysis in this chapter. These limitations and suggestions for future research are presented in the next chapter of this thesis.

6 Conclusion and Policy Recommendation

6.1 Contribution of the Thesis

In this thesis, our contribution to the academic literature is generalised in two different streams; examining the timing of the decision to add RES-E capacity under price and output uncertainty and exploring the effectiveness of RES-E support polices. These contributions are highlighted below.

In Chapter 2 we evaluate wind energy investments under electricity production and electricity price uncertainty using a real options framework. The classical investment appraisal techniques and the real options methodology, when applied to the optimization of the adoption of wind farm technologies, assume that the ex-post electricity production of the adopted technology is fully predictable. We provide empirical evidence regarding a wind farm (the LIDO wind farm project of Centric Energy, located at Skegness, UK), which shows that this is rarely the case.

We use Paxson and Pinto's (2005) model, adjusted for a monopoly market and taking into account the remarks made in Armada et al. (2013) about multifactor real option models, and derive the firm's value function and investment threshold. We calibrate the model with parameters which were estimated from a dataset comprising information on daily electricity spot market prices and daily electricity power production from the LIDO wind farm project of Centrica Energy, for the period between January 2011 and December 2012. The empirical evidence we report highlights the importance of considering weather uncertainty in the timing optimization of the adoption of wind farm technologies as well as the correlation between output price and output production. More specifically, we show that the higher the volatility of the electricity production (wind), which is usually as a result of the weather conditions, the later is the investment, and the more negative (positive) the correlation coefficient between the electricity market prices and the electricity power production is, the earlier (later) is the investment respectively.

Another contribution of this chapter is the practical illustration of the effect of electricity production and electricity price correlation coefficient on the renewable energy investments. This is because, we note the fact that daily electricity production from wind farms and daily spot electricity market prices tend to exhibit negative correlation, and the more negative the correlation is, the more profitable the investment. This is a key finding because our empirical dataset also shows that wind farms may exhibit very different correlation coefficients, and, therefore, those which exhibit more negative correlation coefficients are more valuable due to a gift of nature. To our best knowledge the importance of the above correlation coefficient has been neglected, for instance, in the site selection optimization where, ceteris paribus, the sites with more negative expected correlation coefficients should be selected. The above finding can also affect the design of the government's subsidies to renewable energy related investments.

The following highlights are deduced from Chapter 2: i) price-output correlation affects significantly wind farm investments; ii) price-output correlation can work as a hedging factor in wind farm investments; iii) more negative price-output correlation values accelerate wind farm investments; iv) more negative price-output correlation values are

“Gifts” of the Nature; v) higher electricity price volatility delays investment; vi) higher output production volatility delays investment.

The second contribution of this thesis (in Chapter 4) is to establish the role of RES-E support policies on the capacity development of wind energy in the EU, since we observe in Chapter 2 that without government support schemes, often, wind energy investments are not profitable. For instance, in Chapter 2, our real option model results show the Centrica Energy Plc investment in the LO wind farm should have been delayed had it not received government subsidy. Yet, EU governments have adopted different support schemes to enhance RES-E investments. There is, however, an ongoing discussion on which of these support policies is the most effective.

Hence, in Chapter 4, we use econometric methods to analyse the effectiveness of RES-E support policies considering both the existence of each policy and the number of years each policy has been in place. We use a data sample which comprises information on the use of support schemes per EU country between the years 1992 to 2013. We control for policies which are discontinued. For instance, if a particular policy was discontinued along the years, the dummy variable takes the value of “0” while the experience of the policy also becomes “0” from the year of discontinuation. There is scarce empirical literature regarding the effectiveness of policy experience on the development of wind energy apart from Menz and Vachon (2006) who investigate the effect of policy experience on development of wind energy using one year’s data.

To the best of our knowledge, this is the first study to econometrically examine the effectiveness of RES-E policies by considering both the existence of the policy and the number of years the policy has been in place, with a larger data sample than any other study, and applied to the EU context where reduction of carbon emissions is mandatory. We find a mixed relationship between adopted support policies and wind capacity development.

Although the *FIT* is the most adopted policy in the EU, the dummy variable representation of the policy does not have any significant effect on capacity development of wind energy, which is similar to the finding of Jenner et al. (2013). However, as the experience in using these policy accumulates, it has significant positive impact on wind energy capacity development in consonance with the findings of Polzin et al. (2015), who call for the implementation of long term policies. While the existence of *FIP* on the other hand does not have any significant impact on capacity development of wind energy, the number of years the policy has been in place retards wind energy capacity development in the EU even though insignificant.

The dummy variable representation we use for the existence of *Quota* reveal that it affects renewable energy investments, contrary to the findings of (Carley, 2009). Consequently, our results also show that there is a strong effect of the number of years *Quota* has been in place on capacity development of wind energy since 1992. Our findings suggest that wind energy capacity development is affected by the existence of *Quota* and the number of years *Quota* has been in place. Finally, we find that other policies such as *Tax* incentives and *Cap* do not affect the wind energy capacity development in the EU, and that socio economic factors such as percentage of electricity generated through renewable sources, electricity consumption per capita and coal price have a statistically significant positive impact on wind energy capacity development in the EU. Co2 on the other hand, has a negative significant impact on cumulative capacity of wind energy but added capacity.

In Chapter 5, we investigate the stringency of the *FIS* policies based on policy design and structure considering several market factors, and the resultant effect on wind and solar PV development in the EU. Most of the available empirical studies on the effectiveness of renewable energy policies were applied to the US context, and rely on dichotomous variables which take the value of "1" if a policy is in place and "0" otherwise. Yet, such methodology ignores policy design features and market characteristics (e.g., electricity price, interest rates and production cost) that may influence the strength of the policy as well as other country characteristics (Jenner et al., 2013; Bolkesjø et al., 2014). We observe from Chapter 4 that without controlling for these factors, the impact on capacity development might not be observed. And we also observe from Chapter 2 that the profitability of the investment affects the investment timing, therefore, it is vital we examine the revenue from a policy and determine its impact on capacity development.

Hence, we use a country and time fixed effects model to examine how responsive wind and solar PV development are to the design and structure of *FIS* policies. We introduce a new measure of policy strength that represents the present value of cash flows pertaining to investment in wind or solar PV under *FIS* contract, and find that investments in wind energy and solar PV are more sensitive to the present value of the expected revenue than the dummy variable representation of the policy. This implies that assessing policy effectiveness by representing it with a dummy variable does not capture the heterogeneity in policy design and sometimes could lead to misleading analysis.

Investments in wind and solar PV technologies are strongly affected by changes (or the perception of changes) in future incentives. More specifically, we find that for a positive 1 point change in the present value of revenue per MWh of electricity, there would be 34.8% change in the installed capacity of wind energy and a 66% change in solar PV installed capacity. Isolating the effect of the market revenue from the revenue accrued through *FIS*, we find that present value of the revenue from the *FIS* policy alone drives both wind and solar PV capacity development. For a 1 point movement in present value of revenue, countries with a *FIS* policy would increase their install wind and solar PV energy capacities by 19.5% and 65.7% respectively.

However, we find that, in a country-year where there is no *FIS* policy, the present value of the expected revenue from the competitive open market has a significant positive impact on wind energy capacity development, but with no significant impact on solar PV capacity development, which is consistent with the findings of (Jenner et al., 2013). Wind energy is cheaper when compared with solar PV energy and hence market revenue could be enough to drive capacity development of wind as compared to solar PV which could be non-profitable without subsidy.

In Chapter 5, the following conclusions are derived: i) the dummy variable representation of existence of *FIS* policies does not have an impact on both wind and solar PV capacity development; ii) the capacity development is more sensitive to the stringency of the policies than the mere existence of policies; iii) the strength of the present value of the revenue represented by (*PvRev*) for installing a capacity of wind and solar is very sensitive and has significant explanatory power of both wind and solar PV capacity development; iv) the present value of the future revenue expected when the only revenue is the sale of electricity through *FIS* policy alone (*PvRev_1*), has a very significant relationship with wind and solar PV capacity development in the EU; v) there is only *FIT* policy alone, wind and solar PV capacity development reacts positively to the indicator capturing the stringency of the policy (*PvRev_2*); vi) there is significant positive impact of present value of revenue when the only source to sell electricity is through *FIP* policy, on solar PV capacity development and insignificant impact on wind energy capacity development; vii) in the absence of *FIS* policy, wind capacity development is positively related to the strength of the revenue from the market while solar PV does not (*PvRev_4*). This implies that, in the absence of support policies, solar PV capacity development would stall; viii) the *FIS* policy type, tariff amount, duration of tariff, reduction rate of tariff, cost of electricity production, market electricity price, and cost of capital are more vital explanatory factors of wind and solar energy capacity development than the mere existence of a policy alone. ix) the relative monetary value of the policy as announced by governments has a significant impact on wind capacity development and no impact on solar PV.

6.2 Policy Implications

The findings from this research highlight the importance of considering the weather uncertainty in the evaluation of RES-E investments. Due to high levels of uncertainties, there is the need for more sophisticated evaluation methods such as the real options frame work in assessing such investments. The effect of correlation between output and market price on the timing and value investment should be of major concern to both policy makers and wind energy investors. Some governments are cutting down support for some RES-E technologies, such as the intention of the UK government to cut support for onshore wind farms. Consideration of the impact of correlation coefficient on the investment timing could help determine which sites would be more profitable in the absence of subsidies. Thus, we recommend policy makers to consider the expected correlation coefficient impact of price and output on a possible wind farm site prior to the issuance of a licence. Firms with two possible sites could also benefit from this analysis in deciding on which of the sites to invest in first.

Also, our analysis in Chapter 4 could be beneficial to policy makers in the enactment and management of policies. First, our analysis implies that, the longer the policy is in force, the more certain investors are that such policies are properly designed. The experience of policies to some extent relates to the certainty of the policy, and hence is of much concern to investors. Support policies should be properly designed with long term goals without frequent replacement. Also, switching from *FIT* to *FIP* does not enhance capacity development and hence should be avoided if possible.

Our findings also emphasize the importance of designing well fitted policies for the promotion of RES-E development. We establish that capacity development reacts to the strength of a policy more sharply than the mere existence of the policy. The design of policies in combination with market price, production cost and interest rates is more important in driving the capacity development of wind and solar PV than the mere existence of the policy and hence should be carefully considered during policy formulation. The enactment of a poorly designed policy could be as good as no policy in place. It is also of importance that academics go further in examining the return or revenue from RES-E policies and examine its impact on development, since the dummy variable representation of policies could be misleading.

6.3 Limitation and Suggestions for Further Research

There are a number of limitations regarding the design and modelling of this research. In Chapter 2, first, the use of average daily electricity price data and daily electricity production data might not capture all variations in the data since there is a considerable level of variation within hourly electricity prices. Second, our data sample does not cover the current period (2013 onwards) due to difficulty in obtaining data. Also, our assumption of gBm process could limit our analysis to reality when electricity prices are mean reverting. Also, the use of daily average spot electricity prices might not reflect the true amount of revenue to Centrica from operating the wind farm.

Areas for future research could be to simulate expected production of possible wind farm sites and evaluate the timing of production based on real price data with consideration of correlation and comment on which possible sites would be profitable in the absence of government support schemes. It would also be interesting to apply this analysis to other RES-E technologies such as solar PV, which might exhibit different characteristics from those exhibited by the wind farm. Also, future research could consider subsidy payment and duration of the subsidy and the correlation with output production to determine the timing of investment. Stochastic investment cost, uncertain production cost, technological progress and a mean reversion process for electricity prices could also be considered by future research.

Further research could explore all the wind farm locations in the UK and EU to determine the most common evolution patterns for the correlation coefficient between energy market prices and energy production and its level of stationarity over time and homogeneity across sites. If there is significant heterogeneity among the wind/solar farm's correlation coefficient values, this result would affect both RES-E policy schemes and site optimization.

Also, there are some limitations of our empirical Chapter 4. Firstly, using dummy variables to represent policy does not capture the heterogeneity in policy design and hence limits our comments on the impact of policy design features and uncertainty on capacity development (see, Bergek et al., 2013; Jenner et al., 2013; Polzin et al., 2015). Secondly, our analysis did not include the impact of market factors such as electricity price, investment risk and measure of volatility between price and output among others on the strength of support policies and its ability to enhance capacity development. Our analysis also did not include the impact of policy on other RES-E technologies, which could be driven by support policies.

This analysis could be extended in the future by considering the heterogeneity in policy design such as the duration of policies, monetary value of support policies, specific targets of support policies and their interactions with market conditions such as electricity prices, cost of production and cost of policy uncertainty. In addition, it would be interesting to examine the experience of policy by looking at uncertainties underlying implemented policies and how RES-E investors react to that. Other variables such as the respective RES-E targets of each country, carbon emissions reduction targets and carbon emission prices could have an effect on capacity development of wind and could be considered for future research. Also, it would be interesting to extend this study to examine the impact of policy on other renewable energy technologies such as solar and biomass.

Also, there are some limitations to our empirical Chapter 5. Our *PvRev* indicator could not capture all the heterogeneity attributed to *FIS* policy such as the impact of cost and capacity caps on the strength of the indicator. Also, our results in Chapter 2 indicate the significance of price volatility and correlation between output and price on the investment decision. Yet, our *PvRev* indicator ignores the impact of volatility and correlation. This limits the responsiveness of the investment revenue uncertainty which is seen to affect investment timing in Chapter 2.

Following from Chapter 5, research could be expanded in many different ways. First, since the *FIS* and *Quota* are seen to be the most effective policies, it would be appropriate to further explore the design features of these policies as identified in Yin and Powers (2010), Jenner et al. (2013), Bolkesjø et al. (2014) and this research, by determining their impact on expected revenue to investors. This work could also be extended to evaluate the environmental effectiveness of these policies, rather than just capacity development. Thus, the effectiveness of these policies in reducing carbon emissions could be empirically examined. This could be done either by using carbon emissions as a dependent variable or using RES-E generation by translating the capacity into the amount of emissions (in Tons) that would have occurred with traditional sources of generation. In addition, further research could also explore the stringency of other policies which we observe not to be effective with the mere representation by dummy variables, such as *Tax*, *Tender* and *Cap* for EU countries and to determine its relationship with capacity development of RES-E.

References

Abadie, L. M. & Chamorro, J. M. (2014), "Valuation of wind energy projects: A real options approach." *Energies*, Vol. 7, No.5: pp. 3218-3255.

Adelaja, S. & Hailu, Y. G. (2008), *Effects of renewable portfolio standards and other state policies on wind industry development in the US*. Michigan State University, East Lansing, Michgan.

Adkins, R. & Paxson, D. (2011), "Renewing assets with uncertain revenues and operating costs." *Journal of Financial and Quantitative Analysis*, Vol. 46, No.03: pp. 785-813.

Adkins, R. & Paxson, D. (2013), "Deterministic models for premature and postponed replacement." *Omega,* Vol. 41, No.6: pp. 1008-1019.

Adkins, R. and Paxson, D. (2016), Subsidies for Renewable Energy Facilities under Uncertainty. *The Manchester School*, Vol.84: pp. 222–250. doi: 10.1111/manc.12093.

Aguirre, M. & Ibikunle, G. (2014), "Determinants of renewable energy growth: A global sample analysis." Energy Policy, Vol. 69, pp.374-384.

Alagappan, L., Orans, R. & Woo, C. K. (2011), "What drives renewable energy development?" *Energy Policy*, Vol. 39, No.9: pp. 5099-5104.

Amram, M. & Kulatilaka, N. (1999), *Real Options, Managing Investments in an Uncertain World*. Harvard Business School Press, Boston, MA.

Armada, M. J. R., Pereira, P. J. & Rodrigues, A. (2013), "Optimal investment with two-factor uncertainty." *Mathematics and Financial Economics*, Vol. 7, No.4: pp. 509-530.

Awerbuch, S. (2003), "Determining the real cost-why renewable power is more cost-competitive than previously believed." *Renewable Energy World*, Vol. 6, No.2: pp. 52-61.

Azevedo, A. & Paxson, D. (2014), "Developing real option game models." *European Journal of Operational Research*, Vol. 237, No.3: pp. 909-920.

Baltagi, B. (2008), *Econometric analysis of panel data*, John Wiley & Sons, New York.

Bayer, P., Dolan, L. & Urpelainen, J. (2013), "Global patterns of renewable energy innovation, 1990–2009." *Energy for Sustainable Development*, Vol. 17, No.3: pp. 288-295.

Beck, N. & Katz, J. N. (1995), "What to do (and not to do) with time-series cross-section data." *American Political Science Review*, Vol. 89, No.03: pp. 634-647.

Bergek, A., Mignon, I. & Sundberg, G. (2013), "Who invests in renewable electricity production? Empirical evidence and suggestions for further research." *Energy Policy*, Vol. 56, pp.568-581.

Berry, T. & Jaccard, M. (2001), "The renewable portfolio standard:: design considerations and an implementation survey." *Energy Policy*, Vol. 29, No.4: pp. 263-277.

Bird, L., Bolinger, M., Gagliano, T., Wiser, R., Brown, M. & Parsons, B. (2005), "Policies and market factors driving wind power development in the United States." *Energy Policy*, Vol. 33, No.11: pp. 1397-1407.

Black, F. & Scholes, M. (1973), "The pricing of options and corporate liabilities." *The Journal of Political Economy*, Vol.81, No.3: pp.637-654.

Bolinger, M& Wiser, R. (2001), "Clean energy funds: an overview of state support for renewable energy." *Lawrence Berkeley National Laboratory,* Vol.47705, pp.1-121.

Bolkesjø, T. F., Eltvig, P. T. & Nygaard, E. (2014), "An econometric analysis of support scheme effects on renewable energy investments in Europe." *Energy Procedia*, Vol. 58, pp.2-8.

Boomsma, T. K., Meade, N. & Fleten, S.-E. (2012), "Renewable energy investments under different support schemes: A real options approach." *European Journal of Operational Research*, Vol. 220, No.1: pp. 225-237.

Bozkurt, C. & Akan, Y. (2014), "Economic growth, CO2 emissions and energy consumption: the Turkish case." *International Journal of Energy Economics and Policy*, Vol. 4, No.3: pp. 484.

Brennan, M. J. & Schwartz, E. S. (1985), "Evaluating natural resource investments." *Journal of Business*, Vol 58, No.2: pp.135-157.

Brennan, M. J., Trigeorgis, L. & Bjerksund, P. (2000), *Project flexibility, agency, and competition: New developments in the theory and application of real options*, Oxford University Press, New York.

Breusch, T. S. & Pagan, A. R. (1979), "A simple test for heteroscedasticity and random coefficient variation." *Econometrica: Journal of the Econometric Society*, Vol.47, No.5: pp.1287-1294.

Breusch, T. S. & Pagan, A. R. (1980), "The Lagrange multiplier test and its applications to model specification in econometrics." *The Review of Economic Studies*, Vol. 47, No.1: pp. 239-253.

Brooks, C. (2014), *Introductory econometrics for finance*, Cambridge university press, Cambridge, UK.

Brown, M. A. (2001), "Market failures and barriers as a basis for clean energy policies." *Energy policy*, Vol. 29, No.14: pp. 1197-1207.

Butler, L. & Neuhoff, K. (2008), "Comparison of feed-in tariff, quota and auction mechanisms to support wind power development." *Renewable Energy*, Vol. 33, No.8: pp. 1854-1867.

Cárdenas Rodríguez,M., et al. (2014), Inducing Private Finance for Renewable Energy Projects: Evidence from Micro-Data, *OECD Environment Working Papers*, No. 67, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/5jxvg0k6thr1-en.

Carley, S. (2009), "State renewable energy electricity policies: An empirical evaluation of effectiveness." *Energy Policy*, Vol. 37, No.8: pp. 3071-3081.

Carley, S. (2011), "The era of state energy policy innovation: A review of policy instruments." *Review of Policy Research*, Vol. 28, No.3: pp. 265-294.

Carr, P. (1988), "The valuation of sequential exchange opportunities." *The Journal of Finance*, Vol. 43, No.5: pp. 1235-1256.

Centrica. Lynn and Inner Dowsing wind farms – project background. URL: ⟨http://www.centrica.com/files/pdf/centrica_energy/lynn_and_inner_dowsing_background.pdf⟩.

Chevalier-Roignant, B., Flath, C. M., Huchzermeier, A. & Trigeorgis, L. (2011), "Strategic investment under uncertainty: A synthesis." *European Journal of Operational Research*, Vol. 215, No.3: pp. 639-650.

Chien, T. & Hu, J. L. (2008), "Renewable energy: An efficient mechanism to improve GDP." *Energy Policy*, Vol. 36, No.8: pp. 3035-3042.

Copeland, T. E., Antikarov, V. & Copeland, T. E. (2001), *Real options: a practitioner's guide,* Texere, New York.

Cortazar, G., Schwartz, E. S. & Salinas, M. (1998), "Evaluating environmental investments: A real options approach." *Management Science*, Vol. 44, No.8: pp. 1059-1070.

Crawford, R. (2009), "Life cycle energy and greenhouse emissions analysis of wind turbines and the effect of size on energy yield." *Renewable and Sustainable Energy Reviews*, Vol. 13, No.9: pp. 2653-2660.

DataStream International. (2015). Available: DataStream International.

DECC (2015): Negative pricing in the GB wholesale electricity market available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/441809/Baringa_DECC_CfD_Negative_Pricing_Report.pdf.

del Río González, P. (2008), "Ten years of renewable electricity policies in Spain: An analysis of successive feed-in tariff reforms." *Energy Policy*, Vol. 36, No.8: pp. 2907-2919.

del Río, P. & Bleda, M. (2012), "Comparing the innovation effects of support schemes for renewable electricity technologies: A function of innovation approach." *Energy Policy*, Vol. 50, No.272-282.

del Río, P. & Gual, M. a. (2007), "An integrated assessment of the feed-in tariff system in Spain." *Energy Policy*, Vol. 35, No.2: pp. 994-1012.

Delmas, M. a. & Montes-Sancho, M. J. (2011), "U.S. state policies for renewable energy: Context and effectiveness." *Energy Policy*, Vol. 39, No.5: pp. 2273-2288.

Dinica, V. (2006), "Support systems for the diffusion of renewable energy technologies - An investor perspective." *Energy Policy*, Vol. 34, No.4: pp. 461-480.

Dixit, A. K. & Pindyck, R. S. (1994), *Investment under uncertainty,* Princeton University Press, Princeton, New Jersey.

Dockendorf, J. and Paxson, D. (2010). 'Continuous Rainbow Options in Co-integrated Markets', Presented at Real Options Conference, Rome.

Dombrovski, R. (2015), "Effectiveness of Financial and Fiscal Instruments for Promoting Sustainable Renewable Energy Technologies." *Economic and Business Review,* Vol. 17, No.3: pp. 313-346.

Dong, C. G. (2012), "Feed-in tariff vs. renewable portfolio standard: An empirical test of their relative effectiveness in promoting wind capacity development." *Energy Policy*, Vol. 42, pp.476-485.

Drukker, D. M. (2003), "Testing for serial correlation in linear panel-data models." *Stata Journal*, Vol. 3, No.2: pp. 168-177.

Eerens, H., & De Visser, E. (2008). Wind Energy Potential in Europe 2020-2030, ETC/ACC Technical Paper 2008/6. Bilthoven: EEA.

Elton, E. J. & Gruber, M. J. (1976), "On the optimality of an equal life policy for equipment subject to technological improvement." *Operational Research Quarterly*, Vol.27, No.1: pp.93-99.

Espey, S. (2001), "Renewables portfolio standard: a means for trade with electricity from renewable energy sources?" *Energy Policy*, Vol. 29, No.7: pp. 557-566.

European Environment Agency, (2015), Overview of electricity production and use in Europe, Indicator Assessment Report, Copenhagen, Available at http://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-1/assessment.

European Parliament. (2001), Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market, *Official Journal of the European Communities* Vol.283(1): pp.30-33.

European Parliament. (2009), *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*, Official Journal of the European Union, Vol. 140, No.16: pp. 16-62.

European Union (n.d) Climate action, available online http://europa.eu/pol/clim/index_en.htm

European Wind Energy Association, (2009a), *Wind energy, the facts*, a report by the European Wind Energy Association, available at http://www.ewea.org/fileadmin/files/library/publications/reports/WETFExecutiveSummary.pdf

European Wind Energy Association, (2009b*), The economics of Wind Energy,* by the European Wind Energy Report, available at: http://www.ewea.org/fileadmin/files/library/publications/reports/Economics_of_Wind_Energy.pdf. (Accessed 29/02/2013).

European Wind Energy Association. (2012), "*The European offshore wind industry key 2011 trends and statistics*." European Wind Energy Report.

European Wind Energy Association. (2013), *Building a stable future* The European Wind Energy Association, Annual report, available at http://www.ewea.org/fileadmin/files/library/publications/reports/EWEA_Annual_Report_2013.pdf. (Accessed 26/05/2014).

European Wind Energy, Association, (2014), "*Strategic Research Agenda / Market Deployment Strategy*." .March: pp. 81-81.

Eurostat - Statistical Office of the European, Council, (2010), *Energy - early statistics 2008*. Eurostat Statistical Books on Environment and Energy, pp.473-473.

Eurostat-Statistical Office of the European, Council, (2015), *Statistics Database*, European Commission, Luxembourg.

Felder, F. A. (2011), "Examining electricity price suppression due to renewable resources and other grid investments." *The Electricity Journal*, Vol. 24, No.4: pp. 34-46.

Fiorio, C. V., Florio, M. & Doronzo, R. (2007), *The electricity industry reform paradigm in the European Union: testing the impact on consumers*, Consumers and Utility Reforms in the European Union Conference, Project no. CIT5-CT-2005-028647.

Gan, L., Eskeland, G. S. & Kolshus, H. H. (2007), "Green electricity market development: Lessons from Europe and the US." *Energy Policy*, Vol. 35, No.1: pp. 144-155.

Gan, J. & Smith, C. (2011), "Drivers for renewable energy: A comparison among OECD countries." *Biomass and Bioenergy*, Vol. 35, No.11: pp. 4497-4503.

Geske, R. (1979), "The valuation of compound options." *Journal of Financial Economics*, Vol. 7, No.1: pp. 63-81.

Gillingham, K. & Sweeney, J. (2010), "Market failure and the structure of externalities." In Moselle, M., Padilla, J., and Schalensee, R. (ed) *Harnessing Renewable Energy in Electric Power Systems*: Washington DC, London: Resources For the Future Press, pp.69-92.

Girish, G. (2013), "Spot Electricity Price Modelling and Forecasting." *International Journal of Research in Commerce, IT and Management*, Vol.3, No.2: pp. 154.

Girish, G. & Vijayalakshmi, S. (2013), "Determinants of electricity price in competitive power market." *International Journal of Business and Management*, Vol. 8, No.21: pp. 70.

Graham, P., Vincent, D., Coombes, P. & Duffy, G. (2003), "*Real Options Analysis: A Case Study,*" CSIRO Energy Technology Report for Cooperative Research Centre Coal in Sustainable Development, pp. 1--49.

Green, R. & Vasilakos, N. (2011), "The economics of offshore wind." *Energy Policy,* Vol. 39, No.2: pp. 496-502.

Grenadier, S. R. (1996), "The strategic exercise of options: Development cascades and overbuilding in real estate markets." *The Journal of Finance*, Vol. 51, No.5: pp. 1653-1679.

Grenadier, S. R. (2000), *Game choices: The intersection of real options and game theory*, Risk Books, London, UK.

Groba, F., Indvik, J. & Jenner, S. (2011). Assessing the strength and effectiveness of renewable electricity feed–in tariffs in European Union countries. DIW Berlin Discussion Paper No. 1176, Berlin, Germany.

Haas, R., Panzer, C., Resch, G., Ragwitz, M., Reece, G. & Held, A. (2011), "A historical review of promotion strategies for electricity from renewable energy sources in EU countries." *Renewable and Sustainable Energy Reviews*, Vol. 15, No.2: pp. 1003-1034.

Harmelink, M., Voogt, M. & Cremer, C. (2006), "Analysing the effectiveness of renewable energy supporting policies in the European Union." *Energy Policy*, Vol. 34, No.3: pp. 343-351.

Hausman, J. A. (1978), "Specification tests in econometrics." *Econometrica: Journal of the Econometric Society*, Vol.46, No.6: pp.1251-1271.

Held, A., Ragwitz, M. & Haas, R. (2006), "On the success of policy strategies for the promotion of electricity from renewable energy sources in the EU." *Energy & Environment*, Vol. 17, No.6: pp. 849-868.

Hoechle, D. (2007), "Robust standard errors for panel regressions with cross-sectional dependence." *Stata Journal,* Vol. 7, No.3: p. 281.

Renewable UK (2014), Available online; http://www.renewableuk.com/en/news/renewableuk-news.cfm/electricity-needs-of-more-than-a-quarter-of-uk-homes-powered-by-wind-in-2014

Huang, M. Y., Alavalapati, J. R. R., Carter, D. R. & Langholtz, M. H. (2007), "Is the choice of renewable portfolio standards random?" *Energy Policy*, Vol. 35, No.11: pp. 5571-5575.

Huber, C., Faber, T., Haas, R., Resch, G., Green, J., Ölz, S., White, S., Cleijne, H., Ruijgrok, W. & Morthorst, P. E. (2005), *Green-X. Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market.* Final report of the project Green-X-a research project within the fifth framework programme of the European Commission, supported by DG Research, Contract No.ENG2-CT-2002-00607, pp.1-186.

Huisman, K. (2001), *Technology Investment: A Game Theoretic Real Options Approach.* Kluwer Academic Publishers, Dordrecht, Netherlands.

IEA/OECD (2014), *Energy Prices and Statistics*, International Energy Agency (IEA), Paris.

IEA. (2010), *Projected Cost of Generating Electricity.* Paris: IEA.

IEA (2013), World Energy Outlook 2013. International Energy Agency (IEA), Paris.

IEA/IRENA 2014, Global Renewable Energy Policies and Measures Database, International Energy Agency (IEA) and International Renewable Energy Agency (IRENA), Paris.

IPCC (2007), Climate Change: Synthesis Report, Intergovernmental Panel on Climate Change, Geneva.

IPCC (2011), IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, Working Group III of the Intergovernmental Panel on Climate Change, Cambridge and New York.

Jamasb, T. & Pollitt, M. (2005), "Electricity market reform in the European Union: review of progress toward liberalization & integration." *The Energy Journal*, pp.11-41.

Jamasb, T. & Pollitt, M. (2008), "Liberalisation and R&D in network industries: The case of the electricity industry." *Research Policy*, Vol. 37, No.6: pp. 995-1008.

Jarque, C. M. & Bera, A. K. (1980), "Efficient tests for normality, homoscedasticity and serial independence of regression residuals." *Economics letters*, Vol. 6, No.3: pp. 255-259.

Jenner, S., Groba, F. & Indvik, J. (2013), "Assessing the strength and effectiveness of renewable electricity feed-in tariffs in European Union countries." *Energy Policy*, Vol. 52, pp.385-401.

Kaldellis, J. K. & Zafirakis, D. (2011), "The wind energy (r) evolution: A short review of a long history." *Renewable Energy*, Vol. 36, No.7: pp. 1887-1901.

Karakatsani, N. V. & Bunn, D. W. (2008a), "Forecasting electricity prices: The impact of fundamentals and time-varying coefficients." *International Journal of Forecasting*, Vol. 24, No.4: pp. 764-785.

Karakatsani, N. V. & Bunn, D. W. (2008b), "Intra-day and regime-switching dynamics in electricity price formation." *Energy Economics*, Vol. 30, No.4: pp. 1776-1797.

Kennedy, P. (2008), *A Guide to Modern Econometrics*, Blackwell Publishing, Oxford.

Kydes, A. S. (2007), "Impacts of a renewable portfolio generation standard on US energy markets." *Energy Policy*, Vol. 35, No.2: pp. 809-814.

Lambrecht, B., Perraudin, W. & Satchell, S. (1997), "Time to default in the UK mortgage market." *Economic Modelling*, Vol. 14, No.4: pp. 485-499.

Langniss, O. & Wiser, R. (2003), "The renewables portfolio standard in Texas: An early assessment." *Energy Policy*, Vol. 31, No.6: pp. 527-535.

Lauber, V. (2005), Renewable energy at the level of the European Union, in: Reiche. D. (Ed.), *Handbook of Renewable Energies in the European Union*. Peter Lang, Frankfurt A. M., Vol. 2, pp. 39-53.

Lemming, J. (2003), "Financial risks for green electricity investors and producers in a tradable green certificate market." *Energy Policy*, Vol. 31, No.1: pp. 21-32.

Lesser, J. A. & Su, X. (2008), "Design of an economically efficient feed-in tariff structure for renewable energy development." *Energy Policy*, Vol. 36, No.3: pp. 981-990.

Lipp, J. (2007), "Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom." *Energy Policy*, Vol. 35, No.11: pp. 5481-5495.

Liu, H. & Shi, J. (2013), "Applying ARMA–GARCH approaches to forecasting short-term electricity prices." *Energy Economics*, Vol. 37, No.152-166.

Lyon, T. P. & Yin, H. (2010), "Why Do States Adopt Renewable Portfolio Standards?: An Empirical Investigation." *The Energy Journal*, Vol. 31, No.3: pp. 1-40.

Maddala, G. S. & Lahiri, K. (2009), *Introduction to econometrics,* Wiley, New York.

Majd, S. & Pindyck, R. S. (1987), "Time to build, option value, and investment decisions." *Journal of Financial Economics*, Vol. 18, No.1: pp. 7-27.

Margrabe, W. (1978), "The value of an option to exchange one asset for another." *The Journal of Finance*, Vol. 33, No.1: pp. 177-186.

Marques, A. C. & Fuinhas, J. A. (2011a), "Do energy efficiency measures promote the use of renewable sources?" *Environmental Science and Policy*, Vol. 14, No.4: pp. 471-481.

Marques, A. C. & Fuinhas, J. A. (2011b), "Drivers promoting renewable energy: A dynamic panel approach." *Renewable and Sustainable Energy Reviews*, Vol. 15, No.3: pp. 1601-1608.

Marques, A. C., Fuinhas, J. A. & Manso, J. P. (2011), "A Quantile Approach to Identify Factors Promoting Renewable Energy in European Countries." *Environmental and Resource Economics*, Vol. 49, No.3: pp. 351-366.

Marques, A. C., Fuinhas, J. A. & Pires Manso, J. R. (2010), "Motivations driving renewable energy in European countries: A panel data approach." *Energy Policy*, Vol. 38, No.11: pp. 6877-6885.

Masini, A. & Menichetti, E. (2012), "The impact of behavioural factors in the renewable energy investment decision making process: Conceptual framework and empirical findings." *Energy Policy*, Vol. 40, pp.28-38.

Mason, R. & Weeds, H. (2010), "Investment, uncertainty and pre-emption." *International Journal of Industrial Organization*, Vol. 28, No.3: pp. 278-287.

McDonald, R. & Siegel, D. (1986), "The Value of waiting to invest." *The Quarterly Journal of Economics*, Vol. 101, No.4: pp. 707-728.

McDonald, R. L. & Siegel, D. R. (1985), "Investment and the valuation of firms when there is an option to shut down." *International Economic Review*, Vol.26, No.2: 331-349.

Menanteau, P., Finon, D. & Lamy, M. L. (2003), "Prices versus quantities: Choosing policies for promoting the development of renewable energy." *Energy Policy*, Vol. 31, No.8: pp. 799-812.

Menz, F. C. & Vachon, S. (2006), "The effectiveness of different policy regimes for promoting wind power: Experiences from the states." *Energy Policy*, Vol. 34, No.14: pp. 1786-1796.

Merton, R. C. (1973), "Theory of rational option pricing." *The Bell Journal of Economics and Management Science*, Vol.4, No.1: pp.141-183.

Meyer, N. I. (2003), "European schemes for promoting renewables in liberalised markets." *Energy Policy*, Vol. 31, No.7: pp. 665-676.

Meyer, N. I. (2007), "Learning from wind energy policy in the EU: Lessons from Denmark, Sweden, and Spain." *European Environment*, Vol. 17, No.5: pp. 347-362.

Nagl, S. (2013), The effect of weather uncertainty on the financial risk of green electricity producers under various renewable policies. EWI Working Paper, No 13/15.

Nemet, G. F. (2006), "Beyond the learning curve: factors influencing cost reductions in photovoltaics." *Energy Policy*, Vol. 34, No.17: pp. 3218-3232.

Newbery, D. M. (2002), "Problems of liberalising the electricity industry." European Economic Review, Vol. 46, No.4: pp. 919-927.

Hanley, N. & Owen, A. D. (2004) *The economics of climate change*. Routledge New York, NY, USA.

Paddock, J. L., Siegel, D. R. & Smith, J. L. (1988), "Option valuation of claims on real assets: The case of offshore petroleum leases." *The Quarterly Journal of Economics*, Vol.103, No.3; pp. 479-508.

Painuly, J. P. (2001), "Barriers to renewable energy penetration; a framework for analysis." *Renewable Energy*, Vol. 24, No.1: pp. 73-89.

Palmer, K. & Burtraw, D. (2005), "Cost-effectiveness of renewable electricity policies." *Energy Economics*, Vol. 27, No.6: pp. 873-894.

Parks, R. W. (1967), "Efficient estimation of a system of regression equations when disturbances are both serially and contemporaneously correlated." *Journal of the American Statistical Association*, Vol. 62, No.318: pp. 500-509.

Pawlina, G. & Kort, P. M. (2006), "Real options in an asymmetric duopoly: who benefits from your competitive disadvantage?" *Journal of Economics & Management Strategy*, Vol. 15, No.1: pp. 1-35.

Paxson, D. & Pinto, H. (2005), "Rivalry under price and quantity uncertainty." *Review of Financial Economics*, Vol. 14, No.3-4: pp. 209-224.

Paxson, D. A. (2015), "Real options." *Wiley Encyclopedia of Management*, Vol.4, pp.1-3.

Petersik, T., 2004. *State renewable energy requirements and goals: status through 2003* /http://www.eia.doe.gov/oiaf/analysispaper/rps/index. Html.

Pindyck, R. S. (1993), "Investments of uncertain cost." *Journal of Financial Economics*, Vol. 34, No.1: pp. 53-76.

Pindyck, R. S. (1999), "The long-run evolution of energy prices." *The Energy Journal*, Vol.20, No.2: pp.1-27.

Polzin, F., Migendt, M., Täube, F. A. & von Flotow, P. (2015), "Public policy influence on renewable energy investments—A panel data study across OECD countries." *Energy Policy*, Vol. 80, pp.98-111.

Popp, D., Hascic, I. & Medhi, N. (2011), "Technology and the diffusion of renewable energy." *Energy Economics*, Vol. 33, No.4: pp. 648-662.

Rabe, B. (2006), "Race to the top: The expanding role of US state renewable portfolio standards." *Sustainable Development Law & Policy,* Vol. 7, pp.10.

Ragwitz, M., Schade, W., Breitschopf, B., Walz, R., Helfrich, N., Rathmann, M., Resch, G., Panzer, C., Faber, T. & Haas, R. (2009), *The impact of renewable energy policy on economic growth and employment in the European Union*. A report research project conducted on behalf of the European Commission, DG Energy and Transport, European Commission, Karlsruhe and Brussels, Brussels, Belgium, TREN/D1/474/2006.

Ragwitz, M., Winkler, J., Klessmann, C., Gephart, M. & Resch, G. (2012), *Recent developments of feed-in systems in the EU – A research paper for the International Feed-In Cooperation*. A report commissioned by the Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Germany, pp.1-16.

Reedman, L., Graham, P. & Coombes, P. (2006), "Using a real-options approach to model technology adoption under carbon price uncertainty: An application to the Australian electricity generation sector." *Economic Record*, Vol. 82, No.SPEC. ISS. 1: pp. 1-17.

Reiche, D. & Bechberger, M. (2004), "Policy differences in the promotion of renewable energies in the EU member states." *Energy policy*, Vol. 32, No.7: pp. 843-849.

Reuter, W. H., Szolgayová, J., Fuss, S. & Obersteiner, M. (2012), "Renewable energy investment: Policy and market impacts." *Applied Energy*, Vol. 97, pp.249-254.

Ringel, M. (2006), "Fostering the use of renewable energies in the European Union: The race between feed-in tariffs and green certificates." *Renewable Energy*, Vol. 31, No.1: pp. 1-17.

Romano, A. A. & Scandurra, G. (2011), "The investments in renewable energy sources: do low carbon economies better invest in green technologies?" *International Journal of Energy Economics and Policy*, Vol. 1, No.4: pp. 107-115.

Sadorsky, P. (2009), "Renewable energy consumption, CO 2 emissions and oil prices in the G7 countries." *Energy Economics*, Vol. 31, No.3: pp. 456-462.

Schaeffer, G., Boots, M., Martens, J. & Voogt, M. (1999*), Tradable green certificates: a new market-based incentive scheme for renewable energy: Introduction and analysis*. ECN-I-99-004 (March 1999), ECN, Petten.

Schilling, M. A. & Esmundo, M. (2009), "Technology S-curves in renewable energy alternatives: Analysis and implications for industry and government." *Energy Policy*, Vol. 37, No.5: pp. 1767-1781.

Schwartz, E. & Smith, J. E. (2000), "Short-term variations and long-term dynamics in commodity prices." *Management Science*, Vol. 46, No.7: pp. 893-911.

Sensfuss, F., Ragwitz, M. & Genoese, M. (2008), "The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany." *Energy Policy*, Vol. 36, No.8: pp. 3086-3094.

Shrimali, G. & Kniefel, J. (2011), "Are government policies effective in promoting deployment of renewable electricity resources?" *Energy Policy*, Vol. 39, No.9: pp. 4726-4741.

Smets, F. (1993), Essays on Foreign Direct Investment, Ph. D. Dissertation, Yale University.

Stern, N. (2007), *The economics of climate change: the Stern review*. Cambridge University Press.

Torró, H. (2009), "Electricity futures prices: some evidence on forecast power at Nord Pool." *Journal of Energy Markets*, Vol. 2, No.3: pp. 2-26.

Trigeorgis, L. (1993), "Real options and interactions with financial flexibility." *Financial Management*, Vol.22, No.3: pp.202-224.

Trigeorgis, L. (1996), *Real options: Managerial flexibility and strategy in resource allocation*, MIT press, Massachusetts, USA.

UNFCCC 2007, Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007, Geneva.

United Nations Statistics Division (2014), Demographic year book, Annex 1, No. 634: UN Data - United Nations Organization, New York City.

United Nations statistics Division (2014), UN Data - Energy Statistics Database, United Nations Organization, New York City.

Valentine, S. V. (2011), "Emerging symbiosis: Renewable energy and energy security." *Renewable and Sustainable Energy Reviews*, Vol. 15, No.9: pp. 4572-4578.

Van der Linden, N. H., Uyterlinde, M., Vrolijk, C., Ericsson, K., Khan, J., Nilsson, L., Astrand, K. & Wiser, R. (2005), *Review of international experience with renewable energy obligation support mechanisms*. Energy research Centre of the Netherlands, (ECN-C--05-025), Netherlands.

Van Ruijven, B. & van Vuuren, D. P. (2009), "Oil and natural gas prices and greenhouse gas emission mitigation." *Energy Policy*, Vol. 37, No.11: pp. 4797-4808.

Weitzman, M. L. (1974), "Prices vs. quantities." *The Review of Economic Studies*, Vol. 41, No.4: pp. 477-491.

Winkel, T., Rathmann, M., Ragwitz, M., Steinhilber, S., Winkler, J., Isi, F., Resch, G., Panzer, C., Busch, S., Alberici, S., Gephart, M., Geurts, F., Klessmann, C., Noothout, P., Keeffe, S. O. & Papaefthymiou, G. (2011), *Renewable Energy Policy Country Profiles.: Intelligent Energy Europe Project*, available online: http://www.reshaping-res-policy.eu/downloads/RE-Shaping_CP_final_18JAN2012.pdf (Accessed 15/02/2012).

Wiser, R., Namovicz, C., Gielecki, M. & Smith, R. (2007), "The Experience with Renewable Portfolio Standards in the United States." *Electricity Journal*, Vol. 20, No.4: pp. 8-20.

Wooldridge, J. M. (2002), *Econometric analysis of cross section and panel data*, MIT Press, Cambridge, MA.

Wooldridge, J. M. (2010), *Econometric analysis of cross section and panel data*, MIT Press, Cambridge, MA and London.

Wüstenhagen, R. & Menichetti, E. (2012), "Strategic choices for renewable energy investment: Conceptual framework and opportunities for further research." *Energy Policy*, Vol. 40, pp.1-10.

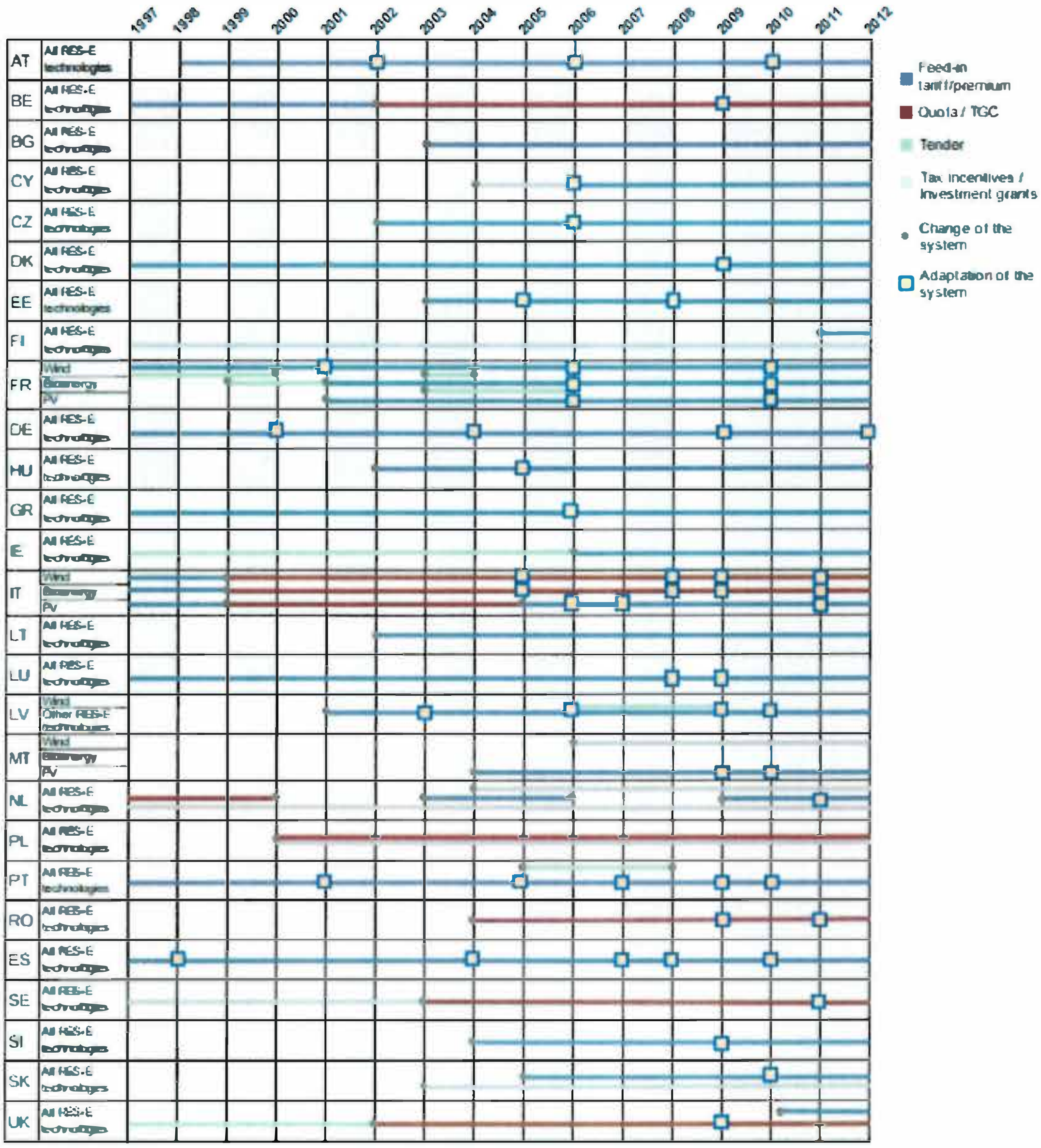
Yin, H. & Powers, N. (2010), "Do state renewable portfolio standards promote in-state renewable generation?." *Energy Policy*, Vol. 38, No.2: pp. 1140-1149.

Zweibel, K. (2010), "Should solar photovoltaics be deployed sooner because of long operating life at low, predictable cost?" *Energy Policy*, Vol. 38, No.11: pp. 7519-7530.

Appendices

Appendix Chapter 3 (AC3)

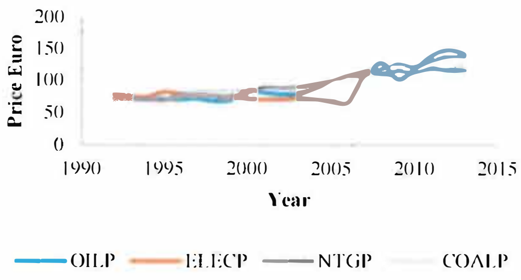
AC3 Figure 1: Evolution of RES-E Support Schemes



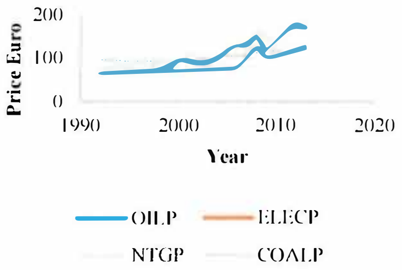
Source: Adopted from (Winkel et al., 2011)

AC3 Figure 2: The Price Movement of Coal, Natural gas, Oil and Electricity among Countries in the EU

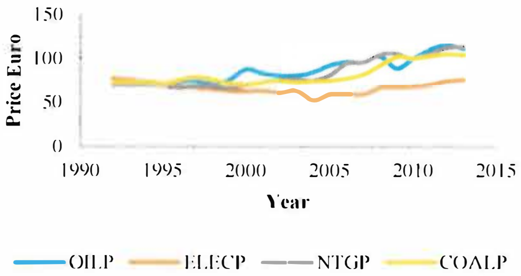
Austria



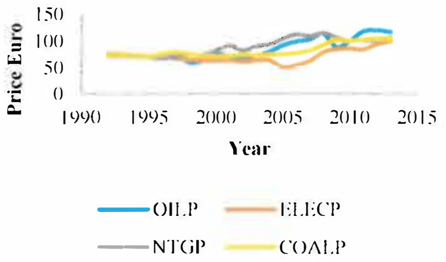
Belgium



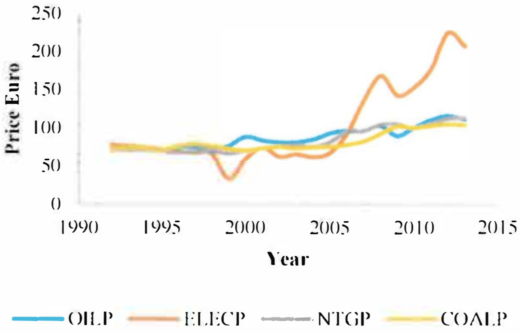
Bulgaria



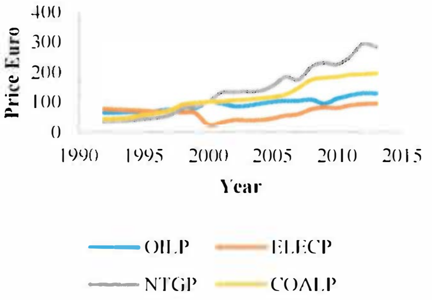
Croatia



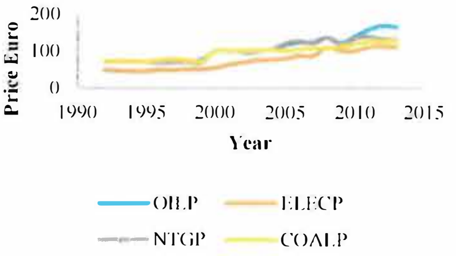
Cyprus



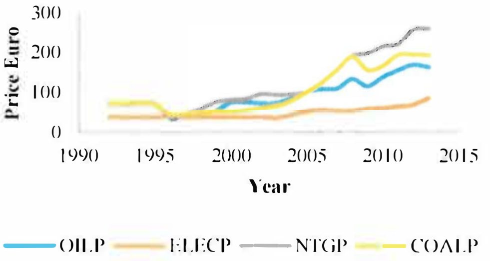
Czech Republic

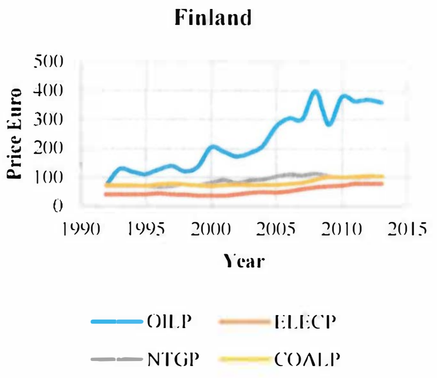


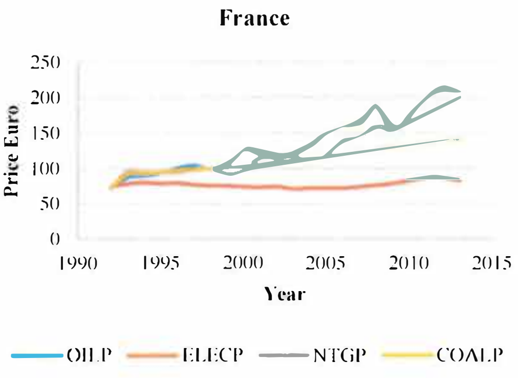
Denmark

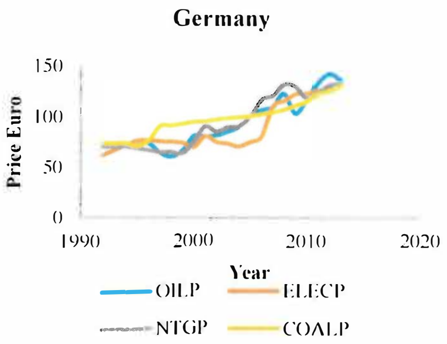


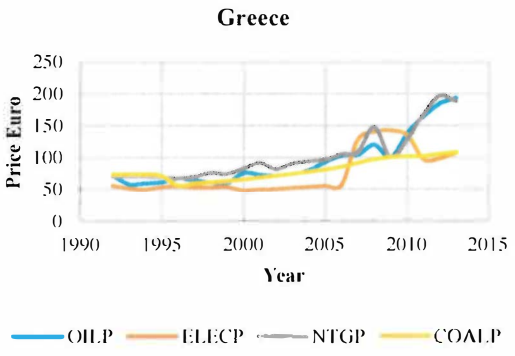
Estonia

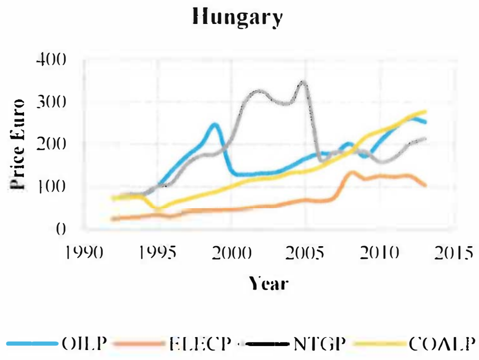


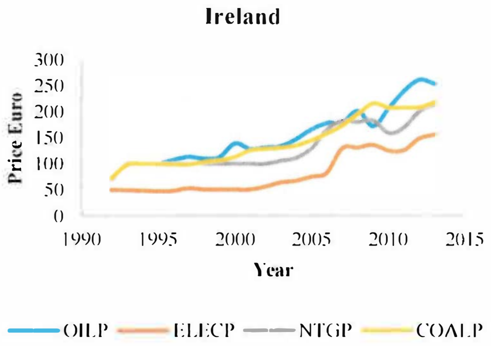

Finland
Price Euro
500
400
300
200
100
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

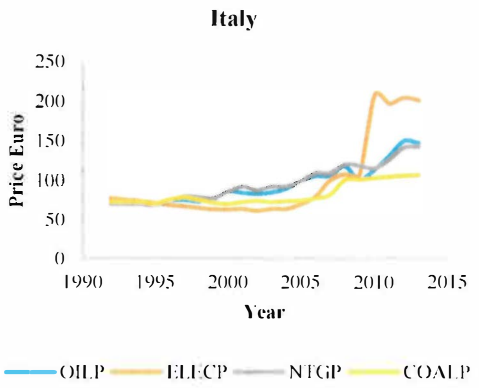

France
Price Euro
250
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

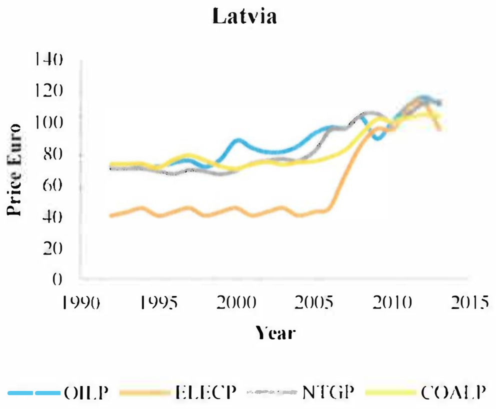

Germany
Price Euro
150
100
50
0
1990
2000
2010
2020
Year
OILP
ELECP
NTGP
COALP

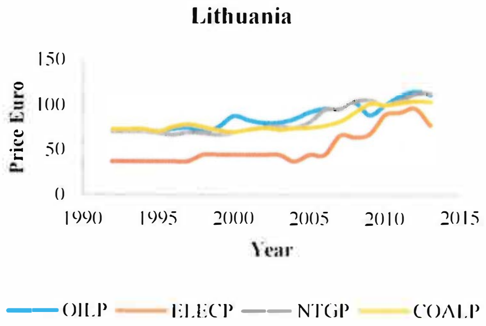

Greece
Price Euro
250
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

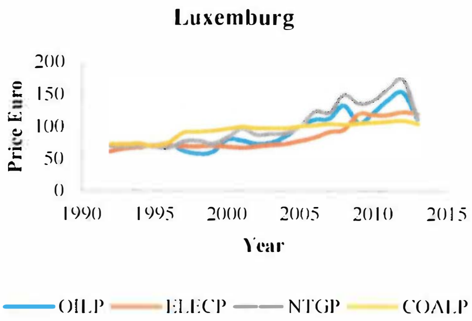

Hungary
Price Euro
400
300
200
100
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

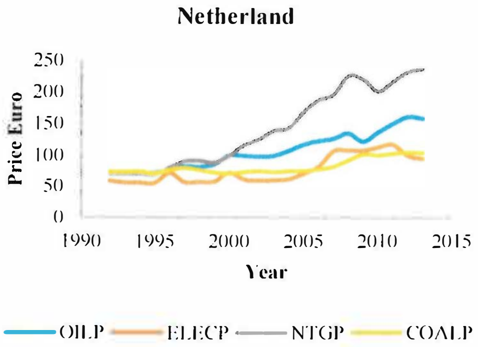

Ireland
Price Euro
300
250
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

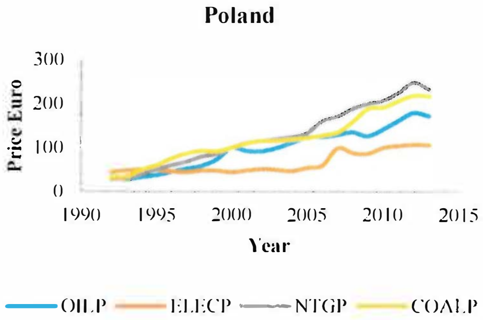

Italy
Price Euro
250
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

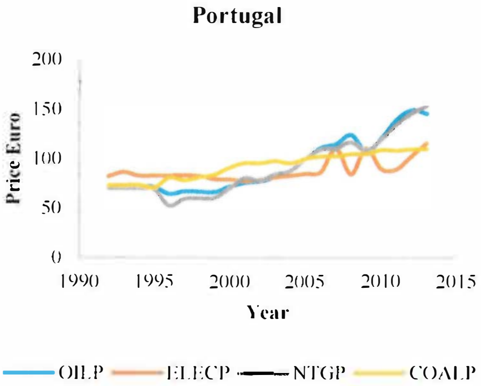

Latvia
Price Euro
140
120
100
80
60
40
20
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

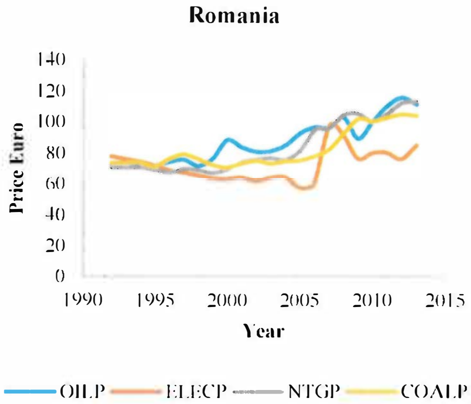

Lithuania
Price Euro
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

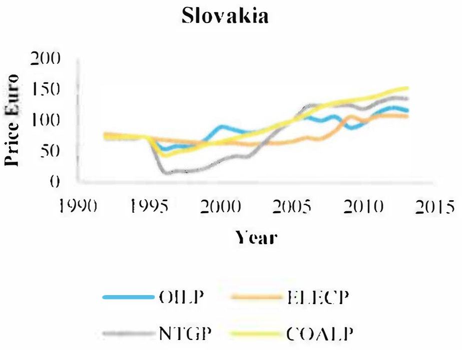

Luxemburg
Price Euro
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

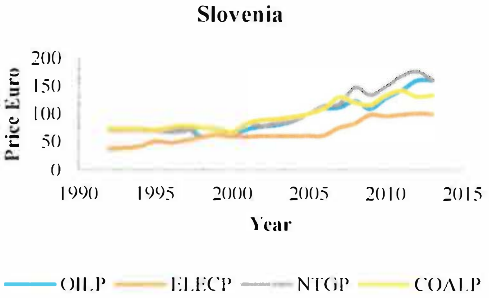

Netherland
Price Euro
250
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

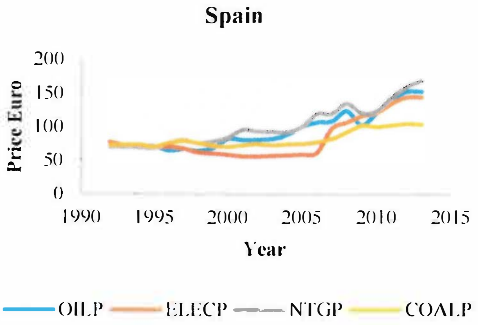

Poland
Price Euro
300
200
100
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

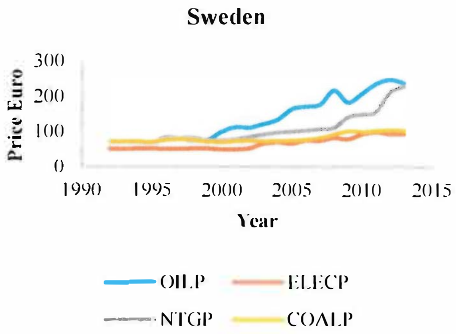

Portugal
Price Euro
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP

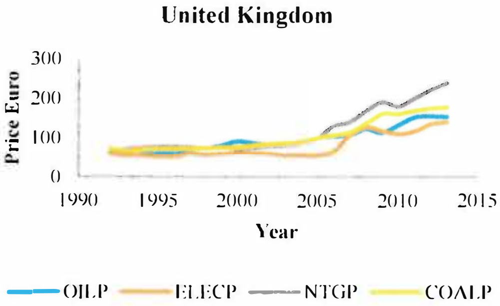

Romania
Price Euro
140
120
100
80
60
40
20
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP


Slovakia
Price Euro
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP


Slovenia
Price Euro
200
150
100
50
0
1990
1995
2000
2005
2010
2015
Year
OILP
ELECP
NTGP
COALP







Note: OILP, ELCP, NTGP and COALP represents oil prices, electricity prices, natural gas prices and coal prices.

Appendix Chapter 4 (AC4)

AC4 Table 1: Fixed Effects and Random Effects Results for the Existence and Experience of Policies on Ln CC and Ln AC without Time Lag

This Table reports the results for the, random effects and fixed effect regression equations (4.1) and (4.2) for the determinants of the wind energy capacity growth due to the existence and experience of RES-E policies. In the second column are the independent variables while the second row are the models used. The dependent variable in all equations is the natural log of cumulative Annual wind Energy Capacity (Ln CC) and natural log of Annual Added Capacity (Ln AC). FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy respectively are dummy variables representing the existence of feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other fiscal benefits, Tender and the first introduction of Cap respectively .FIT_Years, FIP_Years, Quota_Years, Tax_Years, Tender_Years and CAP_Years respectively are policy experience variables representing the number of years feed-in-tariffs, feed-in-premium, Quota and Green Trading Certificate, Taxes and other fiscal benefits, Tender and Cap has been in place. Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Elect. Price, Ln Coal Price, Ln Energy Import, represents the natural logs of Gross domestic product per capita, Electricity consumption per capita, percentage of Electricity production from coal, percentage of Electricity production from Natural gas, percentage of Electricity production from Nuclear, percentage of Electricity production from renewable, Population Growth, Carbon emissions, Wind technical potential, Oil price, Electricity price, Natural gas price, Coal price and Energy import dependence respectively. Constant is the regression intercept while Observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant level, respectively. R-Squared represents the explanatory power of the regression model.

VARIABLES	Existence on Ln CC		Experience on Ln CC		Existence on Ln AC		Experience on Ln AC	
	RE	FE	RE	FE	RE	FE	RE	FE
FIT_Dummy	0.971*	0.725			1.105**	0.815		
	(0.461)	(0.415)			(0.404)	(0.342)		
FIP_Dummy	0.140	-0.166			-0.100	-0.431		
	(0.398)	(0.402)			(0 425)	(0.404)		
Quota_Dummy	1.009**	0.750*			1.354**	1.037*		
	(0.391)	(0.362)			(0.449)	(0.414)		
Tax_Dummy	-0.100	-0.334			-0.148	-0.413		
	(0 335)	(0.294)			(0.269)	(0.249)		
Tender_Dummy	0.198	-0.189			0.301	-0.027		
	(0.422)	(0.332)			(0.355)	(0.235)		
CAP_Dummy	0.566	0.182			0.244	-0.052		
	(0.411)	(0.424)			(0.274)	(0.333)		
FIT&FIP	-0.898	-0.636			-0.797	-0.544		
	(0.536)	(0.459)			(0.469)	(0.421)		
FIT_Years			0.154**	0.147**			0.117**	0.087*
			(0.047)	(0.052)			(0.037)	(0.040)
FIP_Years			-0.087	-0.083			-0.101*	-0.099*
			(0.082)	(0.070)			(0.041)	(0.040)
Quota_Years			0.232***	0.246***			0.274***	0.277***
			(0.051)	(0.049)			(0.049)	(0.050)
Tax_Years			0.038	0.022			0.027	0.008
			(0.043)	(0.034)			(0.036)	(0.026)
Tender_Years			0.023	-0.044			0.030	-0.053
			(0.045)	(0.040)			(0.029)	(0.030)
CAP_Years			0.145*	0.082			0.072*	0.010
			(0.069)	(0.066)			(0.034)	(0.041)
Ln GDP	1.032*	0.056	1.170*	0.264	0.824*	-0.308	0.997**	-0.353
	(0.485)	(0.935)	(0.480)	(0.897)	(0.383)	(0.951)	(0.359)	(0.934)
Ln Elect.Consumption	3.106*	6.787***	3.663*	6.957***	0.954	4 198*	1.187	5.106**
	(1.456)	(1.635)	(1.423)	(1.285)	(1.018)	(1.545)	(1.048)	(1.458)
Ln Coal Share	0.347	0.152	0.400*	0.238	0.406**	0.324*	0.444***	0.362*
	(0.236)	(0.227)	(0.180)	(0.209)	(0.131)	(0.149)	(0.111)	(0.168)
Ln Natural Gas Share	-0.026	-0.170	-0.092	-0.293*	0.058	0.071	0.037	0.005
	(0.112)	(0.146)	(0.096)	(0.133)	(0.091)	(0.134)	(0.089)	(0.129)
Ln Nuclear Share	-0.283*	-0.169	-0.242*	-0.157	-0.071	0.122	-0.081	0.052
	(0.112)	(0.140)	(0.109)	(0.130)	(0.105)	(0.136)	(0.106)	(0.124)
Ln Oil Share	-0.074	0.020	-0.047	0.058	0.088	0.142	0.086	0.134
	(0.148)	(0.153)	(0.123)	(0.125)	(0.131)	(0.146)	(0.126)	(0.142)
Ln Renewable Share	0.396***	0.365***	0.289***	0.265***	0.332***	0.291**	0.250**	0.214**
	(0.077)	(0.079)	(0.064)	(0.071)	(0.086)	(0.081)	(0.078)	(0.075)
Ln Popul.Growth	0.119	0.058	0.104	0.041	0.167	0.093	0.134	0.041
	(0.080)	(0.064)	(0.079)	(0.061)	(0.108)	(0.086)	(0.088)	(0.066)

Ln CO2	-2.445*	-3.048*	-2.434**	-2.345*	-0.863	-1.335	-1.099	-1.080
	(1.007)	(1.265)	(0.909)	(1.001)	(0.780)	(1.102)	(0.761)	(0.934)
Ln Potential	0.718	-41.339	0.585	-46.889	0.741**	-38.649	0.649*	-40.338
	(0.428)	(29.396)	(0.473)	(27.320)	(0.268)	(23.974)	(0.287)	(25.321)
Ln Oil Price	0.812	0.926	0.648	0.752	0.363	0.620	0.244	0.616
	(0.638)	(0.668)	(0.577)	(0.607)	(0.567)	(0.607)	(0.492)	(0.485)
Ln Elect.Price	-0.159	-0.192	-0.721	-0.737	0.009	-0.096	-0.616	-0.755
	(0.414)	(0.412)	(0.509)	(0.413)	(0.381)	(0.379)	(0.523)	(0.465)
Ln Natural Gas Price	0.322	-0.140	-0.102	-0.646	-0.009	-0.564	-0.258	-0.929
	(0.440)	(0.425)	(0.413)	(0.412)	(0.528)	(0.525)	(0.507)	(0.509)
Ln Coal Price	0.859	1.294*	1.549*	1.886**	0.795	1.347	1.329	1.797*
	(0.540)	(0.516)	(0.706)	(0.611)	(0.655)	(0.685)	(0.807)	(0.743)
Ln Energy Import	0.042	0.134	0.154	0.320*	-0.214	-0.187	-0.133	0.018
	(0.172)	(0.137)	(0.161)	(0.155)	(0.136)	(0.127)	(0.148)	(0 192)
Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes
Observations	594	594	594	594	594	594	594	594
R-Squared	0.7853	0.8044	0.8026	0.8233	0.5311	0.5592	0.5432	0.5809
Number of Country	27	27	27	27	27	27	27	27

AC4 Table 2: PCSE Results for the Existence and Experience of Policies on Ln CC and Ln AC with Time Lag

This Table reports the results for PCSE equations (4.3) and (4.4) with one year lag effect for the determinants of the wind energy capacity growth due to the existence and experience of RES-E policies. In the second column are the independent variables while the second row are the models used. The dependent variable in all equations is the natural log of cumulative Annual wind Energy Capacity (Ln CC) and natural log of Annual Added Capacity (Ln AC). FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy respectively are dummy variables representing the existence of feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other fiscal benefits, Tender and the first introduction of Cap respectively with a year lag .FIT_Years, FIP_Years, Quota_Years, Tax_Years, Tender_Years and CAP_Years respectively are policy experience variables representing the number of years feed-in-tariffs, feed-in-premium, Quota and Green Trading Certificate, Taxes and other fiscal benefits, Tender and Cap has been in place with a one year lag. Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Elect. Price, Ln Coal Price, Ln Energy Import, represents the natural logs of Gross domestic product per capita, Electricity consumption per capita, percentage of Electricity production from coal, percentage of Electricity production from Natural gas, percentage of Electricity production from Nuclear, percentage of Electricity production from renewable, Population Growth, Carbon emissions, Wind technical potential, Oil price, Electricity price, Natural gas price, Coal price and Energy import dependence respectively with a one year lag. Constant is the regression intercept while Observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant level, respectively. R-Squared represents the explanatory power of the regression model.

	PCSE Estimates for Existence on Ln CC and Ln AC respectively		PCSE Estimates for Experience on Ln ACC and Ln AC respectively	
VARIABLES	Ln CC	Ln AC	Ln CC	Ln AC
L.FIT_Dummy	1.865*	1.601*		
	(0.174)	(0.180)		
L.FIP_Dummy	1.639***	1.079**		
	(0.303)	(0.370)		
L.Quota_Dummy	1.689**	1.856**		
	(0.186)	(0.228)		
L.Tax_Dummy	0.559***	0.324		
	(0.163)	(0.193)		
L.Tender_Dummy	0.546**	0.533		
	(0.194)	(0.274)		
L.CAP_Dummy	0.505*	0.136		
	(0.248)	(0.342)		
L.FIT&FIP	2.536*	1.964		
	(0.371)	(0.408)		
L.FIT_Years			0.227***	0.170***
			(0.026)	(0.027)
L.FIP_Years			-0.030	-0.044
			(0.030)	(0.040)
L.Quota_Years			0.294***	0.324***
			(0.036)	(0.035)
L.Tax_Years			0.110***	0.073**
			(0.021)	(0.025)
L.Tender_Years			0.079***	0.069
			(0.023)	(0.040)
L.CAP_Years			0.265***	0.151
			(0.079)	(0.091)
L.LnGDP	2.090***	1.457***	2.288***	1.705***
	(0.140)	(0.177)	(0.178)	(0.194)
L.lnElecConsumption	-1.000***	-0.873**	-0.667*	-0.696*
	(0.290)	(0.294)	(0.289)	(0.310)
L.LnCoalShare	0.428***	0.389***	0.517***	0.473***
	(0.048)	(0.059)	(0.059)	(0.062)
L.LnNaturalGasShare	-0.094***	-0.027	-0.134***	-0.058**

	(0.017)	(0.016)	(0.019)	(0.019)
L.LnNuclearShare	-0.016	0.090*	-0.027	0.087*
	(0.035)	(0.043)	(0.033)	(0.041)
L.LnOilShare	-0.182***	0.015	-0.139**	0.029
	(0.048)	(0.067)	(0.051)	(0.062)
L.LnRenewableShare	0.532***	0.376***	0.439***	0.303***
	(0.057)	(0.055)	(0.065)	(0.060)
L.LnPopulGrowth	0.358***	0.363***	0.343***	0.352***
	(0.072)	(0.070)	(0.068)	(0.069)
L.LnCO2	-1.296***	-0.633*	-2.160***	-1.366***
	(0.240)	(0.321)	(0.303)	(0.329)
L.LnPotential	0.830***	0.782***	0.621***	0.614***
	(0.077)	(0.081)	(0.070)	(0.076)
L.LnOilPrice	-1.282***	-1.235***	-1.313***	-1.253***
	(0.304)	(0.348)	(0.292)	(0.352)
L.LnElectPrice	0.537*	0.475	-0.357	-0.312
	(0.249)	(0.243)	(0.226)	(0.234)
L.LnNaturalGasPrice	1.433***	0.843**	1.275***	0.706*
	(0.254)	(0.317)	(0.265)	(0.328)
L.LnCoalPrice	-0.610	-0.179	-0.049	0.234
	(0.362)	(0.354)	(0.427)	(0.405)
L.LnEnergyImport	-0.041	-0.159	0.133	-0.059
	(0.075)	(0.104)	(0.073)	(0.112)
Constant	-4.465	-2.083	-5.535	-2.598
	(2.800)	(2.639)	(3.088)	(2.982)
Observations	567	567	567	567
R-squared	0.820	0.684	0.819	0.680
Number of Country	27	27	27	27

AC4 Table 3: OLS Results for the Existence and Experience of Policies on Ln CC and Ln AC

This table reports the results for the pooled OLS regression equations (4.1) and (4.2) for the determinants of the wind energy capacity growth due to the existence and experience of RES-E policies. In the second column are the independent variables while the second row are the models used. The dependent variable in all equations is the natural log of cumulative Annual wind Energy Capacity (Ln CC) and natural log of Annual Added Capacity (Ln AC). FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy respectively are dummy variables representing the existence of feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other fiscal benefits, Tender and the first introduction of Cap respectively. FIT_Years, FIP_Years, Quota_Years, Tax_Years, Tender_Years and CAP_Years respectively are policy experience variables representing the number of years feed-in-tariffs, feed-in-premium, Quota and Green Trading Certificate, Taxes and other fiscal benefits, Tender and Cap has been in place. Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Elect. Price, Ln Coal Price, Ln Energy Import, represents the natural logs of Gross domestic product per capita, Electricity consumption per capita, percentage of Electricity production from coal, percentage of Electricity production from Natural gas, percentage of Electricity production from Nuclear, percentage of Electricity production from renewable, Population Growth, Carbon emissions, Wind technical potential, Oil price, Electricity price, Natural gas price, Coal price and Energy import dependence respectively. Constant is the regression intercept while Observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant level, respectively. R-Squared represents the explanatory power of the regression model.

	OLS Estimates for Existence on Ln CC and Ln AC respectively		OLS Estimates for Experience on Ln ACC and Ln AC respectively	
VARIABLES	Ln CC	Ln AC	Ln CC	Ln AC
FIT_Dummy	1.676***	1.373***		
	(0.167)	(0.179)		
FIP_Dummy	1.137***	0.569		
	(0.309)	(0.331)		
Quota_Dummy	1.465***	1.564***		
	(0.209)	(0.224)		
Tax_Dummy	0.516**	0.280		
	(0.182)	(0.195)		
Tender_Dummy	0.300	0.178		
	(0.254)	(0.272)		
CAP_Dummy	0.588*	0.327		
	(0.257)	(0.275)		
FIT&FIP	-1.770***	-1.289**		
	(0.367)	(0.392)		
FIT_Years			0.211***	0.152***
			(0.018)	(0.020)
FIP_Years			-0.032	-0.057
			(0.037)	(0.040)
Quota_Years			0.255***	0.271***
			(0.031)	(0.034)
Tax_Years			0.103***	0.060**
			(0.021)	(0.022)
Tender_Years			0.053	0.027
			(0.041)	(0.045)
CAP_Years			0.229***	0.128*
			(0.051)	(0.055)
Ln GDP	1.992***	1.371***	2.149***	1.556***
	(0.162)	(0.173)	(0.155)	(0.168)
Ln Elect.Consumption	-1.142***	-0.959**	-0.796**	-0.740*
	(0.311)	(0.333)	(0.302)	(0.327)
Ln Coal Share	0.387***	0.352***	0.460***	0.427***
	(0.065)	(0.069)	(0.064)	(0.069)
Ln Natural Gas Share	-0.089***	-0.023	-0.119***	-0.046*
	(0.022)	(0.024)	(0.021)	(0.023)
Ln Nuclear Share	-0.012	0.094*	-0.013	0.092*
	(0.043)	(0.046)	(0.041)	(0.045)

Ln Oil Share	-0.173**	0.024	-0.117*	0.050
	(0.058)	(0.062)	(0.057)	(0.062)
Ln Renewable Share	0.623***	0.471***	0.521***	0.399***
	(0.049)	(0.052)	(0.050)	(0.054)
Ln Popul.Growth	0.363***	0.362***	0.336***	0.340***
	(0.063)	(0.068)	(0.062)	(0.067)
Ln CO2	-1.029**	-0.461	-1.809***	-1.133**
	(0.357)	(0.382)	(0.350)	(0.379)
Ln Potential	0.827***	0.782***	0.630***	0.621***
	(0.080)	(0.085)	(0.080)	(0.087)
Ln Oil Price	-1.127***	-1.276***	-1.183***	-1.300***
	(0.259)	(0.277)	(0.255)	(0.277)
Ln Elect.Price	0.775***	0.622*	-0.128	-0.126
	(0.230)	(0.246)	(0.245)	(0.266)
Ln Natural Gas Price	1.393***	0.990**	1.213***	0.834**
	(0.293)	(0.314)	(0.289)	(0.313)
Ln Coal Price	-0.861*	-0.326	-0.300	0.100
	(0.388)	(0.415)	(0.388)	(0.420)
Ln Energy Import	0.048	-0.080	0.191*	-0.001
	(0.084)	(0.089)	(0.082)	(0.089)
Observations	594	594	594	594
R-squared	0.820	0.684	0.827	0.695

AC4 Table 4: Correlation Matrix

	CC	AC	FIT_Dummy	FIP_Dummy	Quota_Dummy	Tax_Dummy	Tender_Dummy
CC	1						
AC	0.8043	1					
FIT_Dummy	0.3046	0.3246	1				
FIP_Dummy	0.204	0.0745	0.0979	1			
Quota_Dummy	0.0203	0.138	-0.2194	-0.1528	1		
Tax_Dummy	-0.0531	-0.0809	-0.1835	0.1938	0.0471	1	
Tender_Dummy	-0.0376	-0.0369	0.0249	-0.1011	0.0012	-0.1218	1
CAP_Dummy	0.1574	0.059	0.1879	0.3311	-0.0469	-0.0314	0.2142
FIT&FIP	0.3538	0.215	0.3296	0.6467	-0.0988	-0.0358	-0.0654
FIT_Years	0.5758	0.4579	0.762	0.1138	-0.2101	-0.1864	-0.0107
FIP_Years	0.1139	-0.0024	0.0983	0.789	-0.121	0.1024	-0.0801
Quota_Years	0.0874	0.2359	-0.148	-0.1302	0.8524	0.0355	0.0206
Tax_Years	-0.0074	-0.0379	-0.1786	0.3544	0.0211	0.8347	-0.1016
Tender_Years	-0.0206	-0.0336	0.0021	-0.0847	-0.0053	-0.102	0.8376
CAP_Years	0.144	0.027	0.1852	0.2602	-0.059	-0.0271	0.1837
Ln GDP	0.2303	0.246	0.2335	0.1083	0.0426	0.1618	0.1169
Ln Elect.Consumption	0.112	0.1141	0.1597	0.1283	-0.0093	0.2093	-0.0091
Ln Coal Share	0.1106	0.1232	-0.021	0.1471	-0.1376	0.0887	-0.0668
Ln Natural Gas Share	-0.0026	-0.0159	0.1953	0.2383	-0.0305	-0.078	0.0141
Ln Nuclear Share	0.1069	0.1376	0.04	0.0077	-0.0172	-0.0615	-0.0534
Ln Oil Share	-0.0332	-0.0413	-0.2098	-0.2217	-0.1941	-0.0274	0.0104
Ln Renewable Share	0.349	0.3281	0.2933	0.2591	0.1195	0.2178	0.0415
Ln CO2	0.0276	0.0209	0.0766	0.1653	-0.1456	0.0927	-0.0436
Ln Potential	0.2961	0.3634	-0.0143	-0.1527	0.205	0.0341	0.0948
Ln Oil Price	0.1456	0.1242	0.2209	0.1883	0.1455	0.2103	0.0174
Ln Elect.Price	0.3558	0.3082	0.3246	0.2574	0.1935	-0.0013	0.0183
Ln Natural Gas Price	0.1865	0.1811	0.3361	0.3005	0.1851	0.133	-0.0043
Ln Coal Price	0.1908	0.2048	0.3798	0.333	0.1728	0.0855	0.0662
Ln Energy Import	-0.0778	-0.1074	-0.2858	0.1777	-0.007	0.2418	0.173

	CAP_Dummy	FITFIP	FIT_Years	FIP_Years	Quota_Years	Tax_Years	Tender_Years
CAP_Dummy	1						
FIT&FIP	0.0633	1					
FIT_Years	0.1655	0.3467	1				

	CAP_Years	Ln GDP	Ln Elect.Consumption	Ln Coal Share	Ln Natural Gas Share	Ln Nuclear Share	Ln Oil Share
FIP_Years	0.2071	0.526	0.1223	1			
Quota_Years	-0.0107	-0.0842	-0.1677	-0.1031	1		
Tax_Years	0.0523	-0.0144	-0.1536	0.2255	0.0674	1	
Tender_Years	0.1562	-0.0548	-0.0015	-0.0671	-0.0132	-0.0851	1
CAP_Years	0.8755	0.0407	0.2	0.2007	-0.0261	0.0572	0.1879
Ln GDP	0.1178	0.027	0.2681	0.0599	0.0504	0.1871	0.1283
Ln Elect.Consumption	0.0348	0.075	0.213	0.0907	-0.0034	0.2099	0.0073
Ln Coal Share	-0.1034	0.1097	-0.0376	0.1535	-0.1276	0.1056	0.0083
Ln Natural Gas Share	0.001	0.3576	0.1622	0.2697	-0.0213	-0.0364	0.0323
Ln Nuclear Share	-0.239	0.2062	0.0082	-0.0047	-0.0356	-0.0627	-0.0454
Ln Oil Share	-0.0534	-0.2355	-0.2271	-0.258	-0.209	-0.0872	0.0288
Ln Renewable Share	0.3052	0.1233	0.3717	0.2342	0.201	0.3125	0.0647
Ln CO2	-0.0064	0.0395	0.1376	0.1192	-0.1229	0.1174	0.0082
Ln Potential	-0.0749	-0.0231	-0.0169	-0.1504	0.1903	0.0337	0.0742
Ln Oil Price	0.1995	0.0785	0.2619	0.1732	0.2015	0.3207	0.0209
Ln Elect.Price	0.3877	0.1852	0.422	0.219	0.3279	0.1384	0.0036
Ln Natural Gas Price	0.2754	0.2011	0.3489	0.2818	0.2609	0.2157	-0.0085
Ln Coal Price	0.3156	0.261	0.3496	0.3677	0.2789	0.173	0.0532
Ln Energy Import	-0.1432	-0.0751	-0.3053	0.2248	-0.0517	0.2373	0.2369

	Ln Renewable Share	Ln CO2	Ln Potential	Ln Oil Price	Ln Elect.Price	Ln Natural Gas Price	Ln Coal Price
CAP_Years	1						
Ln GDP	0.1163	1					
Ln Elect.Consumption	0.0419	0.7729	1				
Ln Coal Share	-0.0548	-0.0667	-0.0403	1			
Ln Natural Gas Share	0.003	0.0792	0.065	0.069	1		
Ln Nuclear Share	-0.2151	-0.0654	0.2168	0.0172	0.1002	1	
Ln Oil Share	-0.0642	-0.099	-0.4283	0.0193	-0.2447	-0.3223	1
Ln Renewable Share	0.3072	0.582	0.5381	-0.0345	0.0721	-0.0618	-0.2152
Ln CO2	0.0013	0.5651	0.6521	0.3687	0.0317	-0.1113	-0.2862
Ln Potential	-0.0589	-0.081	-0.0422	0.2278	-0.3012	0.3233	0.0596
Ln Oil Price	0.2191	0.2498	0.2795	-0.0692	0.0706	0.193	-0.2716
Ln Elect.Price	0.3641	0.347	0.1494	-0.1023	0.0643	-0.1129	-0.0897
Ln Natural Gas Price	0.2736	0.2175	0.1413	0.0289	0.1008	0.0674	-0.2971
Ln Coal Price	0.3144	0.2464	0.1555	0.0447	0.1147	0.0329	-0.3441
Ln Energy Import	-0.1162	0.0165	-0.0334	0.3401	-0.0467	-0.0473	-0.0865

Ln Renewable Share	1						
Ln CO2	0.2774	1					
Ln Potential	0.0247	-0.3433	1				
Ln Oil Price	0.463	-0.0234	0.1385	1			
Ln Elect.Price	0.4753	0.0074	-0.0456	0.3787	1		
Ln Natural Gas Price	0.4075	0.0186	0.0328	0.8092	0.4524	1	
Ln Coal Price	0.448	0.0741	-0.0087	0.6766	0.5438	0.8336	1
Ln Energy Import	-0.0263	0.1343	0.0931	-0.1749	-0.2384	-0.1251	-0.1182

	Ln Energy Import
Ln Energy Import	1

Appendix Chapter 5 (AC5)

AC5 Table 1: Fixed Effects Results for the Impact of FIS on Wind Energy Development without Time Lag

This table reports the results for the fixed effects regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of FIS policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no FIS policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy Import Dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

	(WE1)	(WE2)	(WE3)	(WE4)	(WE5)	(WE6)	(WE7)	(WE8)	(WE9)
VARIABLES	Model	Model	Model	Model	Model	Model	Model	Model	Model
FIS_Dummy	1.552								
	(0.918)								
FIT_Dummy	-0.719								
	(0.943)								
FIP_Dummy	-1.864								
	(0.990)								
LNFIT_ABS		0.180*							0.184*
		(0.072)							(0.067)
LNFIP_ABS			-0.177						-0.180
			(0.112)						(0.117)
LnNpvRev				0.634***					
				(0.110)					

LnNpvRev_1					0.427**				
					(0.120)				
LnNpvRev_2						0.522***			
						(0.125)			
LnNpvRev_3							0.193		
							(0.336)		
LnNpvRev_4								0.646***	
								(0.117)	
FITFIP	0.675								
	(0.472)								
FITTEND	0.425								
	(0.449)								
Quota_Dummy	1.023*	1.003*	0.732	0.448	1.235**	1.189**	0.839	0.439	0.920*
	(0.432)	(0.400)	(0.410)	(0.345)	(0.410)	(0.423)	(0.417)	(0.371)	(0.403)
Tax_Dummy	-0.416	-0.350	-0.421	-0.343	-0.369	-0.204	-0.465	-0.278	-0.313
	(0.246)	(0.236)	(0.257)	(0.255)	(0.223)	(0.206)	(0.256)	(0.246)	(0.232)
Tender_Dummy	-0.195	-0.072	-0.103	0.052	0.066	-0.003	-0.066	0.088	-0.090
	(0.311)	(0.282)	(0.295)	(0.457)	(0.303)	(0.259)	(0.351)	(0.458)	(0.263)
CAP_Dummy	-0.143	-0.189	-0.004	-0.522	-0.662	-0.291	-0.181	-0.520	-0.074
	(0.327)	(0.287)	(0.311)	(0.368)	(0.341)	(0.332)	(0.284)	(0.355)	(0.328)
LnGDP	-0.251	-0.146	0.135	-0.153	-0.094	0.122	-0.038	0.391	0.048
	(0.949)	(0.934)	(0.977)	(0.693)	(0.893)	(0.850)	(1.039)	(0.707)	(0.889)
lnElec.Consumption	4.096*	4.270*	4.323*	3.538*	4.161*	3.522*	4.510*	2.493	4.064*
	(1.517)	(1.602)	(1.586)	(1.516)	(1.679)	(1.466)	(1.748)	(1.546)	(1.473)
LnCoal Share	0.334*	0.265	0.331*	0.274	0.298	0.287	0.314	0.306	0.288
	(0.149)	(0.157)	(0.156)	(0.149)	(0.147)	(0.143)	(0.161)	(0.159)	(0.154)
LnNatural Gas Share	0.084	0.052	0.120	0.190	0.125	0.075	0.124	0.197	0.051
	(0.132)	(0.165)	(0.155)	(0.129)	(0.145)	(0.124)	(0.179)	(0.140)	(0.145)
LnNuclear Share	0.152	0.144	0.147	0.277*	0.240	0.263*	0.122	0.342**	0.172
	(0.128)	(0.143)	(0.128)	(0.113)	(0.137)	(0.123)	(0.149)	(0.112)	(0.124)
LnOil Share	0.143	0.176	0.090	0.212	0.174	0.219	0.088	0.163	0.175
	(0.149)	(0.161)	(0.136)	(0.143)	(0.160)	(0.150)	(0.149)	(0.141)	(0.153)
LnRenewable Share	0.288**	0.302**	0.290**	0.238***	0.265**	0.253**	0.294**	0.204**	0.298***
	(0.083)	(0.082)	(0.081)	(0.056)	(0.084)	(0.083)	(0.083)	(0.056)	(0.080)
LnPopul.Growth	0.094	0.107	0.056	0.071	0.091	0.095	0.077	0.066	0.086
	(0.088)	(0.092)	(0.082)	(0.066)	(0.088)	(0.087)	(0.084)	(0.065)	(0.086)

LnCO2	-1.209	-1.230	-1.436	-1.106	-1.245	-0.950	-1.498	-0.274	-1.154
	(1.018)	(1.091)	(1.106)	(0.993)	(1.065)	(0.981)	(1.160)	(1.035)	(1.055)
LnPotential	-38.591	-31.436	-39.407	-14.545	-22.052	-29.480	-32.496	-17.827	-37.141
	(23.836)	(24.782)	(26.090)	(25.584)	(26.301)	(23.968)	(27.878)	(25.014)	(23.420)
LnOil Price	0.514	0.698	0.306	0.084	0.396	0.615	0.531	-0.075	0.460
	(0.561)	(0.497)	(0.496)	(0.248)	(0.352)	(0.479)	(0.441)	(0.294)	(0.530)
LnNatural Gas Price	-0.503	-0.647	-0.302	-0.508	-0.555	-0.767	-0.498	-0.385	-0.463
	(0.513)	(0.475)	(0.440)	(0.323)	(0.374)	(0.513)	(0.413)	(0.311)	(0.488)
LnCoal Price	1.326	1.007	1.377	0.670	0.864	1.185	1.114	0.664	1.242
	(0.672)	(0.634)	(0.698)	(0.456)	(0.600)	(0.689)	(0.669)	(0.449)	(0.672)
LnEnergy Import	-0.169	-0.211	-0.220	-0.194	-0.269	-0.121	-0.288*	-0.192	-0.159
	(0.138)	(0.129)	(0.121)	(0.209)	(0.169)	(0.149)	(0.126)	(0.174)	(0.127)
Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	594	594	592	594	594	594	594	594	592
R-squared	0.538	0.538	0.540	0.639	0.581	0.538	0.533	0.626	0.554
Number of Countries	27	27	27	27	27	27	27	27	27

AC5 Table 2: Random Effects Results for the Impact of FIS on Wind Energy Development without Time Lag

This table reports the results for the fixed effects regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of FIS policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no FIS policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy Import Dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(WE1) Model	(WE2) Model	(WE3) Model	(WE4) Model	(WE5) Model	(WE6) Model	(WE7) Model	(WE8) Model	(WE9) Model
FIS_Dummy	4.708*								
	(1.146)								
FIT_Dummy	3.241								
	(1.127)								
FIP_Dummy	-3.744								
	(0.991)								
LnFIT_ABS		0.248**							0.249**
		(0.081)							(0.078)
LnFIP_ABS			-0.130						-0.145
			(0.096)						(0.107)
LnNpvRev				0.728***					
				(0.121)					
LnNpvRev_1					0.543***				

					(0.136)				
LnNpvRev_2						0.617***			
						(0.133)			
LnNpvRev_3							0.342		
							(0.337)		
LnNpvRev_4								0.718***	
								(0.118)	
FIT&FIP	2.544***								
	(0.553)								
FIT&TEND	0.342								
	(0.638)								
Quota_Dummy	1.698***	1.323**	0.929*	0.618*	1.640***	1.522***	1.034**	0.548	1.242**
	(0.450)	(0.419)	(0.385)	(0.298)	(0.390)	(0.412)	(0.387)	(0.308)	(0.423)
Tax_Dummy	0.234	-0.035	-0.110	-0.137	-0.070	0.133	-0.195	-0.047	0.022
	(0.320)	(0.254)	(0.226)	(0.233)	(0.198)	(0.218)	(0.229)	(0.223)	(0.238)
Tender_Dummy	0.049	0.245	0.271	0.357	0.451	0.234	0.351	0.346	0.212
	(0.447)	(0.386)	(0.423)	(0.544)	(0.432)	(0.375)	(0.481)	(0.522)	(0.373)
CAP_Dummy	0.359	0.274	0.467	-0.239	-0.337	0.127	0.258	-0.292	0.359
	(0.351)	(0.266)	(0.245)	(0.351)	(0.305)	(0.311)	(0.236)	(0.314)	(0.307)
LnGDP	1.440***	0.982**	1.248**	0.887**	1.101**	1.101***	1.216**	1.029***	1.006**
	(0.329)	(0.374)	(0.396)	(0.317)	(0.349)	(0.326)	(0.394)	(0.312)	(0.374)
lnElec.Consumption	-0.966	0.458	0.361	0.200	0.117	0.226	0.340	0.039	0.530
	(0.714)	(0.979)	(1.031)	(0.711)	(0.787)	(0.871)	(1.016)	(0.799)	(0.998)
LnCoal Share	0.365***	0.351**	0.398**	0.265*	0.338**	0.340**	0.390**	0.284**	0.364**
	(0.104)	(0.125)	(0.122)	(0.104)	(0.112)	(0.110)	(0.122)	(0.109)	(0.125)
LnNatural Gas Share	-0.016	0.030	0.064	0.066	0.037	0.037	0.059	0.089	0.037
	(0.034)	(0.091)	(0.100)	(0.067)	(0.066)	(0.069)	(0.103)	(0.088)	(0.089)
LnNuclear Share	0.109	-0.090	-0.096	-0.026	-0.041	-0.017	-0.118	0.040	-0.067
	(0.068)	(0.096)	(0.094)	(0.082)	(0.083)	(0.094)	(0.095)	(0.096)	(0.095)
LnOil Share	0.030	0.107	-0.019	0.162	0.105	0.147	-0.018	0.116	0.103
	(0.122)	(0.134)	(0.129)	(0.105)	(0.128)	(0.118)	(0.126)	(0.106)	(0.135)
LnRenewable Share	0.477***	0.357***	0.364***	0.280***	0.325***	0.298***	0.364***	0.230***	0.351***
	(0.095)	(0.090)	(0.089)	(0.060)	(0.089)	(0.090)	(0.089)	(0.064)	(0.089)
LnPopul.Growth	0.330**	0.179	0.146	0.126	0.163	0.158	0.156	0.110	0.166
	(0.122)	(0.109)	(0.104)	(0.073)	(0.099)	(0.102)	(0.103)	(0.072)	(0.106)
LnCO2	-0.607	-0.577	-0.961	-0.338	-0.567	-0.470	-0.906	-0.003	-0.653
	(0.624)	(0.738)	(0.776)	(0.591)	(0.621)	(0.659)	(0.766)	(0.695)	(0.756)

LnPotential	0.750***	0.767**	0.801**	0.675***	0.689***	0.635**	0.826***	0.788***	0.743**
	(0.165)	(0.247)	(0.254)	(0.162)	(0.176)	(0.215)	(0.233)	(0.208)	(0.262)
LnOil Price	-1.370***	0.353	-0.024	-0.436	-0.283	0.169	0.094	-0.384	0.222
	(0.402)	(0.504)	(0.484)	(0.382)	(0.400)	(0.456)	(0.470)	(0.338)	(0.510)
LnNatural Gas Price	1.022*	-0.035	0.426	0.151	0.235	-0.081	0.251	0.134	0.107
	(0.449)	(0.512)	(0.416)	(0.331)	(0.406)	(0.524)	(0.406)	(0.319)	(0.504)
LnCoal Price	-0.051	0.602	0.873	0.292	0.406	0.719	0.701	0.323	0.766
	(0.682)	(0.650)	(0.667)	(0.412)	(0.592)	(0.723)	(0.613)	(0.444)	(0.678)
LnEnergy Import	-0.126	-0.174	-0.305*	-0.127	-0.241	-0.077	-0.360*	-0.198	-0.151
	(0.126)	(0.122)	(0.142)	(0.148)	(0.133)	(0.114)	(0.147)	(0.130)	(0.132)
Constant	-0.057	-13.611*	-16.192**	-7.448	-10.023*	-12.830**	-14.904	-8.365*	-15.129**
	(4.490)	(5.542)	(5.879)	(3.915)	(4.459)	(4.805)	(5.842)	(4.262)	(5.691)
Effects	Random	Random	Random	Random	Random	Random	Random	Random	Random
Observations	594	594	594	594	594	594	594	594	594
R-squared	0.4509	0.513	0.607	0.538	0.5	0.553	0.491	0.604	0.521
Number of Countries	27	27	27	27	27	27	27	27	27

AC5 Table 3: Random Effects Results for the Impact of FIS on Wind Energy Development with Time Lag

This table reports the results for the fixed effects regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of FIS policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no FIS policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln RenewableShare, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy Import Dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

	(WE1)	(WE2)	(WE3)	(WE4)	(WE5)	(WE6)	(WE7)	(WE8)	(WE9)
VARIABLES	Model	Model	Model	Model	Model	Model	Model	Model	Model
L.FIS_Dummy	5.024*								
	(1.329)								
L.FIT_Dummy	3.368								
	(1.271)								
L.FIP_Dummy	-3.668								
	(1.068)								
L.LNFIT_ABS		0.267**							0.274**
		(0.091)							(0.085)
L.LNFIP_ABS			-0.151						-0.181
			(0.107)						(0.121)
L.LnNpvRev				0.522***					
				(0.141)					

L.LnNpvRev_1					0.384*				
					(0.154)				
L.LnNpvRev_2						0.479***			
						(0.122)			
L.LnNpvRev_3							-0.267		
							(0.387)		
L.LnNpvRev_4								0.444***	
								(0.119)	
L.FIT&FIP	2.447***								
	(0.612)								
L.FIT&TEND	0.318								
	(0.657)								
L.Quota_Dummy	1.944***	1.505**	1.072*	0.869*	1.571***	1.542***	1.127*	0.852*	1.417**
	(0.482)	(0.475)	(0.436)	(0.337)	(0.439)	(0.437)	(0.442)	(0.364)	(0.482)
L.Tax_Dummy	0.283	-0.030	-0.105	-0.058	-0.018	0.076	-0.161	-0.064	0.043
	(0.360)	(0.290)	(0.228)	(0.224)	(0.224)	(0.245)	(0.253)	(0.217)	(0.267)
L.Tender_Dummy	0.416	0.586	0.601	0.662	0.734*	0.579	0.597	0.677	0.547
	(0.505)	(0.311)	(0.327)	(0.419)	(0.356)	(0.309)	(0.350)	(0.387)	(0.323)
L.CAP_Dummy	0.156	0.142	0.353	-0.226	-0.276	0.063	0.368	-0.211	0.236
	(0.417)	(0.336)	(0.296)	(0.314)	(0.328)	(0.331)	(0.281)	(0.293)	(0.397)
L.LnGDP	1.516***	1.157**	1.456***	1.264***	1.391***	1.341***	1.397**	1.326***	1.204**
	(0.347)	(0.404)	(0.439)	(0.378)	(0.396)	(0.376)	(0.429)	(0.379)	(0.411)
L.lnElec.Consumption	-0.894	0.504	0.314	-0.095	-0.068	0.179	0.362	0.072	0.536
	(0.712)	(0.914)	(0.993)	(0.737)	(0.797)	(0.844)	(1.007)	(0.824)	(0.930)
L.LnCoal Share	0.395***	0.388**	0.425***	0.330**	0.387***	0.396***	0.408***	0.355***	0.406***
	(0.113)	(0.120)	(0.124)	(0.108)	(0.115)	(0.107)	(0.122)	(0.107)	(0.119)
L.LnNatural Gas Share	-0.023	0.030	0.064	0.046	0.030	0.035	0.058	0.075	0.037
	(0.037)	(0.097)	(0.106)	(0.072)	(0.076)	(0.080)	(0.111)	(0.098)	(0.093)
L.LnNuclear Share	0.101	-0.108	-0.106	-0.051	-0.065	-0.061	-0.126	-0.040	-0.082
	(0.070)	(0.109)	(0.106)	(0.087)	(0.090)	(0.100)	(0.106)	(0.109)	(0.109)
L.LnOil Share	0.018	0.105	-0.032	0.066	0.027	0.075	-0.017	0.043	0.100
	(0.127)	(0.136)	(0.136)	(0.117)	(0.133)	(0.122)	(0.133)	(0.117)	(0.139)
L.LnRenewable Share	0.379***	0.233*	0.243*	0.213*	0.239*	0.206	0.246*	0.165	0.228*
	(0.105)	(0.105)	(0.105)	(0.085)	(0.107)	(0.106)	(0.106)	(0.089)	(0.104)
L.LnPopul.Growth	0.335**	0.188	0.156	0.152	0.174	0.167	0.167	0.137	0.176
	(0.117)	(0.109)	(0.103)	(0.087)	(0.099)	(0.100)	(0.103)	(0.087)	(0.105)
L.LnCO2	-0.723	-0.641	-0.980	-0.555	-0.743	-0.717	-0.909	-0.422	-0.721
	(0.649)	(0.705)	(0.795)	(0.615)	(0.671)	(0.664)	(0.787)	(0.694)	(0.725)

L.LnPotential	0.761***	0.794**	0.833**	0.736***	0.745***	0.697**	0.851**	0.835***	0.768**
	(0.179)	(0.254)	(0.270)	(0.181)	(0.198)	(0.227)	(0.262)	(0.225)	(0.272)
L.LnOil Price	-1.294**	0.460	0.041	-0.348	-0.181	0.155	0.219	-0.101	0.291
	(0.398)	(0.521)	(0.514)	(0.462)	(0.470)	(0.480)	(0.532)	(0.450)	(0.515)
L.LnNatural Gas Price	0.859	-0.232	0.294	0.155	0.156	-0.096	0.160	0.039	-0.064
	(0.456)	(0.555)	(0.462)	(0.367)	(0.447)	(0.516)	(0.486)	(0.393)	(0.559)
L.LnCoal Price	0.035	0.922	1.218	0.612	0.745	1.006	1.084	0.778	1.126
	(0.745)	(0.753)	(0.758)	(0.526)	(0.690)	(0.785)	(0.737)	(0.557)	(0.761)
L.LnEnergy Import	-0.191	-0.229	-0.361*	-0.242*	-0.341**	-0.203	-0.358*	-0.320**	-0.197
	(0.141)	(0.132)	(0.159)	(0.111)	(0.123)	(0.124)	(0.173)	(0.114)	(0.149)
Constant	-1.347	-16.656**	-18.989**	-9.803*	-12.394**	-15.387**	-18.464**	-13.374**	-18.154***
	(4.653)	(5.274)	(5.774)	(4.252)	(4.730)	(4.873)	(5.847)	(4.525)	(5.398)
Effects	Random	Random	Random	Random	Random	Random	Random	Random	Random
Observations	567	567	567	567	567	567	567	567	567
R-squared	0.428	0.491	0.476	0.491	0.462	0.490	0.469	0.499	0.504
Number of Country	27	27	27	27	27	27	27	27	27

AC5 Table 4: Pearson Correlated Standard Errors (PCSE) Results for the Effect of FIS on Wind Energy Development without Time Lag

This table reports the results for the Pearson Correlated Standard Errors estimates of regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of *FIS* policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no *FIS* policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy import dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

	(WE1)	(WE2)	(WE3)	(WE4)	(WE5)	(WE6)	(WE7)	(WE8)	(WE9)
VARIABLES	Model	Model	Model	Model	Model	Model	Model	Model	Model
FIS_Dummy	4.708**								
	(1.261)								
FIT_Dummy	3.241								
	(1.259)								
FIP_Dummy	-3.744*								
	(1.204)								
LNFIT_ABS		0.300***							0.306***
		(0.039)							(0.040)
LNFIP_ABS			-0.074						-0.102*
			(0.043)						(0.044)
LnNpvRev				0.833***					

				(0.050)					
LnNpvRev_1					0.652***				
					(0.056)				
LnNpvRev_2						0.696***			
						(0.068)			
LnNpvRev_3							0.549*		
							(0.231)		
LnNpvRev_4								0.835***	
								(0.060)	
FIT&FIP	2.544*								
	(1.154)								
FIT&TENDER	0.342								
	(0.581)								
Quota_Dummy	1.698***	1.631***	0.891***	0.631***	1.928***	1.766***	1.012***	0.378*	1.571***
	(0.211)	(0.212)	(0.185)	(0.145)	(0.222)	(0.210)	(0.186)	(0.166)	(0.214)
Tax_Dummy	0.234	0.272	0.071	-0.021	0.099	0.427*	-0.050	0.139	0.350
	(0.178)	(0.173)	(0.170)	(0.147)	(0.142)	(0.173)	(0.162)	(0.148)	(0.180)
Tender_Dummy	0.049	0.004	-0.012	0.303	0.405	-0.088	0.178	0.068	-0.082
	(0.335)	(0.253)	(0.274)	(0.238)	(0.260)	(0.255)	(0.289)	(0.237)	(0.259)
CAP_Dummy	0.359	0.560*	0.606*	-0.266	-0.379	0.414	0.298	-0.200	0.681*
	(0.312)	(0.280)	(0.292)	(0.207)	(0.242)	(0.243)	(0.308)	(0.193)	(0.304)
LnGDP	1.440***	1.454***	1.792***	1.143***	1.326***	1.400***	1.783***	1.389***	1.453***
	(0.160)	(0.170)	(0.167)	(0.129)	(0.144)	(0.151)	(0.167)	(0.145)	(0.167)
LnElec.Consumption	-0.966***	-0.979***	-1.425***	-0.594*	-0.503	-0.762**	-1.336***	-1.250***	-1.012***
	(0.279)	(0.274)	(0.295)	(0.234)	(0.266)	(0.280)	(0.295)	(0.286)	(0.273)
LnCoal Share	0.365***	0.343***	0.379***	0.214***	0.325***	0.306***	0.388***	0.204***	0.341***
	(0.061)	(0.061)	(0.062)	(0.055)	(0.056)	(0.056)	(0.061)	(0.049)	(0.061)
LnNatural Gas Share	-0.016	-0.043*	-0.032	0.019	-0.005	-0.008	-0.035	0.014	-0.038*
	(0.015)	(0.017)	(0.018)	(0.013)	(0.013)	(0.013)	(0.018)	(0.014)	(0.017)
LnNuclear Share	0.109**	0.045	0.064	0.032	0.034	0.067	0.036	0.100**	0.065
	(0.041)	(0.039)	(0.043)	(0.033)	(0.042)	(0.036)	(0.044)	(0.034)	(0.039)
LnOil Share	0.030	0.061	-0.107	0.119*	0.090	0.109	-0.111*	0.043	0.065
	(0.063)	(0.064)	(0.055)	(0.048)	(0.054)	(0.060)	(0.054)	(0.047)	(0.065)
LnRenewable Share	0.477***	0.496***	0.567***	0.339***	0.388***	0.424***	0.542***	0.355***	0.506***
	(0.052)	(0.051)	(0.057)	(0.044)	(0.051)	(0.054)	(0.057)	(0.050)	(0.051)

LnPopul.Growth	0.330***	0.305***	0.313***	0.209***	0.248***	0.283***	0.314***	0.241***	0.300***
	(0.065)	(0.064)	(0.065)	(0.054)	(0.057)	(0.056)	(0.066)	(0.059)	(0.063)
LnCO2	-0.607	-0.497	-0.775*	-0.217	-0.593	-0.355	-0.843**	0.154	-0.482
	(0.337)	(0.318)	(0.315)	(0.274)	(0.312)	(0.296)	(0.310)	(0.264)	(0.316)
LnPotential	0.750***	0.718***	0.787***	0.656***	0.643***	0.632***	0.790***	0.803***	0.711***
	(0.080)	(0.069)	(0.064)	(0.063)	(0.068)	(0.062)	(0.065)	(0.059)	(0.066)
LnOil Price	-1.370***	-1.043**	-1.516***	-1.302***	-1.257***	-1.126***	-1.396***	-1.575***	-1.174***
	(0.354)	(0.339)	(0.350)	(0.254)	(0.304)	(0.328)	(0.348)	(0.267)	(0.339)
LnNatural Gas Price	1.022***	0.865**	1.334***	0.824***	0.890**	0.901**	1.191***	1.071***	0.966**
	(0.310)	(0.315)	(0.293)	(0.242)	(0.272)	(0.295)	(0.290)	(0.244)	(0.316)
LnCoal Price	-0.051	-0.098	0.115	-0.268	-0.103	-0.217	0.055	-0.620*	-0.027
	(0.313)	(0.318)	(0.318)	(0.285)	(0.291)	(0.314)	(0.309)	(0.293)	(0.325)
LnEnergy Import	-0.126	-0.005	-0.240*	-0.018	-0.168	0.040	-0.302**	-0.065	0.017
	(0.104)	(0.097)	(0.095)	(0.104)	(0.105)	(0.089)	(0.101)	(0.088)	(0.095)
Constant	-0.057**	-0.265*	-0.160**	0.456	-3.064***	-1.420	-0.539**	5.135*	-0.155
	(2.391)	(2.339)	(2.679)	(2.215)	(2.386)	(2.575)	(2.641)	(2.550)	(2.393)
Observations	594	594	594	594	594	594	594	594	594
R-squared	0.696	0.683	0.654	0.768	0.725	0.717	0.656	0.746	0.685
Number of Countries	27	27	27	27	27	27	27	27	27

AC5 Table 5: Pearson Correlated Standard Errors (PCSE) Results for the Effect of FIS on Wind Energy Development with Time Lag

This table reports the results for the Pearson Correlated Standard Errors estimates of regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of *FIS* policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no *FIS* policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy import dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(WE1) Model	(WE2) Model	(WE3) Model	(WE4) Model	(WE5) Model	(WE6) Model	(WE7) Model	(WE8) Model	(WE9) Model
L.FIS_Dummy	5.024**								
	(1.579)								
L.FIT_Dummy	3.368								
	(1.582)								
L.FIP_Dummy	-3.668								
	(1.539)								
L.LNFIT_ABS		0.318***							0.328***
		(0.042)							(0.043)
L.LNFIP_ABS			-0.076						-0.121*
			(0.046)						(0.048)
L.LnNpvRev				0.659***					

				(0.067)					
L.LnNpvRev_1					0.532***				
					(0.074)				
L.LnNpvRev_2						0.594***			
						(0.083)			
L.LnNpvRev_3							0.114		
							(0.272)		
L.LnNpvRev_4								0.601***	
								(0.078)	
L.FIT&FIP	2.447								
	(1.507)								
L.FIT&TENDER	0.318								
	(0.606)								
L.Quota_Dummy	1.944***	1.807***	1.037***	0.824***	1.843***	1.755***	1.102***	0.661***	1.744***
	(0.230)	(0.235)	(0.196)	(0.167)	(0.250)	(0.237)	(0.195)	(0.184)	(0.235)
L.Tax_Dummy	0.283	0.314	0.100	0.080	0.179	0.381*	0.039	0.171	0.404*
	(0.193)	(0.194)	(0.189)	(0.162)	(0.164)	(0.188)	(0.186)	(0.170)	(0.205)
L.Tender_Dummy	0.416	0.266	0.230	0.514	0.618*	0.204	0.316	0.317	0.170
	(0.358)	(0.271)	(0.298)	(0.268)	(0.283)	(0.282)	(0.313)	(0.275)	(0.278)
L.Cap_Dummy	0.156	0.489	0.543	-0.272	-0.364	0.332	0.413	-0.151	0.618
	(0.346)	(0.313)	(0.328)	(0.282)	(0.305)	(0.297)	(0.366)	(0.278)	(0.337)
L.LnGDP	1.516***	1.532***	1.896***	1.407***	1.550***	1.572***	1.889***	1.633***	1.532***
	(0.165)	(0.179)	(0.178)	(0.151)	(0.164)	(0.166)	(0.179)	(0.169)	(0.178)
L.Ln Elec.Consumption	-0.894**	-0.890**	-1.388***	-0.759**	-0.686*	-0.801**	-1.347***	-1.286***	-0.928***
	(0.278)	(0.278)	(0.301)	(0.274)	(0.291)	(0.292)	(0.304)	(0.304)	(0.276)
L.Ln Coal Share	0.395***	0.374***	0.406***	0.288***	0.373***	0.357***	0.407***	0.295***	0.374***
	(0.064)	(0.064)	(0.064)	(0.062)	(0.062)	(0.062)	(0.064)	(0.059)	(0.064)
L.Ln Natural Gas Share	-0.023	-0.048**	-0.037	0.005	-0.014	-0.017	-0.041*	-0.004	-0.043*
	(0.016)	(0.018)	(0.019)	(0.016)	(0.016)	(0.016)	(0.020)	(0.018)	(0.017)
L.Ln Nuclear Share	0.101*	0.031	0.055	0.026	0.027	0.049	0.039	0.076	0.053
	(0.044)	(0.042)	(0.049)	(0.041)	(0.047)	(0.042)	(0.049)	(0.042)	(0.042)
L.Ln Oil Share	0.018	0.054	-0.126*	0.037	0.013	0.045	-0.127*	-0.032	0.058
	(0.069)	(0.073)	(0.062)	(0.064)	(0.068)	(0.068)	(0.062)	(0.062)	(0.074)
L.Ln Renewable Share	0.379***	0.402***	0.475***	0.304***	0.336***	0.358***	0.464***	0.330***	0.413***
	(0.055)	(0.055)	(0.063)	(0.053)	(0.056)	(0.059)	(0.062)	(0.059)	(0.055)
L.Ln Popul.Growth	0.335***	0.304***	0.308***	0.221***	0.251***	0.283***	0.309***	0.254***	0.300***

	(0.069)	(0.068)	(0.067)	(0.059)	(0.060)	(0.062)	(0.067)	(0.063)	(0.066)
L.LnCO2	-0.723*	-0.621	-0.859*	-0.499	-0.791*	-0.619	-0.875**	-0.275	-0.609
	(0.361)	(0.348)	(0.338)	(0.335)	(0.353)	(0.334)	(0.339)	(0.327)	(0.345)
L.Ln Potential	0.761***	0.730***	0.799***	0.692***	0.677***	0.663***	0.802***	0.810***	0.722***
	(0.082)	(0.072)	(0.068)	(0.070)	(0.069)	(0.068)	(0.069)	(0.069)	(0.069)
L.Ln Oil Price	-1.294***	-0.990**	-1.475***	-1.258***	-1.214***	-1.155**	-1.370***	-1.473***	-1.137**
	(0.365)	(0.362)	(0.373)	(0.308)	(0.337)	(0.357)	(0.374)	(0.327)	(0.358)
L.Ln Natural Gas Price	0.859**	0.772*	1.266***	0.804**	0.839**	0.893**	1.176***	1.024***	0.879**
	(0.321)	(0.338)	(0.310)	(0.275)	(0.298)	(0.310)	(0.313)	(0.285)	(0.333)
L.Ln Coal Price	0.035	0.030	0.258	-0.072	0.071	-0.010	0.198	-0.297	0.116
	(0.346)	(0.343)	(0.346)	(0 350)	(0.353)	(0.349)	(0.339)	(0.356)	(0.348)
L.Ln Energy Import	-0.191	-0.034	-0.280**	-0.128	-0.246*	-0.057	-0.303**	-0.177	-0.008
	(0.109)	(0.101)	(0.095)	(0.103)	(0.105)	(0.095)	(0.100)	(0.092)	(0.099)
Constant	-1.347***	-1.924**	-1.823*	-1.106**	-3.922***	-2.992*	-1.948**	2.143**	-1.792**
	(2.540)	(2.482)	(2.897)	(2.528)	(2.575)	(2.694)	(2.846)	(2.800)	(2.531)
Observations	567	567	567	567	567	567	567	567	567
R-squared	0.688	0.668	0.636	0.704	0.679	0.679	0.635	0.681	0.671
Number of Country	27	27	27	27	27	27	27	27	27

AC5 Table 6: Fixed Effects Results for the Impact of FIS on Solar Photovoltaic Development without Time Lag

This table reports the results for the fixed effects regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of FIS policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no FIS policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy Import Dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(PV1) Model	(PV2) Model	(PV3) Model	(PV4) Model	(PV5) Model	(PV6) Model	(PV7) Model	(PV8) Model	(PV9) Model
FIS_Dummy	-0.762								
	(2.332)								
FIT_Dummy	1.385								
	(2.141)								
FIP_Dummy	0.683								
	(2.217)								
LNFIT_ABS		0.095							0.092
		(0.088)							(0.086)
LNFIP_ABS			0.186						0.183
			(0.130)						(0.133)
LnNpvRev				0.571***					
				(0.095)					

LnNpvRev_1					0.563***				
					(0.096)				
LnNpvRev_2						0.582***			
						(0.097)			
LnNpvRev_3							0.514*		
							(0.220)		
LnNpvRev_4								0.6	
								(0.227)	
FIT&FIP	0.885								
	(1.122)								
FIT&TENDER	-1.182								
	(0.636)								
Quota_Dummy	-0.010	-0.229	-0.233	0.210	0.220	0.183	-0.197	-0.204	-0.133
	(0.422)	(0.452)	(0.461)	(0.391)	(0.389)	(0.410)	(0.440)	(0.427)	(0.448)
Tax_Dummy	-0.035	-0.076	-0.116	0.078	0.057	0.181	-0.199	-0.271	-0.035
	(0.389)	(0.394)	(0.429)	(0.334)	(0.335)	(0.369)	(0.389)	(0.374)	(0.407)
Tender_Dummy	0.251	-0.160	-0.070	-0.111	-0.121	-0.113	-0.153	-0.142	-0.135
	(0.685)	(0.650)	(0.643)	(0.521)	(0.538)	(0.530)	(0.671)	(0.669)	(0.618)
Cap_Dummy	0.323	-0.045	-0.248	-0.012	0.015	0.016	0.040	-0.054	-0.206
	(0.856)	(0.748)	(0.750)	(0.627)	(0.630)	(0.626)	(0.744)	(0.746)	(0.732)
LnGDP	-4.363**	-3.993**	-4.124**	-3.487**	-3.640**	-3.308*	-4.184**	-4.356**	-4.158**
	(1.247)	(1.309)	(1.280)	(1.093)	(1.131)	(1.272)	(1.217)	(1.179)	(1.238)
Ln Elec.Consumption	3.953*	3.707	4.113*	2.562	2.870	2.528	4.397*	4.829*	3.822
	(1.902)	(1.955)	(1.947)	(1.528)	(1.545)	(1.655)	(1.891)	(1.891)	(1.940)
LnCoal Share	0.256	0.294	0.282	0.295	0.304	0.281	0.282	0.290	0.252
	(0.183)	(0.181)	(0.196)	(0.162)	(0.166)	(0.176)	(0.189)	(0.184)	(0.185)
Ln Natural Gas Share	-0.109	-0.069	-0.030	-0.169	-0.176	-0.166	-0.058	-0.095	-0.078
	(0.144)	(0.177)	(0.148)	(0.129)	(0.131)	(0.138)	(0.135)	(0.140)	(0.165)
Ln Nuclear Share	-0.368*	-0.331	-0.386*	-0.265	-0.272	-0.251	-0.392*	-0.395*	-0.362*
	(0.155)	(0.168)	(0.168)	(0.155)	(0.156)	(0.168)	(0.168)	(0.160)	(0.169)
Ln Oil Share	-0.390	-0.416	-0.443	-0.388	-0.388	-0.369	-0.399	-0.411	-0.398
	(0.225)	(0.222)	(0.225)	(0.200)	(0.205)	(0.210)	(0.232)	(0.228)	(0.219)
Ln Renewable Share	0.319***	0.319**	0.319**	0.247**	0.248**	0.254**	0.305**	0.301**	0.331**
	(0.086)	(0.088)	(0.090)	(0.082)	(0.082)	(0.083)	(0.086)	(0.085)	(0.089)
Ln Popul.Growth	0.230**	0.232**	0.223**	0.198*	0.196*	0.205*	0.191*	0.194*	0.243**
	(0.071)	(0.069)	(0.071)	(0.078)	(0.079)	(0.078)	(0.077)	(0.076)	(0.072)
LnCO2	-4.788**	-4.801**	-5.230***	-3.929**	-4.111**	-4.096**	-5.083***	-5.309***	-4.963**
	(1.346)	(1.390)	(1.388)	(1.166)	(1.184)	(1.193)	(1.363)	(1.392)	(1.424)
Ln Potential	-25.302	-23.656	-19.905	-18.979	-19.421	-15.205	-28.133	-30.215	-19.761
	(27.381)	(28.264)	(27.040)	(22.017)	(22.040)	(22.282)	(27.229)	(27.041)	(27.737)

Ln Oil Price	0.534	0.215	0.403	0.209	0.219	0.150	0.465	0.262	0.496
	(0.708)	(0.726)	(0.649)	(0.479)	(0.481)	(0.491)	(0.658)	(0.686)	(0.672)
Ln Natural Gas Price	1.082	1.306	1.272	0.938	0.932	1.007	1.152	1.278	1.143
	(0.724)	(0.651)	(0.720)	(0.615)	(0.614)	(0.600)	(0.696)	(0.683)	(0.715)
Ln Coal Price	-0.866	-0.440	-0.717	-0.136	-0.118	-0.142	-0.652	-0.488	-0.771
	(0.848)	(0.921)	(0.892)	(0.833)	(0.837)	(0.855)	(0.877)	(0.891)	(0.879)
Ln Energy Import	-0.402*	-0.353*	-0.403*	-0.330*	-0.329*	-0.329*	-0.392*	-0.374*	-0.376*
	(0.176)	(0.157)	(0.177)	(0.128)	(0.128)	(0.132)	(0.174)	(0.170)	(0.165)
Constant	-70.715	-68.028	-56.147	-48.830	-51.188	-37.193	-86.114	-94.919	-52.907
	(88.663)	(91.319)	(86.918)	(71.768)	(71.823)	(72.695)	(87.357)	(86.970)	(89.762)
Effect	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	594	594	594	594	594	594	594	594	594
R-squared	0.449	0.449	0.462	0.449	0.552	0.449	0.449	0.449	0.449
Number of Country	27	27	27	27	27	27	27	27	27

AC5 Table 7: Random Effects Results for the Impact of FIS on Solar Photovoltaic Development without Time Lag

This table reports the results for the fixed effects regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of FIS policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no FIS policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy Import Dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(PV1) Model	(PV2) Model	(PV3) Model	(PV4) Model	(PV5) Model	(PV6) Model	(PV7) Model	(PV8) Model	(PV9) Model
FIS_Dummy	0.746								
	(1.999)								
FIT_Dummy	0.016								
	(1.865)								
FIP_Dummy	-1.190								
	(1.726)								
LNFIT_ABS		0.127							0.123
		(0.071)							(0.071)
LNFIP_ABS			0.125						0.122
			(0.127)						(0.131)
LnNpvRev				0.623***					
				(0.083)					

LnNpvRev_1					0.609***				
					(0.086)				
LnNpvRev_2						0.640***			
						(0.087)			
LnNpvRev_3							0.443*		
							(0.182)		
LnNpvRev_4								0.514	
								(0.183)	
FIT&FIP	2.348**								
	(0.841)								
FIT&TENDER	-0.784								
	(0.731)								
Quota_Dummy	0.041	-0.175	-0.342	0.287	0.287	0.294	-0.281	-0.308	-0.150
	(0.512)	(0.516)	(0.541)	(0.448)	(0.447)	(0.453)	(0.536)	(0.533)	(0.516)
Tax_Dummy	-0.389	-0.391	-0.509	-0.245	-0.274	-0.118	-0.549	-0.598	-0.403
	(0.392)	(0.426)	(0.433)	(0.355)	(0.358)	(0.380)	(0.416)	(0.419)	(0.422)
Tender_Dummy	-0.200	-0.400	-0.237	-0.424	-0.425	-0.423	-0.300	-0.278	-0.362
	(0.444)	(0.493)	(0.521)	(0.353)	(0.368)	(0.365)	(0.520)	(0.527)	(0.491)
CAP_Dummy	0.764	0.321	0.148	0.284	0.336	0.308	0.403	0.344	0.205
	(0.889)	(0.706)	(0.752)	(0.576)	(0.583)	(0.576)	(0.735)	(0.739)	(0.709)
LnGDP	0.511	0.358	0.428	0.312	0.283	0.341	0.403	0.347	0.291
	(0.358)	(0.361)	(0.395)	(0.255)	(0.261)	(0.255)	(0.401)	(0.406)	(0.368)
lnElec.Consumption	-0.426	-0.087	0.011	-0.216	-0.114	-0.249	0.073	0.246	0.005
	(0.806)	(0.834)	(0.920)	(0.644)	(0.670)	(0.658)	(0.945)	(0.973)	(0.858)
LnCoal Share	0.302**	0.322**	0.336**	0.295**	0.304**	0.287**	0.336**	0.351**	0.313*
	(0.099)	(0.117)	(0.126)	(0.104)	(0.106)	(0.107)	(0.126)	(0.127)	(0.123)
LnNatural Gas Share	-0.050	-0.025	-0.014	-0.058	-0.060	-0.056	-0.016	-0.029	-0.033
	(0.041)	(0.055)	(0.064)	(0.038)	(0.039)	(0.039)	(0.057)	(0.060)	(0.060)
LnNuclear Share	-0.014	-0.029	-0.065	0.003	-0.002	0.023	-0.070	-0.074	-0.055
	(0.097)	(0.104)	(0.102)	(0.099)	(0.102)	(0.105)	(0.099)	(0.100)	(0.107)
LnOil Share	-0.230	-0.251	-0.307*	-0.202	-0.197	-0.187	-0.279	-0.290	-0.241
	(0.155)	(0.159)	(0.156)	(0.125)	(0.129)	(0.129)	(0.160)	(0.161)	(0.158)
Ln Renewable Share	0.407***	0.401***	0.411***	0.295**	0.299**	0.301**	0.400***	0.398***	0.407***
	(0.109)	(0.112)	(0.113)	(0.092)	(0.093)	(0.093)	(0.113)	(0.113)	(0.112)
LnPopul.Growth	0.240***	0.246***	0.243***	0.193**	0.193**	0.189**	0.228**	0.233**	0.259***
	(0.056)	(0.063)	(0.070)	(0.069)	(0.070)	(0.071)	(0.076)	(0.073)	(0.064)
LnCO2	-1.264*	-1.661*	-1.958**	-1.467*	-1.566*	-1.536*	-1.856*	-1.999**	-1.769**

	(0.582)	(0.647)	(0.719)	(0.646)	(0.667)	(0.664)	(0.723)	(0.746)	(0.681)
LnPotential	0.151	0.126	0.175	-0.064	-0.078	-0.094	0.167	0.148	0.140
	(0.164)	(0.179)	(0.187)	(0.121)	(0.130)	(0.131)	(0.193)	(0.197)	(0.172)
LnOil Price	-0.220	-0.246	-0.214	-0.091	-0.084	-0.166	-0.114	-0.260	-0.040
	(0.624)	(0.648)	(0.615)	(0.436)	(0.442)	(0.415)	(0.651)	(0.666)	(0.613)
LnNatural Gas Price	1.178	1.290	1.414	0.948	0.958	0.960	1.356	1.486*	1.190
	(0.688)	(0.658)	(0.747)	(0.567)	(0.569)	(0.551)	(0.730)	(0.719)	(0.693)
LnCoal Price	-1.118	-0.823	-1.006	-0.666	-0.666	-0.565	-1.077	-0.976	-1.054
	(0.923)	(1.018)	(1.000)	(0.846)	(0.853)	(0.881)	(1.006)	(1.017)	(0.941)
LnEnergy Import	-0.323*	-0.299*	-0.395**	-0.196*	-0.199*	-0.200*	-0.387**	-0.375**	-0.296*
	(0.149)	(0.145)	(0.141)	(0.099)	(0.101)	(0.102)	(0.139)	(0.141)	(0.143)
Constant	1.549	-0.723	-1.458	0.087	-0.446	-0.112	-1.857	-2.864	0.020
	(5.187)	(5.502)	(5.776)	(4.301)	(4.464)	(4.422)	(5.741)	(5.854)	(5.638)
Effects	Random	Random	Random	Random	Random	Random	Random	Random	Random
Observations	594	594	594	594	594	594	594	594	594
R-squared	0.400	0.388	0.389	0.504	0.497	0.498	0.400	0.400	0.397
Number of Country	27	27	27	27	27	27	27	27	27

AC5 Table 8: Random Effects Results for the Impact of FIS on Solar Photovoltaic Development with Time Lag

This table reports the results for the fixed effects regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of FIS policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no FIS policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy Import Dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(PV1) Model	(PV2) Model	(PV3) Model	(PV4) Model	(PV5) Model	(PV6) Model	(PV7) Model	(PV8) Model	(PV9) Model
L.FIS_Dummy	-0.031								
	(2.080)								
L.FIT_Dummy	1.081								
	(1.962)								
L.FIP_Dummy	-0.138								
	(1.796)								
L.LNFIT_ABS_WIND		0.178*							0.172*
		(0.070)							(0.070)
L.LNFIP_ABS_WIND			0.146						0.136
			(0.134)						(0.132)
L.LnNpvRev				0.714***					
				(0.077)					
L.LnNpvRev__1					0.707***				
					(0.079)				
L.LnNpvRev_2						0.726***			

						(0.088)			
L.LnNpvRev_3							0.625***		
							(0.127)		
L.LnNpvRev_4								0.580	
								(0.150)	
L.FIT&FIP	1.290								
	(0.875)								
L.FIT&TENDER	-0.367								
	(0.756)								
L.Quota_Dummy	0.312	0.143	-0.098	0.545	0.549	0.546	-0.020	-0.072	0.170
	(0.548)	(0.546)	(0.576)	(0.472)	(0.472)	(0.483)	(0.566)	(0.568)	(0.543)
L.Tax_Dummy	-0.383	-0.372	-0.531	-0.265	-0.286	-0.132	-0.584	-0.617	-0.387
	(0.422)	(0.449)	(0.459)	(0.378)	(0.380)	(0.408)	(0.444)	(0.446)	(0.445)
L.Tender_Dummy	-0.372	-0.426	-0.219	-0.395	-0.397	-0.396	-0.290	-0.262	-0.387
	(0.438)	(0.505)	(0.561)	(0.314)	(0.325)	(0.320)	(0.554)	(0.561)	(0.507)
L.CAP_Dummy	0.679	0.399	0.186	0.273	0.315	0.309	0.485	0.394	0.272
	(0.816)	(0.700)	(0.737)	(0.558)	(0.562)	(0.554)	(0.727)	(0.742)	(0.676)
L.LnGDP	0.453	0.300	0.385	0.205	0.187	0.262	0.322	0.310	0.223
	(0.376)	(0.382)	(0.428)	(0.258)	(0.262)	(0.261)	(0.435)	(0.437)	(0.387)
L.LnElec.Consumption	-0.129	0.211	0.377	0.333	0.408	0.231	0.530	0.613	0.347
	(0.880)	(0.898)	(1.049)	(0.689)	(0.710)	(0.705)	(1.084)	(1.093)	(0.935)
L.LnCoal Share	0.284**	0.304*	0.311*	0.296**	0.305**	0.287**	0.311*	0.328*	0.291*
	(0.110)	(0.120)	(0.134)	(0.105)	(0.107)	(0.105)	(0.138)	(0.137)	(0.127)
L.LnNatural Gas Share	-0.034	-0.011	0.008	-0.043	-0.045	-0.038	0.006	-0.005	-0.019
	(0.048)	(0.059)	(0.073)	(0.042)	(0.043)	(0.041)	(0.066)	(0.069)	(0.064)
L.LnNuclear Share	-0.017	-0.038	-0.085	-0.036	-0.040	-0.017	-0.100	-0.091	-0.068
	(0.100)	(0.105)	(0.103)	(0.096)	(0 099)	(0.103)	(0.100)	(0.101)	(0.106)
L.LnOilShare	-0.138	-0.165	-0.241	-0.129	-0.125	-0.116	-0.204	-0.227	-0.150
	(0.152)	(0.160)	(0.166)	(0.132)	(0.134)	(0 133)	(0.168)	(0.172)	(0.157)
L.LnRenewable Share	0.391***	0.385***	0.392***	0.271**	0.273**	0.276**	0.377***	0.378***	0.390***
	(0.108)	(0.108)	(0.110)	(0.086)	(0.086)	(0.086)	(0.109)	(0.110)	(0.108)
L.LnPopul.Growth	0.281***	0.289***	0.276**	0.225**	0.224**	0.226**	0.251*	0.264**	0.301***
	(0.074)	(0.079)	(0.092)	(0.078)	(0.079)	(0.078)	(0.100)	(0.096)	(0.081)
L.LnCO2	-1.277*	-1.660*	-2.041*	-1.774*	-1.858**	-1.793*	-1.976*	-2.084*	-1.792*
	(0.645)	(0.685)	(0.806)	(0.692)	(0.710)	(0.707)	(0.819)	(0.823)	(0.729)
L.LnPotential	0.196	0.160	0.221	-0.067	-0.080	-0.083	0.209	0.192	0.175

	(0.176)	(0.188)	(0.202)	(0.134)	(0.140)	(0.138)	(0.209)	(0.212)	(0.182)
L.LnOil Price	-0.399	-0.471	-0.464	-0.383	-0.373	-0.420	-0.284	-0.527	-0.258
	(0.635)	(0.650)	(0.622)	(0.411)	(0.414)	(0.408)	(0.654)	(0.673)	(0.620)
L.LnNaturalGas Price	1.190	1.351*	1.569*	1.106*	1.108*	1.098*	1.465*	1.641*	1.256
	(0.704)	(0.672)	(0.758)	(0.538)	(0.539)	(0.527)	(0.723)	(0.733)	(0.701)
L.LnCoal Price	-0.721	-0.490	-0.685	-0.327	-0.328	-0.286	-0.804	-0.611	-0.740
	(1.013)	(1.088)	(1.103)	(0.901)	(0.906)	(0.935)	(1.083)	(1.113)	(1.027)
L.LnEnergy Import	-0.241	-0.227	-0.348*	-0.116	-0.117	-0.127	-0.335	-0.329	-0.220
	(0.159)	(0.154)	(0.169)	(0.111)	(0.112)	(0.106)	(0.171)	(0.171)	(0.158)
Constant	-1.012*	-3.128	-4.610**	-3.561	-3.965**	-3.328***	-5.281	-6.204	-2.555*
	(5.725)	(5.899)	(6.556)	(4.593)	(4.715)	(4.711)	(6.504)	(6.524)	(6.168)
Effect	Random	Random	Random	Random	Random	Random	Random	Random	Random
Observations	567	567	567	567	567	567	567	567	567
R-squared	0.404	0.399	0.394	0.401	0.537	0.532	0.418	0.404	0.408
Number of Country	27	27	27	27	27	27	27	27	27

AC5 Table 9: Pearson Correlated Standard Errors (PCSE) Results for the Effect of FIS on Wind Energy Development without Time Lag

This table reports the results for the Pearson Correlated Standard Errors estimates of regression equations (WE1)-(WE9) for the determinants of the wind energy capacity growth due to the strength of *FIS* policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no *FIS* policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy import dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(PV1) Model	(PV2) Model	(PV3) Model	(PV4) Model	(PV5) Model	(PV6) Model	(PV7) Model	(PV8) Model	(PV9) Model
FIS_Dummy	2.931								
	(1.932)								
FIT_Dummy	-2.036								
	(1.932)								
FIP_Dummy	-2.819								
	(1.899)								
LNFIT_ABS_WIND		0.155*							0.156
		(0.036)							(0.036)
LNFIP_ABS_WIND			0.149						0.150**
			(0.046)						(0.049)
LnNpvRev				0.670***					
				(0.054)					
LnNpvRev__1					0.657***				
					(0.055)				
LnNpvRev_2						0.679***			
						(0.058)			
LnNpvRev_3							0.424***		

							(0.085)		
LnNpvRev_4								0.524	
								(0.092)	
FIT&FIP	3.857*								
	(1.883)								
FIT&TENDER	-0.739								
	(0.596)								
Quota_Dummy	0.451*	0.331	-0.061	0.869***	0.882***	0.903***	-0.030	-0.061	0.390
	(0.217)	(0.205)	(0.153)	(0.226)	(0.236)	(0.239)	(0.154)	(0.149)	(0.213)
Tax_Dummy	-0.314*	-0.272	-0.473**	-0.205	-0.229	-0.062	-0.495**	-0.538***	-0.318*
	(0.160)	(0.159)	(0.161)	(0.116)	(0.119)	(0.126)	(0.159)	(0.160)	(0.157)
Tender_Dummy	-0.486	-0.802***	-0.621**	-0.812***	-0.833***	-0.800***	-0.708**	-0.703**	-0.731***
	(0.326)	(0.231)	(0.237)	(0.222)	(0.227)	(0.223)	(0.242)	(0.245)	(0.220)
CAP_Dummy	0.514	0.303	-0.044	0.316*	0.370**	0.349**	0.254	0.206	0.124
	(0.270)	(0.169)	(0.224)	(0.138)	(0.138)	(0.135)	(0.200)	(0.195)	(0.206)
LnGDP	0.910***	0.892***	1.151***	0.670**	0.664**	0.654**	1.111***	1.089***	0.959***
	(0.257)	(0.253)	(0.261)	(0.231)	(0.229)	(0.226)	(0.253)	(0.255)	(0.266)
lnElec.Consumption	-1.313***	-1.360***	-1.677***	-1.063**	-1.050**	-1.061**	-1.626***	-1.589***	-1.443***
	(0.333)	(0.321)	(0.328)	(0.355)	(0.355)	(0.339)	(0.326)	(0.340)	(0.324)
LnCoal Share	0.237***	0.228***	0.254***	0.166**	0.163**	0.164**	0.243***	0.246***	0.231***
	(0.067)	(0.067)	(0.068)	(0.055)	(0.053)	(0.054)	(0.064)	(0.065)	(0.068)
LnNatural Gas Share	-0.048*	-0.026	-0.036	-0.024	-0.024	-0.023	-0.032	-0.043*	-0.040
	(0.021)	(0.018)	(0.020)	(0.015)	(0.015)	(0.014)	(0.020)	(0.021)	(0.021)
LnNuclear Share	0.097*	0.125**	0.120**	0.105*	0.108*	0.128**	0.118**	0.120**	0.110*
	(0.042)	(0.047)	(0.045)	(0.043)	(0.043)	(0.049)	(0.044)	(0.043)	(0.044)
LnOil Share	-0.216**	-0.220***	-0.331***	-0.128*	-0.117*	-0.106	-0.309***	-0.317***	-0.222***
	(0.070)	(0.066)	(0.060)	(0.056)	(0.058)	(0.057)	(0.057)	(0.059)	(0.067)
LnRenewable Share	0.432***	0.438***	0.501***	0.307***	0.313***	0.312***	0.486***	0.490***	0.447***
	(0.056)	(0.059)	(0.065)	(0.047)	(0.048)	(0.048)	(0.064)	(0.064)	(0.059)
LnPopul.Growth	0.177*	0.164*	0.198*	0.087	0.085	0.065	0.195*	0.194**	0.186*
	(0.077)	(0.080)	(0.077)	(0.077)	(0.078)	(0.083)	(0.076)	(0.074)	(0.081)
LnCO2	-0.512	-0.407	-0.640	-0.289	-0.287	-0.336	-0.519	-0.520	-0.454
	(0.373)	(0.333)	(0.351)	(0.312)	(0.310)	(0.299)	(0.335)	(0.336)	(0.336)
LnPotential	0.215**	0.226***	0.294***	0.044	0.040	0.005	0.294***	0.292***	0.247***
	(0.078)	(0.068)	(0.060)	(0.067)	(0.068)	(0.070)	(0.061)	(0.062)	(0.065)
LnOil Price	-0.813**	-0.982***	-1.154***	-0.507*	-0.511*	-0.527*	-1.133***	-1.252***	-0.798**
	(0.290)	(0.290)	(0.323)	(0.231)	(0.232)	(0.214)	(0.318)	(0.321)	(0.292)
LnNatural Gas Price	0.893**	0.955***	1.181***	0.848***	0.852***	0.764**	1.243***	1.361***	0.798**
	(0.289)	(0.277)	(0.296)	(0.253)	(0.254)	(0.247)	(0.290)	(0.302)	(0.267)
LnCoal Price	-0.633	-0.199	-0.453	-0.471	-0.451	-0.280	-0.561	-0.498	-0.390
	(0.382)	(0.355)	(0.358)	(0.334)	(0.334)	(0.310)	(0.379)	(0.367)	(0.350)

LnEnergy Import	-0.386***	-0.381***	-0.552***	-0.188**	-0.190**	-0.207**	-0.527***	-0.521***	-0.387***
	(0.082)	(0.081)	(0.098)	(0.070)	(0.071)	(0.071)	(0.092)	(0.092)	(0.083)
Constant	5.400**	4.343*	5.912***	3.172	3.008	2.726	5.820**	5.508**	5.304**
	(1.660)	(1.761)	(1.792)	(1.851)	(1.874)	(1.802)	(1.807)	(1.859)	(1.699)
Observations	594	594	594	594	594	594	594	594	594
R-squared	0.448	0.422	0.406	0.561	0.552	0.552	0.412	0.412	0.429
Number of Country	27	27	27	27	27	27	27	27	27

AC5 Table 10: Pearson Correlated Standard Errors (PCSE) Results for the Effect of FIS on Wind Energy Development with Time Lag

This table reports the results for the Pearson Correlated Standard Errors estimates of regression equations (WEI)-(WE9) for the determinants of the wind energy capacity growth due to the strength of *FIS* policy. In the second column are the independent variables while the first row are the dependent variables. WE represents Wind Energy. The dependent variable is the natural log of annual added wind energy capacity (*Ln AC*). *Ln PvRev* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the wind farm. *Ln PvRev_1* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIS* policy is the only source of revenue. *Ln PvRev_2* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIT* policy is the only source of revenue. *Ln PvRev_3* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when *FIP* policy is the only source of revenue. *Ln PvRev_4* is the natural log of the revenue per MWh of electricity generated from a wind farm which was adopted in country *j* at time *t* for the entire life of the farm, when there is no *FIS* policy in place and the competitive market is the only source of revenue. FIS_Dummy, FIT_Dummy, FIP_Dummy, Quota_Dummy, Tax_Dummy, Tender_Dummy and CAP_Dummy are dummy variables representing the existence of feed-in-systems (FIT or FIP), Feed-in-Tariffs, Feed-in-Premium, Quota and Green Trading Certificate, Taxes and other Fiscal Benefits, Tender and Cap respectively in a country at a given time. FIT&FIP represent the interaction between Fixed Tariff and Premium Tariff. FIS&TEND represents the interactions between FIS with Tender in any country at a given time. *Ln GDP, Ln Elect.Consumption, Ln Coal Share, Ln Natural Gas Share, Ln Nuclear Share, Ln Oil Share, Ln Renewable Share, Ln Popul.Growth, Ln CO2, Ln Potential, Ln Oil Price, Ln Natural Gas Price, Ln Coal Price, Ln Energy Import* represents the natural logs of Gross Domestic Product per Capita, Electricity Consumption per Capita, Percentage of Electricity Production from Coal Sources, Percentage of Electricity Production from Natural Gas sources, Percentage of Electricity Production from Nuclear Sources, , Percentage of Electricity Production from Oil Sources, Percentage of Electricity Production from Renewable Sources, Population Growth, Carbon Emissions, Land Size as a Proxy for Technical Potential of Wind, Oil price, Natural gas price, coal price and Energy import dependence respectively. Constant is the regression intercept while observations is the number of observations in the model. The Robust standard errors are in parentheses and *, **, *** denote 10%, 5% and 1% significant levels, respectively.

VARIABLES	(PV1) Model	(PV2) Model	(PV3) Model	(PV4) Model	(PV5) Model	(PV6) Model	(PV7) Model	(PV8) Model	(PV9) Model
L.FIS_Dummy	2.345								
	(2.776)								
L.FIT_Dummy	1.226								
	(2.773)								
L.FIP_Dummy	-2.017								
	(2.732)								
L.LNFIT_ABS_WIND		0.193							0.193
		(0.038)							(0.039)
L.LNFIP_ABS_WIND			0.162*						0.160
			(0.048)						(0.050)
L.LnNpvRev				0.754***					
				(0.054)					
L.LnNpvRev__1					0.747***				
					(0.054)				
L.LnNpvRev_2						0.761***			

						(0.056)			
L.LnNpvRev_3							0.588***		
							(0.076)		
L.LnNpvRev_4								0.586	
								(0.086)	
L.FIT&FIP	3.045								
	(2.727)								
L.FIT&TENDER	-0.325								
	(0.613)								
L.Quota_Dummy	0.667**	0.592**	0.107	1.080***	1.093***	1.110***	0.152	0.102	0.652**
	(0.218)	(0.216)	(0.154)	(0.228)	(0.235)	(0.240)	(0.158)	(0.151)	(0.224)
L.Tax_Dummy	-0.283	-0.229	-0.460**	-0.187	-0.204	-0.045	-0.499**	-0.521**	-0.271
	(0.165)	(0.169)	(0.169)	(0.115)	(0.117)	(0.129)	(0.167)	(0.169)	(0.165)
L.Tender_Dummy	-0.672*	-0.817***	-0.627*	-0.789***	-0.806***	-0.775***	-0.715**	-0.710**	-0.746**
	(0.331)	(0.236)	(0.253)	(0.225)	(0.229)	(0.226)	(0.254)	(0.258)	(0.227)
L.CAP_Dummy	0.461	0.399*	0.011	0.340*	0.384*	0.378*	0.346	0.271	0.218
	(0.284)	(0.183)	(0.244)	(0.149)	(0.152)	(0.148)	(0.221)	(0.216)	(0.220)
L.LnGDP	0.881**	0.836**	1.145***	0.570**	0.567**	0.573**	1.109***	1.084***	0.897**
	(0.270)	(0.262)	(0.265)	(0.218)	(0.217)	(0.217)	(0.258)	(0.258)	(0.273)
L.lnElec.Consumption	-1.210***	-1.207***	-1.604***	-0.819*	-0.809*	-0.839*	-1.550***	-1.515***	-1.283***
	(0.338)	(0.332)	(0.340)	(0.349)	(0.351)	(0.337)	(0.332)	(0.350)	(0.335)
L.LnCoal Share	0.221**	0.219**	0.242***	0.159**	0.157**	0.159**	0.231***	0.236***	0.220**
	(0.071)	(0.071)	(0.071)	(0.055)	(0.055)	(0.054)	(0.067)	(0.068)	(0.071)
L.LnNatural Gas Share	-0.037	-0.017	-0.028	-0.014	-0.014	-0.011	-0.025	-0.033	-0.031
	(0.022)	(0.018)	(0.021)	(0.014)	(0.014)	(0.014)	(0.021)	(0.022)	(0.021)
L.LnNuclear Share	0.114*	0.135**	0.137**	0.117*	0.118*	0.135*	0.131**	0.138**	0.122**
	(0.044)	(0.048)	(0.047)	(0.050)	(0.050)	(0.055)	(0.045)	(0.045)	(0.045)
L.LnOil Share	-0.149*	-0.157*	-0.294***	-0.060	-0.052	-0.044	-0.268***	-0.281***	-0.156*
	(0.071)	(0.068)	(0.060)	(0.055)	(0.056)	(0.056)	(0.058)	(0.059)	(0.069)
L.LnRenewable Share	0.419***	0.421***	0.494***	0.296***	0.299***	0.299***	0.477***	0.483***	0.430***
	(0.055)	(0.057)	(0.064)	(0.047)	(0.047)	(0.047)	(0.063)	(0.063)	(0.057)
L.LnPopul.Growth	0.209**	0.198*	0.224**	0.106	0.104	0.092	0.220**	0.220**	0.216**
	(0.078)	(0.081)	(0.076)	(0.078)	(0.079)	(0.084)	(0.075)	(0.074)	(0.081)
L.LnCO2	-0.397	-0.346	-0.576	-0.319	-0.319	-0.364	-0.450	-0.461	-0.389
	(0.386)	(0.356)	(0.377)	(0.327)	(0.325)	(0.319)	(0.351)	(0.356)	(0.359)
L.LnPotential	0.265***	0.253***	0.326***	0.043	0.040	0.013	0.329***	0.324***	0.272***

	(0.072)	(0.068)	(0.056)	(0.062)	(0.063)	(0.067)	(0.055)	(0.056)	(0.063)
L.LnOil Price	-1.005**	-1.165***	-1.409***	-0.738**	-0.734**	-0.727**	-1.343***	-1.511***	-0.986**
	(0.313)	(0.309)	(0.342)	(0.232)	(0.234)	(0.228)	(0.329)	(0.341)	(0.308)
L.LnNatural Gas Price	0.889**	1.017***	1.328***	0.991***	0.991***	0.890***	1.365***	1.500***	0.867**
	(0.292)	(0.286)	(0.311)	(0.255)	(0.256)	(0.247)	(0.298)	(0.317)	(0.277)
L.LnCoal Price	-0.209	0.089	-0.173	-0.205	-0.193	-0.074	-0.338	-0.193	-0.105
	(0.381)	(0.362)	(0.365)	(0.346)	(0.347)	(0.327)	(0.382)	(0.374)	(0.359)
L.LnEnergy Import	-0.338***	-0.336***	-0.542***	-0.149*	-0.149*	-0.170**	-0.515***	-0.514***	-0.341***
	(0.081)	(0.079)	(0.097)	(0.067)	(0.068)	(0.066)	(0.092)	(0.092)	(0.081)
Constant	3.854*	2.922	4.636*	1.408	1.282	1.207	4.655*	4.158*	3.862*
	(1.672)	(1.790)	(1.872)	(1.811)	(1.834)	(1.769)	(1.834)	(1.929)	(1.730)
Observations	567	567	567	567	567	567	567	567	567
R-squared	0.453	0.440	0.414	0.595	0.589	0.585	0.427	0.419	0.448
Number of Country	27	27	27	27	27	27	27	27	27

AC5 Table 11: Correlation Matrix

	Added Capacity Wind	Added Capacity Solar	FIS_Dummy Wind	FIS Dummy Solar	FIT_Dummy Wind	FIT_Dummy Solar	FIP_Dummy Wind
Added Capacity Wind	1						
Added Capacity Solar	0.4484	1					
FIS_Dummy	0.2901	0.1137	1				
FIS_Dummy solar	0.3105	0.1404	0.8158	1			
FIT_Dummy	0.3246	0.1357	0.8727	0.7691	1		
FIT_Dummy Solar	0.343	0.1565	0.7408	0.9153	0.8548	1	
FIP_Dummy	0.0745	0.0722	0.4448	0.3397	0.0979	0.124	1
FIP_Dummy Solar	-0.0289	0.0684	0.3591	0.4146	0.1158	0.1472	0.8074
FIT&FIP	0.215	0.2268	0.2877	0.3181	0.3296	0.3483	0.6467
FIT&FIP Solar	0.0907	0.2166	0.2484	0.2868	0.2847	0.3133	0.5585
FIT&TENDER	0.0288	-0.0259	0.1993	0.2081	0.2283	0.2287	-0.0618
Ln PvRev Wind	0.4644	0.252	0.5051	0.4618	0.356	0.3813	0.3145
Ln PvRev Solar	0.5025	0.2837	0.5293	0.616	0.5967	0.6621	0.1554
Ln PvRev_1 Wind	0.4104	0.1828	0.7377	0.6599	0.5585	0.5653	0.4228
Ln PvRev_1 Solar	0.5014	0.2745	0.5263	0.6119	0.6035	0.6685	0.1428
Ln PvRev_2 Wind	0.4577	0.2315	0.6402	0.6273	0.7332	0.6919	0.0175
Ln PvRev_2 Solar	0.5183	0.289	0.5183	0.6028	0.5943	0.6585	0.1032
Ln PvRev_3 Wind	0.1206	0.0175	0.3425	0.2195	0.0232	0.0517	0.7349
Ln PvRev_3 Solar	-0.0595	-0.0086	0.1888	0.218	0.2164	0.2382	0.4245
Ln PvRev_4 Wind	0.4056	0.2753	0.4223	0.3421	0.3189	0.2927	0.2315
Ln PvRev_4 Solar	-0.0528	-0.0088	0.1555	0.1795	0.1782	0.1961	0.3496
Quota_Dummy	0.138	0.0863	-0.2657	-0.2069	-0.2194	-0.1788	-0.1528
Tax_Dummy	-0.0809	-0.069	-0.0337	-0.1617	-0.1835	-0.1979	0.1938
Tender_Dummy	-0.0369	-0.0464	-0.0114	0.0268	0.0249	0.0506	-0.1011
CAP_Dummy	0.059	-0.0126	0.3668	0.3016	0.1879	0.096	0.3311
Ln GDP	0.246	0.1218	0.2902	0.144	0.2335	0.1415	0.1083
ln Elect.Consumption	0.1141	0.0606	0.2048	0.1323	0.1597	0.1215	0.1283
Ln Coal Share	0.1232	0.0618	0.0258	-0.0145	-0.021	-0.0362	0.1471
Ln Natural Gas Share	-0.0159	0.0044	0.163	0.1532	0.1953	0.1857	0.2383
Ln Nuclear Share	0.1376	0.04	-0.0585	0.1006	0.04	0.1721	0.0077
Ln Oil Share	-0.0413	-0.0407	-0.2314	-0.2721	-0.2098	-0.2614	-0.2217
Ln Renewable Share	0.3281	0.2028	0.402	0.2585	0.2933	0.2267	0.2591
Ln Popul.Growth	-0.0411	-0.041	-0.0856	-0.0128	-0.1054	-0.0454	-0.0852
Ln CO2	0.0209	0.0202	0.1663	0.0789	0.0766	0.0114	0.1653
Ln Potential	0.3634	0.1603	-0.0957	-0.0568	-0.0143	0.0141	-0.1527

Ln Oil Price	0 1242	0.1075	0.3031	0.2208	0.2209	0.1941	0.1883
Ln Natural Gas Price	0.1811	0.1247	0.4255	0.3964	0.3361	0.3205	0.3005
Ln Coal Price	0.2048	0.1462	0.4623	0.3755	0.3798	0.3186	0.333
Ln Energy Import	-0.1074	-0.0967	-0.1239	-0.2864	-0.2858	-0.3051	0.1777

	FIP_Dummy Solar	FIT&FIP	FIT&FIP Solar	FIT&TEND	Ln PvRev Wind	Ln PvRev Solar	Ln PvRev_1 Wind
FIP_Dummy Solar	1						
FIT&FIP	0.607	1					
FIT&FIP Solar	0.6917	0.8896	1				
FIT&TEND	-0.0499	-0.04	-0.0345	1			
Ln PvRev Wind	0.1836	0.1136	0.0518	0.1712	1		
Ln PvRev Solar	0.1508	0.3311	0.2771	0.1787	0.4127	1	
Ln PvRev_1 Wind	0.2658	0.1867	0.1154	0.2079	0.7843	0.5447	1
Ln PvRev_1 Solar	0.1347	0.3336	0.2792	0.1803	0.4033	0.9948	0.5403
Ln PvRev_2 Wind	0.0074	0.1892	0.1348	0.279	0.6083	0.6418	0.7872
Ln PvRev_2 Solar	0.0848	0.2818	0.2188	0.1867	0.4186	0.9552	0.554
Ln PvRev_3 Wind	0.4364	0.3228	0.1701	-0.0478	0.4731	0.1184	0.5745
Ln PvRev_3 Solar	0.5258	0.587	0.661	-0.0262	0.0532	0.3365	0.1021
Ln PvRev_4 Wind	0.1105	0.1011	0.038	0.2133	0.9197	0.3608	0.6538
Ln PvRev_4 Solar	0.433	0.4834	0.5443	-0.0216	-0.0462	0.2633	-0.009
Quota_Dummy	-0.1234	-0.0988	-0.0853	0.0498	0.2595	-0.1631	-0.1728
Tax_Dummy	0.0465	-0.0358	-0.0133	-0.0744	0.0682	-0.1514	-0.0082
Tender_Dummy	-0.0816	-0.0654	-0.0565	0.611	0.025	0.0395	0.0273
CAP_Dummy	0.3096	0.0633	-0.0656	0.3814	0.357	0.1277	0.4388
Ln GDP	0.0083	0.027	0.0095	-0.006	0.2943	0.1749	0.1998
ln Elect.Consumption	0.0805	0.075	0.0751	-0.0452	0.1914	0.1478	0.1053
Ln Coal Share	0.1216	0.1097	0.1146	-0.1473	0.0309	0.0654	0.062
Ln Natural Gas Share	0.2797	0.3576	0.3931	0.0191	-0.0492	0.0721	-0.0246
Ln Nuclear Share	0.0367	0.2062	0.1902	-0.1219	0.0183	0.135	-0.0022
Ln Oil Share	-0.2564	-0.2355	-0.276	-0.0683	-0.245	-0.1611	-0.1761
Ln Renewable Share	0.1065	0.1233	0.0689	0.1434	0.5127	0.2804	0.4157
Ln Popul.Growth	-0.0716	-0.1426	-0.1526	-0.0175	-0.0071	-0.0582	-0.0147
Ln CO2	0.1598	0.0395	0.0577	-0.1642	0.0176	0.0392	0.033
Ln Potential	-0.2151	-0.0231	-0.0967	0.0175	0.216	0.1674	0.1173
Ln Oil Price	0.0983	0.0785	0.0611	0.0678	0.464	0.1314	0.3404
Ln Natural Gas Price	0.2896	0.2011	0.1805	0.0586	0.5314	0.2098	0.4211
Ln Coal Price	0.3258	0.261	0.2718	0.0931	0.5369	0.2471	0.4344
Ln Energy Import	-0.0142	-0.0751	-0.045	-0.1121	-0.1378	-0.2268	-0.0799

	Ln PvRev_1 Solar	Ln PvRev_2 Wind	Ln *Pv*Rev_2 Solar	Ln PvRev_3 Wind	Ln PvRev_3 Solar	Ln PvRev_4 Wind	Ln PvRev_4 Solar
Ln PvRev_1 Solar	1						
Ln PvRev_2 Wind	0.6471	1					
Ln PvRev_2 Solar	0.9603	0.6723	1				
Ln PvRev_3 Wind	0.1062	0.1073	0.101	1			
Ln PvRev_3 Solar	0.3384	0.0935	0.1787	0.2312	1		
Ln PvRev_4 Wind	0.3511	0.5588	0.3646	0.3877	0.0295	1	
Ln PvRev_4 Solar	0.2648	-0.0341	0.0877	0.0712	0.7886	-0.0454	1
Quota_Dummy	-0.1679	-0.115	-0.1649	-0.1181	-0.0649	0.3092	-0.0534
Tax_Dummy	-0.1481	-0.2089	-0.195	0.235	0.0545	0.0628	0.0991
Tender_Dummy	0.0417	0.0899	0.0469	-0.0782	-0.0429	0.0655	-0.0354
CAP_Dummy	0.1124	0.2732	0.1198	0.3583	-0.0499	0.3952	-0.0411
Ln GDP	0.1725	0.1274	0.1786	0.1378	-0.019	0.3074	-0.0074
ln Elect.Consumption	0.1499	0.0607	0.1539	0.1034	0.042	0.2114	0.0275
Ln Coal Share	0.0745	0.0017	0.0814	0.082	0.0703	-0.0335	0.03
Ln Natural Gas Share	0.0757	0.0041	0.0612	-0.0094	0.2395	-0.0171	0.3501
Ln Nuclear Share	0.1435	0.0654	0.1266	-0.0301	0.1594	-0.0558	0.1385
Ln Oil Share	-0.1741	-0.188	-0.1777	-0.0864	-0.2336	-0.24	-0.1658
Ln Renewable Share	0.2743	0.3056	0.2727	0.2905	0.0523	0.5561	0.04
Ln Popul.Growth	-0.0609	-0.019	-0.0373	-0.0382	-0.1167	0.0219	-0.1254
Ln CO2	0.0422	-0.0569	0.0552	0.1172	0.0303	0.0038	-0.0194
Ln Potential	0.1746	0.1789	0.1904	-0.0489	-0.0983	0.133	-0.1157
Ln Oil Price	0.128	0.2843	0.126	0.1954	0.0582	0.518	0.0607
Ln Natural Gas Price	0.2067	0.3636	0.2072	0.2613	0.1804	0.5636	0.1038
Ln Coal Price	0.2438	0.3966	0.2308	0.243	0.2561	0.5888	0.1736
Ln Energy Import	-0.2197	-0.2707	-0.2108	0.1947	-0.0261	-0.1646	-0.0554

	Quota_Dummy	Tax_Dummy	Tender_Dummy	CAP_Dummy	Ln GDP	Ln Elect.Consumption	Ln Coal Share
Quota_Dummy	1						
Tax_Dummy	0.0471	1					
Tender_Dummy	0.0012	-0.1218	1				
CAP_Dummy	-0.0469	-0.0314	0.2142	1			
Ln GDP	0.0426	0.1618	0.1169	0.1178	1		
ln Elect.Consumption	-0.0093	0.2093	-0.0091	0.0348	0.7729	1	
Ln Coal Share	-0.1376	0.0887	-0.0668	-0.1034	-0.0667	-0.0403	1
Ln Natural Gas Share	-0 0305	-0.078	0.0141	0.001	0.0792	0.065	0.069

Ln Nuclear Share	-0.0172	-0.0615	-0.0534	-0.239	-0.0654	0.2168	0.0172
Ln Oil Share	-0.1941	-0.0274	0.0104	-0.0534	-0.099	-0.4283	0.0193
Ln Renewable Share	0.1195	0.2178	0.0415	0.3052	0.582	0.5381	-0.0345
Ln Popul.Growth	0.0353	-0.1902	0.0039	0.021	-0.1571	-0.1501	-0.228
Ln CO2	-0.1456	0.0927	-0.0436	-0.0064	0.5651	0.6521	0.3687
Ln Potential	0.205	0.0341	0.0948	-0.0749	-0.081	-0.0422	0.2278
Ln Oil Price	0.1455	0.2103	0.0174	0.1995	0.2498	0.2795	-0.0692
Ln Natural Gas Price	0.1851	0.133	-0.0043	0.2754	0.2175	0.1413	0.0289
Ln Coal Price	0.1728	0.0855	0.0662	0.3156	0.2464	0.1555	0.0447
Ln Energy Import	-0.007	0.2418	0.173	-0.1432	0.0165	-0 0334	0.3401

	Ln Natural Gas Share	Ln Nuclear Share	Ln Oil Share	Ln Renewable Share	Ln Popul.Growth	Ln CO2	Ln Potential
Ln Natural Gas Share	1						
Ln Nuclear Share	0.1002	1					
Ln Oil Share	-0.2447	-0.3223	1				
Ln Renewable Share	0.0721	-0.0618	-0.2152	1			
Ln Popul.Growth	-0.0852	-0.0997	0.0218	-0.1341	1		
Ln CO2	0.0317	-0.1113	-0.2862	0.2774	-0.0769	1	
Ln Potential	-0.3012	0.3233	0.0596	0.0247	-0.263	-0.3433	1
Ln Oil Price	0.0706	0.193	-0.2716	0.463	0.0982	-0.0234	0.1385
Ln Natural Gas Price	0.1008	0.0674	-0.2971	0.4075	0.079	0.0186	0.0328
Ln Coal Price	0.1147	0.0329	-0.3441	0.448	0.0079	0.0741	-0.0087
Ln Energy Import	-0.0467	-0.0473	-0.0865	-0.0263	-0.0915	0.1343	0.0931

	Ln Oil Price	Ln Natural Gas Price	Ln Coal Price	Ln Energy Import
Ln Oil Price	1			
Ln Natural Gas Price	0.8092	1		
Ln Coal Price	0.6766	0.8336	1	
Ln Energy Import	-0.1749	-0.1251	-0.1182	1

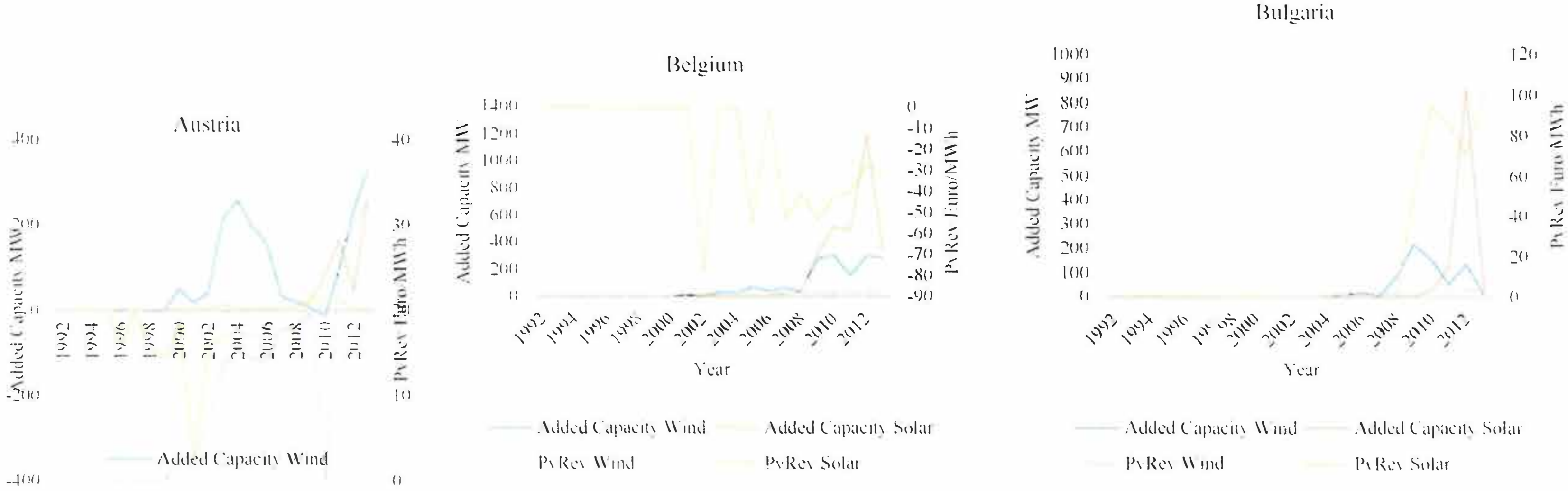
AC5 Table 12: Description of Variables

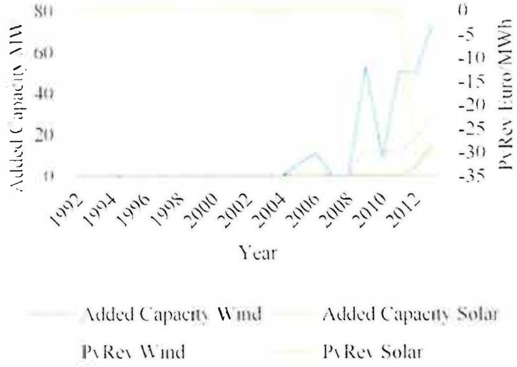
This Table describes the variables used in this research with their definitions, notation and sources

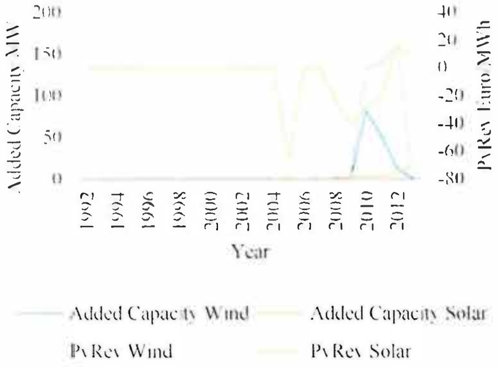
Variables	**Notation**	**Definition**	**Source of Data**
Wind Energy Data			
Natural log of Annual Wind added Capacity 1992-2013 MW	Ln AC Wind	Total annual added wind capacity by all countries from 1992-2013.	European Wind Energy Association/Eurostat
Natural log of Annual Solar PV added Capacity 1992-2013 MW	Ln AC Solar	Total annual added solar capacity from 1992-2013.	European Wind Energy Association/Eurostat Own Computation
Wind Energy Policies			
Feed-In-Tariff Wind (Dummy)	FIT_Dummy/Years	Dummy variable representing existence or experience of FIT.	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Feed-In-Premium Wind (Dummy)	FIP_Dummy	Dummy variable representing existence or experience of FIP.	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Interaction between Fit &FIP	FIT&FIP	Dummy variable with value of 1 if both premium and fixed tariffs are in place and zero otherwise.	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Contribution of FIT	FIT_ABS	Monetary value of the FIT euro per MWh per unit of time	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Contribution of FIP	FIP_ABS	Monetary value of the FIP euro per MWh per unit of time	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
PvRev	PvRev	Present value of revenue per MWh for generating electricity from wind or solar for the entire technology life.	Own computation
PvRev_1	PvRev_1	Present value of revenue per MWh for generating electricity from wind or solar under FIS policy.	Own computation
PvRev_2	PvRev_2	Present value of revenue per MWh for generating electricity from wind or solar when only FIT policy in place.	Own computation
PvRev_3	PvRev_3	Present value of revenue per MWh for generating electricity from wind or solar when there is only FIP in place.	Own computation
PvRev_4	PvRev_4	Present value of revenue for generating per MWh for generating electricity from wind or solar when there is no FIS in place.	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Quota and Tradable Green Certificates (Dummy)	Quota_Dummy/Years	Dummy variable representing existence or experience of Quota.	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Fiscal Incentives (Dummy)	Tax_Dummy/Years	Dummy variable representing existence or experience of FIS.	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014

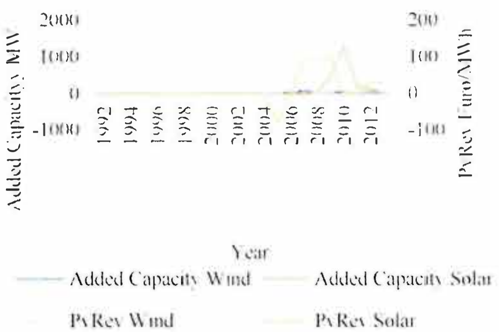
Tender (Dummy)	Tender_Dummy/Years	Dummy variable representing existence or experience of Tender.	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Cap (Dummy)	Cap_Dummy/Years	Dummy variable representing existence or experience of Cap.	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Interaction between Fit &FIP	FIT&FIP	Interaction between FIT &FIP	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Interaction between Fit &Tender	FIS&Tender	Interaction between FIT &Tender	Huber et al. (2004), Haas et al. (2011) and IEA/IRENA 2014
Control Variables			
Gross Domestic Product per capita	GDP	Country's annual GDP per capita, Constant 2005 international USD in dollars	The World Bank
Electric power consumption (kWh per capita)	Elect.Consumption	Total Electricity power consumption per capita in Kwh	The World Bank
Electricity production from Coal sources(% of total)	Coal Share	Percentage annual electricity production from coal	The World Bank/Eurostat
Electricity production from Natural gas sources (% of total)	Natural Gas Share	Percentage annual electricity production from Natural gas	The World Bank/Eurostat
Electricity production from Nuclear sources (% of total)	Nuclear Share	Percentage annual electricity production from Nuclear	The World Bank/Eurostat
Electricity production from oil	Oil Share	Percentage annual electricity production from oil	The World Bank/Eurostat
Electricity production from renewable sources, excluding hydroelectric (% of total)	Renewable Share	Percentage annual electricity production from all Renewable Sources Excluding hydroelectric	The World bank/Eurostat
CO2 emissions (metric tons per capita)	CO2	Total carbon emission per capita	The World bank
Population growth (annual %)	Popul.Growth	Total annual percentage growth in population	The World bank
Wind Technical Potential (Land Dimension)	Potential	Technical Potential of Wind	UN Statistics Division, Demographic year Book,
Oil prices Euro	Oil Price	Annual oil prices in Euro	IEA/OECD fact book, Eurostat
Coal Prices Euro	Natural Gas Price	Annual coal prices Euro	IEA/OECD fact book, Eurostat
Natural Gas Prices	Coal Price	Annual natural gas prices in Euro	IEA/OECD fact book, Eurostat
Energy Import Dependence	Energy Import	Energy dependence is the amount of energy a country needs to satisfy its energy consumption. This is calculated by dividing net energy imports by gross inland energy consumption plus maritime bunkers	Eurostat

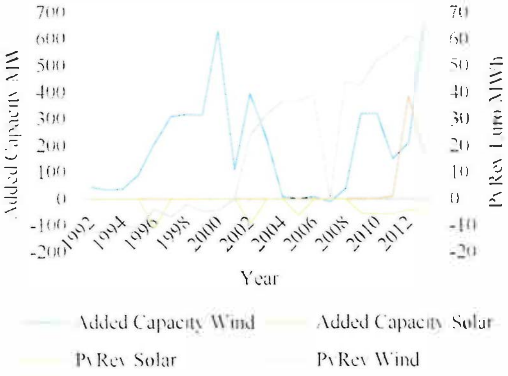
AC5 Figure 1: Graph of Movement between *NpRev* Values and Annual Added Capacity

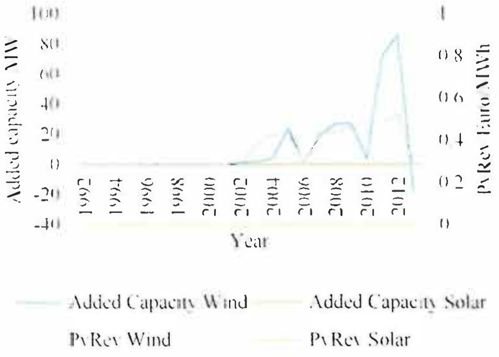


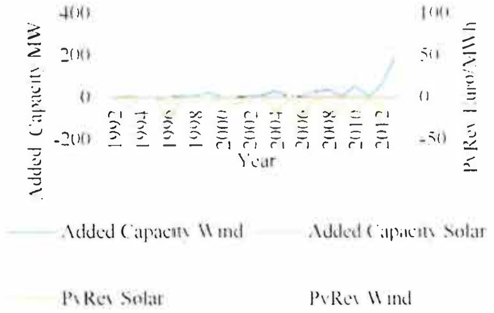

Croatia

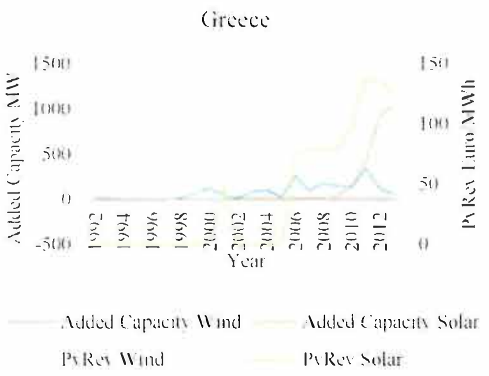

Cyprus

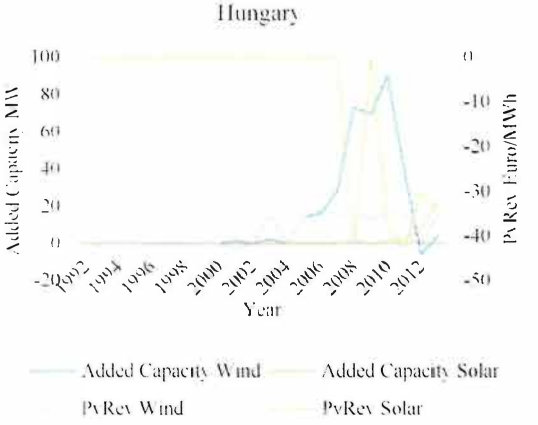

Czech Republic

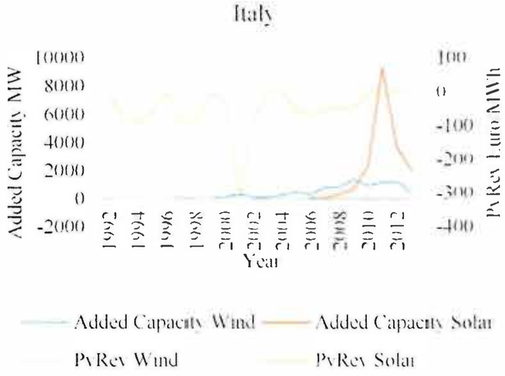

Denmark


Estonia

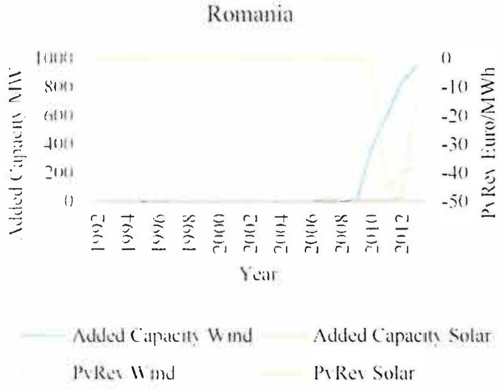

Finland

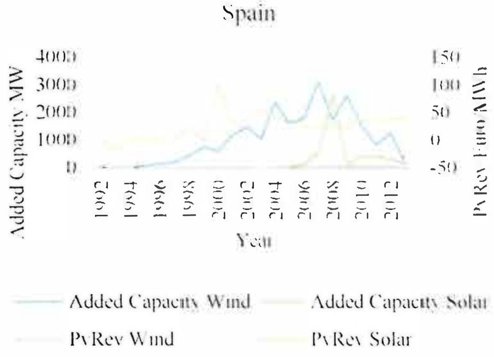

Greece
Added Capacity MW
1500
1000
500
0
-500
PvRev Euro/MWh
150
100
50
0
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar

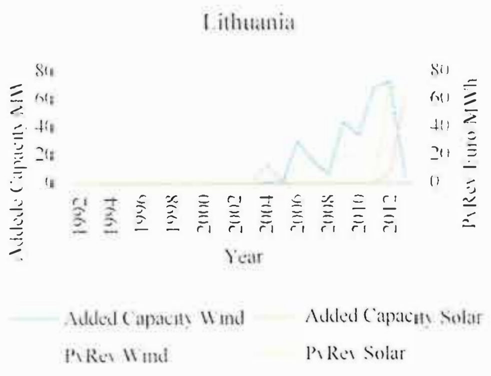

Hungary
Added Capacity MW
100
80
60
40
20
0
-20
PvRev Euro/MWh
0
-10
-20
-30
-40
-50
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar

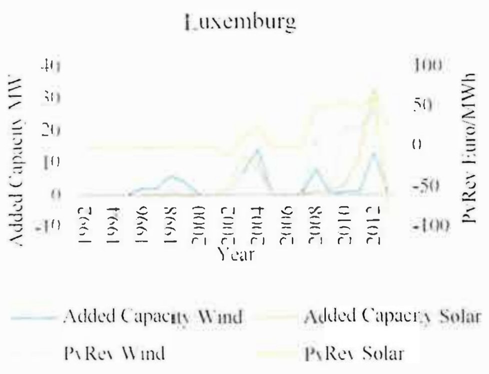

Italy
Added Capacity MW
10000
8000
6000
4000
2000
0
-2000
PvRev Euro/MWh
100
0
-100
-200
-300
-400
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar

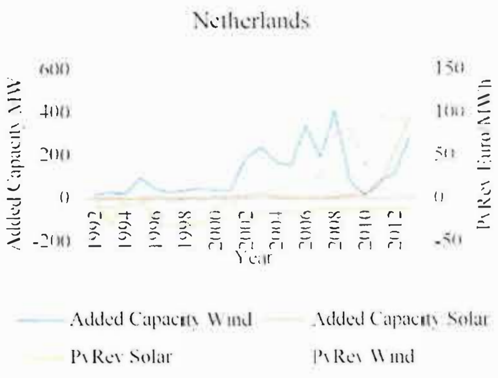

Ireland
Added Capacity MW
400
200
0
-200
PvRev Euro/MWh
1
0.5
0
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
AYear
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar

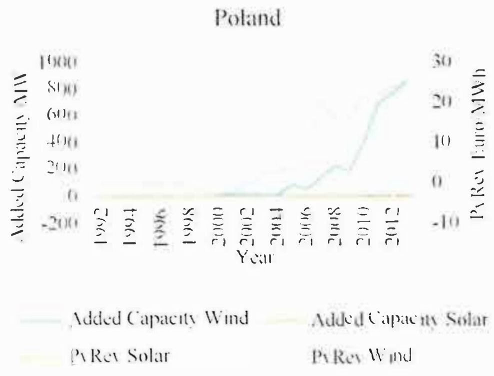

Romania
Added Capacity MW
1000
800
600
400
200
0
PvRev Euro/MWh
0
-10
-20
-30
-40
-50
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar

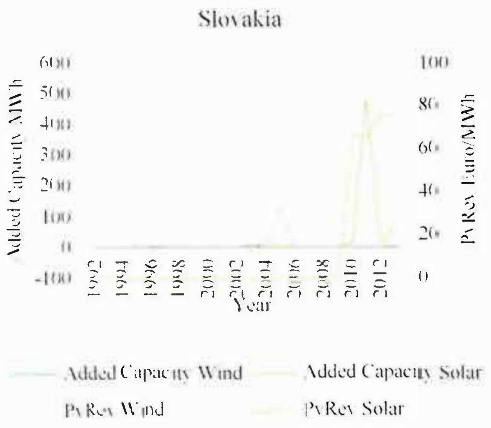

Spain
Added Capacity MW
4000
3000
2000
1000
0
PvRev Euro/MWh
150
100
50
0
-50
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar

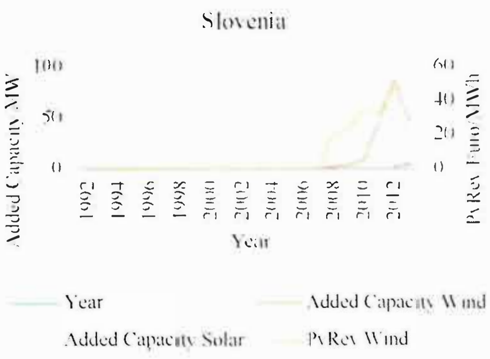

Lithuania
Addede Capacity MW
80
60
40
20
0
PvRev Euro MWh
80
60
40
20
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar

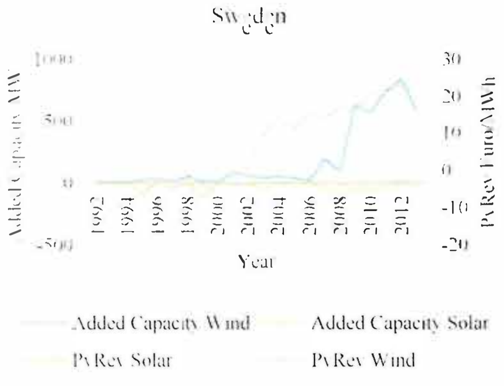

Luxemburg
Added Capacity MW
40
30
20
10
0
-10
PvRev Euro/MWh
100
50
0
-50
-100
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar


Netherlands
Added Capacity MW
600
400
200
0
-200
PvRev Euro MWh
150
100
50
0
-50
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Solar
PvRev Wind

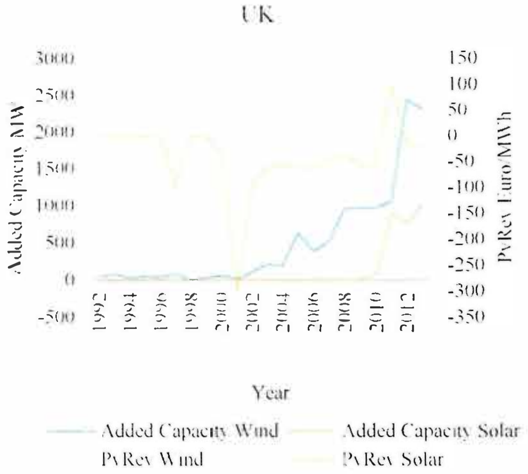

Poland
Added Capacity MW
1000
800
600
400
200
0
-200
PvRev Euro MWh
30
20
10
0
-10
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Solar
PvRev Wind


Slovakia
Added Capacity MWh
600
500
400
300
200
100
0
-100
PvRev Euro/MWh
100
80
60
40
20
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind
PvRev Solar

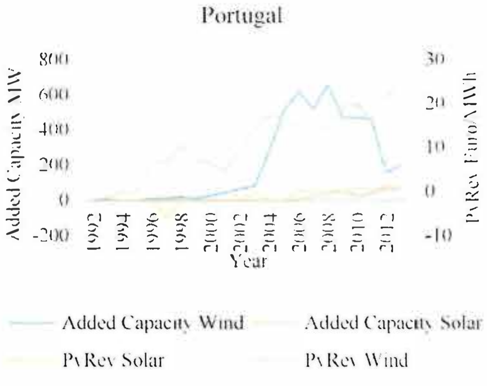

Slovenia
Added Capacity MW
100
50
0
PvRev Euro MWh
60
40
20
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
Year
Added Capacity Wind
Added Capacity Solar
PvRev Wind



Sweden



UK



Portugal