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Factors Affecting the Evolution of Renewable Electricity Generating Capacities: A Panel Data Analysis of European Countries

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ABSTRACT

Promoting renewable sources in the energy sector became an important goal for policymakers, especially in the European Union, where related to the 2020 goals of the Community, concrete targets have been set for each member state. This paper aims to analyse, what factors have an effect on the development of renewable energy sources in the electricity sector. Empirical analysis was conducted based on data from 30 European countries from the years between 2009 and 2016. The results of fixed effects vector decomposition estimation show that there are a number of factors - import dependency, total capacity, electricity price, per capita gross domestic product, support schemes and natural endowment - that affect the development of new renewable electricity generating capacities. It is also proved by the results that consumer commitment has not had any effect on RES development so far.

Keywords: Renewable Energy Sources, Electricity Generation, Panel Data Estimation, Fixed Effect Vector Decomposition
JEL Classifications: O52, Q42, Q43

1. INTRODUCTION

Renewable energy sources (hereafter RES) are the core elements in shifting energy systems toward environmental sustainability. However, there are other motivating factors apart from environmental concerns for RES utilization. Lipp (2007) identifies three major objectives regarding this movement: Decreasing negative environmental impacts, energy security, and economic development.

In the European Union (hereafter EU) each member state (hereafter MS) has taken obligatory targets to achieve a 20% share of RES on an EU-level in the gross final energy consumption by 2020. Gross final energy consumption shall be calculated as a sum of three elements: (a) Electricity consumption; (b) heating and cooling; and (c) transport (European Parliament, 2009a). MSs have implemented various measures to ensure that the targets will be reached, however, it can be said that MSs are not equally successful in their actions. While some MSs will hardly be able to reach their targets, others seem to succeed in accelerating RES development (EUFORES, 2015; Proskurina et al., 2016; Liobikiené and Butkus, 2017). Although, national policy measures play a key role in RES development, the differences between MSs performances might be explained also by market environment, economic effects, public acceptance or natural endowments. RES development is a result of the interaction of such different factors. The exact identification of these factors is necessary to make grounded policy decisions.

Therefore, RES share has been a widely analysed topic in scientific research. Since similar trends and targets emerged in all other continents (e.g. Bugaje, 2006; Lo, 2014; Chen et al., 2014; Barbose et al., 2016), researchers from non-European countries also focus on these issues.

A number of reviews or qualitative findings have been already issued in connection with this topic. Some of them aim to summarize the RES potential or future possibilities of one country (e.g. Lund and Mathiesen, 2009; Golusin et al., 2010; Kohlheb, 2015), others attempt to draw general conclusions based on different policy measures, first of all RES support instruments (Fouquet and Johansson, 2008; Kitzing et al., 2012; Del Río and Mir-Artigues, 2014).

Empirical studies regarding factors influencing RES development or the effectiveness of policy measures have also been published. Table 1 provides a summary of the relevant papers and applied models in this topic. The table indicates a wide variety regarding the scope of conducted analysis, applied econometric models, and used specifications. Estimations on total energy values and particularly on electricity have been conducted as well. While some papers measure the impact on consumption, others choose to set generation, capacity, or even the number of patent applications in specific technologies as dependent variable.

Taking all previous relevant research into consideration, the aim of this paper is to provide a contribution to the results of former empirical studies with RES electricity in the focal point by identifying factors influencing RES development. This paper improves existing literature in three ways. First, by integrating good and avoiding bad solutions applied in previous papers, a deliberate choice of variables and econometric model ensures an estimation methodologically valid and results explainable from an energy perspective as well. Second, this analysis uses a sample of 30 European countries. None of the previous studies (Table 1) covered so many European countries in their samples so far. This enables to improve the precision of the estimates. Finally, data used for this analysis are taken from the period between 2009 and 2016. In contrast to other empirical studies on this topic these are more recent data and they allow us to inspect the latest trends of RES development in Europe.

Table 1: Relevant empirical studies on RES development

Author	Dependent variable	Model specification	Timeframe	Units
Menz and Vachon (2006)	Cumulative wind electricity generating capacity	OLS cross-section	1998–2003	50 US states
Carley (2009)	Share of RES in electricity generation, total amount of RES electricity generation	FE, FEVD	1998–2006	50 US states
Sadorsky (2009)	Natural logarithm of RES energy consumption per capita	panel cointegration	1994–2003	18 emerging countries
Yin and Powers (2009)	Share of RES in electricity generation	FE	1993–2006	50 US states
Brunnschweiler (2010)	Per capita amount of RES/hydro/ Non-hydro RES electricity generation	RE	1980–2006	119 non-OECD countries
Marques et al. (2010)	Share of RES in total primary energy supply	FE, FEVD	1990–2006	24 European countries
Marques et al. (2011)	Share of RES in total primary energy supply	quantile	1990–2006	24 European countries
Menegaki (2011)	Share of RES in energy consumption	RE	1997–2007	27 European countries
Shrimali and Kniefel (2011)	Share of wind/biomass/geothermal/solar Electricity generating capacity	FE	1991–2007	50 US states
Marques and Fuinhas (2012)	Share of RES in total primary energy supply	PCSE, FE, RE	1990–2006	24 European countries
Romano and Scandurra (2011)	Share of RES in electricity generation	GMM	1980–2008	29 countries
Dong (2012)	Cumulative wind electricity generating capacity	OLS	2005–2009	53 countries
Jenner et al. (2013)	RES electricity generating capacity added to previous year	FE	1992–2008	26 EU countries
Smith and Urpelainen (2014)	Share of RES in electricity generation	IV	1979–2005	26 industrialized countries
Emodi et al. (2015)	Number of patent applications for solar/ wind power technology	OLS	1997–2011	12 countries
Omri et al. (2015)	Total amount of RES/nuclear energy consumption	DSEM	1990–2011	17 developed and developing countries
Polzin et al. (2015)	RES/wind/solar/biomass electricity generating capacity added to previous year	PCSE, OLS, RE	2003–2011	18 372 investments
Maguire and Munasib (2016)	Non-hydro RES electricity generating capacity	SCM	1990–2008	50 US states
Li et al. (2017)	Total amount of wind/photovoltaic electricity generation	FE	1996–2013	21 EU countries
Lin and Omoju (2017)	Share of non-hydro RES in electricity generation, total amount of non-hydro RES electricity generation	DOLS, FMOLS	1980–2011	46 countries
Jacqmin (2018)	Natural logarithm of non-hydro RES electricity generation	LSDV	2003–2012	EU28 countries

DSEM refers to dynamic simultaneous-equation model; FE refers to fixed effects model; FEVD refers to fixed effects vector decomposition model; FMOLS refers to fully modified least squares; IV refers to instrumental variables; LSDV refers to least squares dummy variable; OLS refers to ordinary least squares; PCSE refers to panel corrected standard error; RE refers to random effects model; SCM refers to synthetic control method. RESL: Renewable energy sources

The structure of this paper can be outlined as follows. Section 2 describes the methodology used for the analysis and the choice of the dependent variable. Section 3 presents the determinants of RES development included in the analysis as a core model specification issue. This section also provides data sources used. Section 4 presents the estimation results. Section 5 contains the discussion and description of limitations. Finally, Section 6 presents conclusions.

2. METHODOLOGY

The analysis tries to answer the question what factors influence RES electricity development. Therefore, econometric regression was executed on a sample. Beside 27 of the 28 EU MSs, 3 non-EU countries - Iceland, Norway and Switzerland - were object to this analysis. Due to lack of data one MS, Malta, was dropped from the sample. Accordingly, the database contains data for these 30 countries. Besides cross-sectional dimension, a time series spread was also added for the years between 2009 and 2016. With panel data structure more efficient estimation, higher degrees of freedom can be reached (Greene, 2003; Wooldridge, 2006).

The dependent variable for RES development is measured by the annual change of RES installed capacity. Some papers use the share or the total amount of annual RES electricity generation (Carley, 2009; Romano and Scandurra, 2011; Smith and Urpelainen, 2014; Li et al., 2017; Lin and Omoju, 2017; Jacqmin, 2018) or supply (Marques et al., 2010; 2011; 2012; Omri et al., 2015) as dependent variable. A similar approach is used by Sadorsky (2009) who has taken the natural logarithm of per capita renewable energy consumption. However, annual RES generation or supply values may be influenced by special weather conditions in any given year and this might result in unnecessary oscillation in the data. Therefore, production or consumption data does not seem to be a valid measure of real RES development. For this reason, annual change in installed RES capacity (ΔRESCAP) can be regarded as a more consistent measure in case of RES development. This approach is similar to what Jenner et al. (2013), Polzin et al. (2015) and Sisodia et al. (2016) follow. Jenner et al. (2013) use “added RES capacity” but they take only wind and solar photovoltaic technologies into their model. Polzin et al. (2015) take added capacity separately for specific renewable sources and together for RES as well. Sisodia et al. (2016) measures RES development with solar and wind investments. Data were taken from the annual statistical publications of the European Network of Transmission System Operators for Electricity (ENTSO-E, 2010; 2011; 2012; 2013; 2014; 2015; 2016) and the Baltic Transmission System Operators (BALTSO, 2010). Table 2 indicates the dependent variable for the countries included in the study.

There are several methods for the estimation with panel data. An equation for panel data can be formulated as the following:

Table 2: RES development in European countries between 2009 and 2016

Country	RESCAP (MW)	ΔRESCAP (MW)						
	2009	2010	2011	2012	2013	2014	2015	2016
Austria	13,696	-	277	1283	476	1250	−611	1126
Belgium	3171	909	1482	940	668	370	334	−1550
Bulgaria	3354	267	299	954	67	37	26	−983
Croatia	2193	36	−1	66	117	112	85	57
Cyprus	-	82	20	42	-	-	11	98
Czech republic	2838	1542	−29	214	67	−32	847	−1206
Denmark	4160	−349	166	1180	812	151	260	1281
Estonia	171	−11	98	89	30	34	−1	60
Finland	5128	259	24	179	62	171	441	123
France	30947	2030	2566	2174	1735	2102	2073	3211
Germany	47,900	10,200	4641	18,959	6440	4055	6729	2225
Greece	4344	193	622	1006	1057	159	132	864
Hungary	599	81	65	−170	−43	57	71	78
Iceland	2457	1	63	−	2	2	110	-
Ireland	1772	274	77	63	242	391	189	317
Italy	28,087	3426	10,643	4974	6426	178	746	1431
Latvia	1584	30	−28	77	55	23	−2	46
Lithuania	939	129	60	86	239	8	−899	153
Luxemburg	1208	15	2	45	38	203	10	−1237
Netherlands	3068	−88	−503	189	1245	401	1194	1852
Norway	30059	555	-	935	−39	458	124	−455
Poland	3046	651	853	963	948	441	1540	−659
Portugal	8924	434	889	20	219	382	1146	1031
Romania	5926	662	586	823	1295	1198	134	165
Slovakia	2539	82	610	70	32	111	−7	−758
Slovenia	879	184	-	35	31	418	−30	−86
Spain	41,671	2229	1820	3510	1215	−183	790	−3131
Sweden	20,864	651	776	1063	389	993	1000	−545
Switzerland	13,792	-	439	96	253	339	-	−1188
United Kingdom	6504	375	775	3256	2395	1143	9860	7489

RESCAP refers to total installed RES capacity in MW at the end of year; ΔRESCAP refers to annual change in installed RES capacity.

$$Y_{i,t} = \beta_0 + \sum_{n=1}^{n} \beta_{n,i,t} X_{i,t} + a_i + u_{i,t} ,$$

where $Y_{i,t}$ represents the dependent variable, β_0 is the constant, $X_{n,i,t}$ represents the explanatory variables, a_i represents the unobserved time-invariant - and thus unit-specific - fixed effects, $u_{i,t}$ is the error term, i represents the units and t denotes the year.

Making estimation on panel data, the core challenge is to deal with the correlation between the unobserved fixed effects (a_i) and the explanatory variables. Ordinary least squares estimation (hereafter OLS) gives biased and inconsistent results if a_i and $x_{i,t}$ are correlated (Wooldridge, 2006). Therefore, nor OLS, neither from OLS derived panel corrected standard errors estimation (PCSE) was applied. A plausible solution is first differencing of the variables, but it removes time-invariant explanatory variables from the model. Similarly, fixed effects (hereafter FE) estimation which is widely used, has the drawback that it ignores time-invariant effects. Therefore, FE provided weak models. Random effects (hereafter RE) estimation is a method which may be used even with time-invariant explanatory variables. However, using RE estimation one should assume that the covariance of the unobserved fixed effect with the independent variables is zero. Unfortunately, Hausman test gave evidence on that this assumption does not hold and RE estimates are not consistent. Therefore, fixed-effects vector decomposition model (hereafter FEVD) presented by Plümper and Troeger (2007; 2011) was used for the estimation. FEVD can handle time-invariant variables and is more efficient than FE, if (i) the between variation is larger than the within variation of the dependent variable or (ii) the correlation between the unobserved fixed effects and the explanatory variables is low. Since assumption (i) is true (Table 3), FEVD estimation is computed in the analysis. In this paper the results of FE, RE and FEVD estimations are also presented for the sake of comparing, but conclusions are made only based on the results of FEVD estimation.

A change in the economic environment, a new policy measure or an investment decision in the electricity sector cannot bring immediate development - licencing procedure, construction of a power plant may take time. Therefore, a lagged model was used in the analysis. This approach was also used by Brunnschweiler (2010).

After introducing considerations on model specifications the econometric model used in this analysis is the presented:

$$Y_{i,t} = \propto_0 + \sum_{m=1}^{m} \beta_m X_{m,i,t-1} + \sum_{n=1}^{n} \delta_n Z_{n,i} + \mu_i + u_{i,t} ,$$

where Y is the dependent variable (ΔRESCAP), X are the time-variant variables, Z are the time-invariant variables, α_0 indexes the constant, μ represents the unit-specific fixed effects and u represents the identically distributed random error term. The subscripts i and t index countries and years.

For all models, the null hypothesis of non-significance of all coefficients and independent variables were tested via the usual F or Wald tests. RE and FE models were additionally matched by Hausman test.

3. DATA

The choice of the dependent variable was already explained in the previous section. The correct choice of the explanatory variables is a crucial model specification issue. With the deliberate choice of explanatory variables the model aims to augment and also exceed previous analyses. Another additional gain of this study is that it uses more recent data that allows to draw conclusions on the latest developments and trends regarding RES.

The following subsections present the explanatory variables chosen for the empirical analysis. Since compared to former studies entirely different types of variables were used in this analysis, an own database was composed. At the end of this section, Table 4 summarizes all variables.

3.1. Electricity Sector Specific Indicators

The model controls for some energy sector-specific indicators which indicate current positions and crucial trends of the countries.

First, total installed electricity generating capacity (CAPACITY) is included in the model. CAPACITY indicates the total installed capacity on the 31st of December in each year and each country in megawatt (MW). Knowing that besides more existing capacities there may be less motivation to raise new power plants, a negative effect on the dependent variable is expected. The impact of electricity exchange balance (BALANCE) is expected to be similar. BALANCE indicates the annual electricity exchange balance (imports minus exports) of a country in MW hours (MWh). A higher value indicates higher import dependence. Taking Fodor's (2013) conclusions into account, it is expected that higher import dependence results in more motivation to build new RES capacities. Similar variables to BALANCE were used by Marques et al. (2010; 2011), Marques and Fuinhas (2012) and Jenner et al. (2013) too. Capacity and balance values – similarly to installed capacity data – were taken from the annual statistical publications of ENTSOE and BALTSO.

Electricity price (ELPRICE) is also included in the model indicating the retail electricity price for households of each country and year in euro per kilowatt hours (kWh). A proportional contact may be expected between electricity price and RES development. First, high

Table 3: Summarizing the dependent variableΔRESCAP

ΔRESCAP	Mean	Standard deviation	Minimum	Maximum	Observations
Overall	818.6571	2123.623	−3131	18959	N=210
Between		1611.813	−132	7607	n=30
Within		1409.403	−4563.343	12170.66	T=7

Table 4: Descriptive statistics of included variables

Variable	Definition	Variable type	Time variation	Number of observations	Mean	Standard deviation	Minimum value	Maximum value
ΔRESCAP	Change in installed RES capacity to previous year (MW)	Continuous	Variant	210	818.6571	2123.623	−3131	18959
L.CAPACITY	Total installed electricity generating at the end of calendar year (MW)	Continuous	Variant	210	31761.64	42189.32	1075	190063
L.BALANC	Annual electricity exchange balance (imports minus exports, MWh)	Continuous	Variant	210	166.7667	15402.29	−67,225	47403
NUC	Existence of nuclear electricity generating capacity	Binary	Invariant	210	0.5333	0.5001	0	1
L.GASPRICE	Annual average European import price for natural gas (USD/mmbtu)	Continuous	Variant	210	9.7263	1.57142	7.2608	1.7858
L.ELPRICE	Retail electricity price for households (EUR/kWh)	Continuous	Variant	207	0.1691	0.04927	0.0813	0.3068
L.GDP/CAPITA	GDP per capita (PPS/capita)	Continuous	Variant	210	27522.38	11666.04	11200	76100
L.GDPGROW	GDP growth rate to previous year (%)	Continuous	Variant	210	0.2195	3.9757	−14.6	25.5
L.UNTRACKED	Share of untracked electricity (%)	Continuous	Variant	210	0.8233	0.2358	0.014	1
L.PRICEBASED	Existence of price based support scheme in effect at the end of calendar year	Binary	Variant	210	0.7714	0.4209	0	1
L.QUANTBASED	Existence of quantity based support scheme in effect at the end of calendar year	Binary	Variant	210	0.2190	0.4146	0	1
L.DISCLOSURE	Existence of national regulation on energy mix disclosure according to Article 3 (9) of Directive 2009/72/EC	Binary	Variant	210	0.7762	0.4178	0	1
COAST	Length of marine coastline (km)	Continuous	Invariant	210	3402.47	5403.013	0	25148
LATITUDE	Latitude of country centroid	Continuous	Invariant	210	50.4425	7.8749	35.0312	7.47
L.RESLEVEL_0–10	Share of RES electricity generation is below 10%	Binary	Variant	210	0.1667	0.3736	0	1
L.RESLEVEL_10–20	Share of RES electricity generation is equal or greater than 10% and below 20%	Binary	Variant	210	0.2095	0.4079	0	1
L.RESLEVEL_20–30	Share of RES electricity generation is equal or greater than 20% and below 30%	Binary	Variant	210	0.1524	0.3602	0	1
L.RESLEVEL_30–50	Share of RES electricity generation is equal or greater than 30% and below 50%	Binary	Variant	210	0.2048	0.4045	0	1

electricity price may indicate market scarcity of electricity supply and therefore may have a positive effect on RES development as new investments are needed to cover the demand for electricity. Second, high electricity prices may also indicate that high support is paid for RES electricity generators – as the costs of the support scheme are shifted on consumers in most cases (Fouquet and Johansson, 2008; Del Río and Mir-Artigues, 2014), and therefore it may have a positive effect again. Electricity price data were taken from Eurostat database and from publications of the Swiss Federal Office of Energy (SFOE, 2011; 2012; 2013; 2014; 2015; 2016; 2017) for Switzerland. However, it has to be emphasized that ELPRICE data are missing for three years in case of Iceland.

Two variables control for other energy sources competing with RES in electricity generation. NUC as a dummy variable indicates if a country has nuclear capacity at the end of the year. NUC variable was deduced from ENTSOE and BALTSO publications. On the one hand, considering that nuclear power plants do not cause pollution in the air – and therefore this may count as an environment friendly technology – it may be assumed that the existence of nuclear capacities hinder energy policy decision makers to initiate RES development. On the other, however, knowing the risks of radioactivity one can also assume that beside the existence of nuclear plants governments attempt to accelerate RES penetration to replace the dangerous nuclear technology. Other papers also included a variable measuring nuclear generation (Marques et al., 2010; 2011; Marques and Fuinhas, 2012; Jenner et al, 2013; Smith and Urpelainen, 2014) and furthermore Omri et al. (2015) put the relationship between RES and nuclear electricity generation into the focus. Gas price (GASPRICE) indicates the average European import price for natural gas of each year in USD per mmbtu. Gas price data were taken from the Worldbank database. GASPRICE has no cross-sectional variation in the data set. Lower gas price is expected to hinder RES development, since due to lower gas prices RES investments may not seem profitable and the fear of energy source dependency may decrease as well.

3.2. Economic Indicators

Economic indicators such as gross domestic product (GDP) were used in several empirical studies. While Marques et al. (2010; 2011) apply absolute economic size measure, others use per capita values in their estimations (Carley, 2009; Sadorsky, 2009; Menegaki, 2011; Jenner et al., 2013; Smith and Urpelainen, 2014; Omri et al., 2015; Lin and Omoju, 2017). This model includes per capita GDP in purchasing power standards (GDP/CAPITA) and also the GDP growth rate (GDPGROW) to control for economic trend. It is expected that both indicators have a positive effect on RES development. GDP data were taken from the Eurostat database.

3.3. Consumer Commitment

Although several authors have already recognized the business potential of renewable energy markets, until now, no previous econometric studies have used any indicator measuring the effect of consumer's choice for RES. On the one hand, this seems to be reasonable since since single investment decisions in the electricity sector usually have been made independently from local consumer's wishes – in the conventional electricity system the consumer had no opportunity to influence the orientation of development. However, market and legal developments in Europe during the past decades have created a new framework that may result in a slow shift in this regard. Directives 2003/54/EC and 2009/72/EC ensured market liberalization on the retail markets (European Parliament, 2003; 2009b). Directive 2001/77/EC (European Parliament, 2001) defined the so called guarantees of origin (hereafter GOs) as a tracking tool for the attributes of electricity and directive 2009/28/EC (European Parliament, 2009a) made GOs mandatory for member states. GO means by the definition of the directive "an electronic document which has the sole function of providing proof to a final customer that a given share or quantity of energy was produced from renewable sources". The international trade of both electricity and GOs became possible. Due to these regulations there remain no more barriers hindering the promotion of green electricity products throughout Europe. Market liberalization enabled European consumers the free choice between energy sources. Suppliers can purchase GOs in order to provide consumers with a proof of renewable origin of electricity for a price premium. A part of the price for GOs will certainly be realized at the producers. Therefore, theoretically consumer preferences regarding specific energy sources or other attributes might have an effect on the income of generators.

The European Commission (2016) states that a properly functioning GO market "can help supplement or possibly in a longer term supersede" public support schemes. It also declares that "the higher prices paid for specific types of renewable technology" may have an impact on certain project types. Therefore, a factor measuring the status of consumer demand on green electricity is taken into the model. The "Reliable Disclosure Systems for Europe" project (hereafter RE-DISS) of the EU has made calculations for electricity tracking in European countries since 2009. GOs are used for almost the entire proportion of tracked electricity to promote green electricity products (Klimscheffskij et al., 2015). We assume that the share of electricity consumption covered by GOs or such tracking tools is an appropriate measure for consumer commitment. RE-DISS publications (2010; 2011; 2012; 2013; 2014; 2015a) contain information on the share of untracked electricity in each country (UNTRACKED). Since 2016, another organization, the Association of Issuing Bodies (AIB, 2016) – a fellowship of several national GO and other certificate administrators in Europe – has taken this task over from RE-DISS. The higher value UNTRACKED takes, the lower consumer demand arises for RES electricity.

3.4. Policy Indicators

The contribution of policy factors to RES development is a more obvious element than consumer demand. Most European countries apply public support schemes and other measures to promote RES electricity generation. For MSs of the EU it is crucial to achieve their national targets to reach a 20% share of RES in gross energy consumption on an EU-level (European Parliament, 2009a). The most common types of support schemes are feed in tariffs (FIT) or premiums (FIP) and tradeable green certificate (TGC) systems. FIT and FIP systems guarantee a fixed price or a price premium for RES generators, therefore these support schemes are called "price based." TGC systems guarantee a fixed level of demand for RES electricity, accordingly, these are "quantity based" support schemes. Based on the analysis of support schemes in EU MSs, Fouquet and Johansson (2008) assessed that FIT systems deliver a higher RES development than TGC systems. Nevertheless, it is certain that any national incentive similar to support schemes do have an impact on RES penetration. However, while some studies place support schemes in the centre of their analysis (Jenner et al., 2013; Smith and Urpelainen, 2013), others leave out any variables measuring the effect of support schemes (Sadorsky, 2009; Marques et al., 2010; Marques et al., 2011). Considering that numerous papers confirmed that support schemes have an effect on RES development (Fouquet and Johansson, 2008; Jenner et al., 2013; Lehmann and Gawel, 2013; Smith and Urpelainen, 2013; Del Río and Mir-Artigues, 2014; Polzin et al., 2015), the latter practice might be regarded as a model specification mistake. In this model two dummy variables were considered: One for price based (PRICEBASED) and one for quantity based (QUANTBASED) support schemes. Similarly, Emodi et al. (2015) uses dummy variables indicating FIT support scheme in effect. These variables indicate in case of each country and year whether such a support scheme was in effect or not.

Directives 2003/54/EC and 2009/72/EC (European Parliament, 2003; 2009b) obliged suppliers to inform their consumers about the share of energy sources in the supplied electricity (disclosure). This measure is related to market liberalization and consumer choice. A dummy variable (DISCLOSURE) is applied for disclosure, indicating if the disclosure regulation of the directives has been already implemented in national legislation.

Since so far no study has summarized the evolution in time of support and disclosure regulations of all 30 European countries that are included in this study, a number of sources were used to collect data. Beside three papers (Draeck et al., 2009; Jenner et al., 2013; Del Río and Mir-Artigues, 2014) country profiles written by the RE-DISS project (RE-DISS, 2015b), domain protocols of

AIB member organizations and the res-legal.eu website provided help in completing the database for this study with support scheme and disclosure dummy figures.

3.5. Natural Resource Endowment

It is widely agreed that the natural endowment of a country plays an important role in the development of RES (Vachon and Menz, 2006; Marcotullio and Schulz, 2007; Carley, 2009). Although, natural endowment cannot be improved by policymakers, including this factor in the model is crucial to avoid omitted variable bias. However, it may be difficult to measure or to find valid proxy variables for this factor. Some researchers seem to avoid to include any variable controlling for natural endowment (Jenner et al., 2013; Polzin et al., 2015; Li et al., 2017). Taking the results of the above mentioned papers into consideration, this omission of variables may bring bias in the estimations (Wooldridge, 2006). Carley (2009) was able to use exact values from previous studies measuring wind, solar and biomass potential of every 50 states of the USA. In her FEVD analysis all three variables were significant. However, this study analyses European countries, therefore data sources used by Carley cannot provide any support in this case. Until now, no study that provided comparable and consistent measures for each European country regarding the potential of specific renewable sources has been conducted. In the study of Smith and Urpelainen (2014) the three-year moving average of renewable share, lagged one period, was used to control for natural endowments. However, it may be problematic, because the RES share of previous years can involve many other factors, not only natural endowments. Marques et al. (2010; 2011) used the geographic area of European countries as a proxy for renewable potential for each country, based on the assumption that a larger area contains more potential. The area variables were significant in both of these models, however, with different sign. This fact may be an argument against using geographic surface area as a proxy for natural endowment. In addition, taking small European countries, such as Austria, Switzerland or Iceland, that have obviously better endowments for RES than some big countries, the appropriateness of this proxy variable may be problematic. Furthermore, countries with a small surface area may have large territories in the sea that are highly favourable for offshore wind energy installations – as it is the case of e.g. Denmark. Taking these into consideration, other proxy variables were also searched for.

The vast majority of new RES capacities in Europe were installed in wind and solar generation. According to the data of the European Environment Agency (2013; 2014; 2015; 2016; 2017) 77% of the increase in RES electricity consumption were generated from wind or photovoltaic sources between 2010 and 2015. Taking this into account, two variables control for natural endowment in the analysis, one for wind and one for solar potential of each country.

The length of the marine coastline of a country in kilometres (COAST) controls for the wind potential. This may be a valid proxy for wind power potential for two reasons. First, taking onshore wind generation into consideration, New et al. (1999; 2002) confirmed that closer to the coasts wind speed increases. These results were also used by Hoogwijk et al. (2004) and de Vries et al. (2007) for assessing regional and global RES potential. Second, while in case of offshore technology there is no need to argue the validity of this proxy, the fact that between the years 2009 and 2016, the period covered in our study, 12% of new wind power generating capacities were offshore devices (WindEurope, 2017), highlights an important trend: There has been an ongoing shift from onshore to offshore wind generation.

The development of Photovoltaic Geographical Information System and related studies (Šúri et al., 2007; Huld et al., 2012; Amillo et al., 2014) brought data on solar radiation which is the most important element in valuing solar potential (Angelis-Dimakis et al., 2011). However, these studies do not cover all countries that are subject to this paper. Therefore – bearing in mind that distance from the equator is in strong correlation with solar irradiation, the latitude of country centroid (LATITUDE) was added to the model as a proxy for solar potential.

Coastline data were taken from CIA World Factbook, while latitude data were taken from the database of Portland State University.

3.6. Other Indicators

Development of RES electricity generation may hang on the current status of RES penetration. Those countries that already have a significant share of RES generation in their energy mixes, or moreover even those that already reached their 2020 goals for RES development, may be less motivated in further improvement of RES electricity generation. Therefore, the model includes dummy variables (RESLEVEL) indicating the level of the share of RES in electricity generation. Five levels were set: RES share under 10%, between 10% and 20%, between 20% and 30%, between 30% and 50%, above 50%. These dummy variables were figured upon the data in the annual statistical publications of ENTSOE and BALTSO.

4. RESULTS

Table 5 shows correlations between variables used. Correlation coefficients show a tendency of being rather small. The only exception is the correlation between L.PRICEBASED and L.QUANTBASED, but these two variables indicate together the presence and type of a support scheme. In most cases states applying any support scheme choose between the two approaches of price based and quantity based mechanisms. According to this table, no variables should be dropped from the model.

Table 6 presents the results from the FE, RE and FEVD estimations. The results of validity tests are also presented in the table. According to F tests and the Wald test all three models are appropriate. However, the null hypothesis of Hausman test should be rejected, therefore RE estimation is not consistent and FE should be preferred. But, FE model cannot include the time-invariant variables and so it has low R-squared value and weak explanatory power. FEVD model provides valid and robust results that enable the drawing of grounded conclusions. In short, FEVD estimation results indicate the following.

L.CAPACITY has a significant and negative effect on ΔRESCAP. Less capacity results in more new RES capacities. L.BALANC

Table 5: Correlation matrix

		1	2	3	4	5	6	7	8	9
1	ΔRESCAP	1.0000								
2	L.CAPACITY	0.6248	1.0000							
3	L.BALANC	−0.0086	−0.2709	1.0000						
4	NUC	0.1242	0.2557	−0.2628	1.0000					
5	L.GASPRICE	0.0459	0.0053	−0.0066	−0.0056	1.0000				
6	L.ELPRICE	0.2866	0.3796	0.0640	−0.1433	0.0789	1.0000			
7	L.GDP/CAPITA	0.0319	0.0810	−0.0013	−0.1508	−0.0109	0.4165	1.0000		
8	L.GDPGROW	−0.0078	−0.0258	−0.0566	0.0444	−0.0331	0.0323	0.0824	1.0000	
9	L.UNTRACKED	−0.0754	−0.1706	−0.0144	−0.0760	−0.0565	−0.3645	−0.4752	−0.1142	1.0000
10	L.PRICEBASED	0.1071	0.0072	0.0650	−0.0623	0.0428	0.0730	−0.0575	−0.0718	0.0978
11	L.QUANTBASED	0.1750	0.2287	0.2129	0.0725	0.0096	0.0520	−0.0091	0.0534	−0.1586
12	L.DISCLOSURE	0.1472	0.2289	0.0902	−0.0046	0.0584	0.3789	0.2249	0.1259	−0.3141
13	COAST	0.1297	0.2122	0.0456	−0.3148	0.0015	0.1322	0.1919	−0.1321	0.0541
14	LATITUDE	−0.0498	−0.1085	−0.0420	0.0090	0.0097	−0.0307	0.2957	0.1596	−0.1013
15	L.RESLEVEL_0–10	−0.0760	−0.1050	0.0057	0.0275	−0.0164	−0.0988	−0.2198	−0.1056	0.1626
16	L.RESLEVEL_10–20	0.1892	0.1596	−0.2529	0.1705	0.0636	−0.1033	−0.0737	0.0129	0.0740
17	L.RESLEVEL_20–30	0.1750	0.1208	0.0993	0.0720	−0.0559	0.1304	−0.0358	−0.0055	0.0325
18	L.RESLEVEL_30–50	−0.1053	0.0452	0.1693	0.0653	0.0317	0.0780	0.0215	0.0755	0.0718
		10	11	12	13	14	15	16	17	18
10	L.PRICEBASED	1.0000								
11	L.QUANTBASED	−0.6761	1.0000							
12	L.DISCLOSURE	−0.2452	0.2777	1.0000						
13	COAST	−0.2348	0.2419	0.1657	1.0000					
14	LATITUDE	−0.4085	0.1758	0.0919	0.2699	1.0000				
15	L.RESLEVEL_0–10	−0.0122	0.0999	−0.1122	−0.0789	−0.1068	1.0000			
16	L.RESLEVEL_10–20	0.0734	−0.0505	−0.0475	−0.0899	−0.0645	−0.2344	1.0000		
17	L.RESLEVEL_20–30	0.0958	0.0607	0.0262	−0.0138	−0.1388	−0.1929	−0.2222	1.0000	
18	L.RESLEVEL_30–50	0.0389	−0.0732	0.1496	−0.0419	−0.0329	−0.2310	−0.2660	−0.2190	1.0000

Table 6: Estimation results

Independent variables	FE		RE		FEVD	
L.CAPACITY	−0.1587484	(0.0280288)	0.0294463	(0.0059889)***	−0.1587483	(0.0153075)***
L.BALANC	0.0253676	(0.020293)	0.0411804	(0.0124602)***	0.0253676	(0.0069284)***
NUC			172.4317	(465.3849)	0.0000617	(208.5303)
L.GASPRICE	64.68274	(62.37893)	44.52061	(67.05742)	64.68274	(53.17239)
L.ELPRICE	9007.429	(6347.507)	842.3637	(4263.696)	9007.427	(2291.165)***
L.GDP/CAPITA	0.037151	(0.0672608)	−0.000042	(0.0199611)	0.037151	(0.0097681)***
L.GDPGROW	21.8665	(32.04724)	23.74227	(29.14458)	21.8665	(21.96465)
L.UNTRACKED	310.5733	(734.3811)	730.1228	(708.1172)	310.573	(469.4502)
L.PRICEBASED	1735.116	(631.6192)	1179.406	(539.8724)*	1735.116	(345.1186)***
L.QUANTBASED	−61.99331	(1041.315)	426.7002	(585.8639)	−61.99324	(347.2467)
L.DISCLOSURE	−273.3726	(354.2767)	42.7964	(345.3263)	−273.3725	(241.463)
COAST			0.0076196	(0.0434682)	0.3862883	(0.0367831)***
LATITUDE			35.62868	(29.61022)	−143.2404	(19.01065)***
RESLEVEL_0–10	535.4053	(936.4843)	357.3335	(548.9339)	535.4055	(301.362)
RESLEVEL_10–20	1045.779	(833.0889)	1013.735	(514.8582)*	1045.779	(285.4689)***
RESLEVEL_20–30	896.3229	(637.101)	381.8294	(502.1405)	896.3229	(312.2866)**
RESLEVEL_30–50	−51.564	(501.9089)	−730.6846	(444.967)	−51.56395	(290.0507)
HHAT					0.9999999	(0.0787598)***
CONSTANT	931.3157	(2420.304)	−4441.964	(1983.358)*	6821.103	(1379.212)***
Observations	207		207		207	
R-squared	0.3690		0.1304		0.7215	
F-test	6.81***		-		27.06***	
Wald (chi2)	-		73.89***		-	
Hausman test	227.92***				-	

*P<0.05, **P<0.01, ***P<0.001

is also significant in the estimation. As the difference of import and export (electricity import dependence) rises, so appears an increase in ΔRESCAP. Similarly, L.ELPRICE has a significant and positive effect. However, the effect of other non-RES (NUC, GASPRICE) does not appear to be significant.

L.GDP/CAPITA has a significant and positive effect on ΔRESCAP but L.GDPGROW is not significant. The results regarding L.GDP/CAPITA are in line with the findings of most previous studies (Carley, 2009; Sadorsky, 2009; Jenner et al., 2013; Smith and Urpelainen, 2014).

The variable measuring consumer commitment (UNTRACKED) is not significant.

Two dummy variables were included in the model indicating the effect of support schemes. According to the results, only one of them (L.PRICEBASED) has a significant and positive effect. The coefficient for L.QUANTBASED is not significant. The third policy dummy variable L.DISCLOSURE also does not have a significant effect.

Both proxy variables controlling for natural endowment do have a significant effect on ΔRESCAP with the anticipated orientation. Higher value for COAST brings more, higher distance from the equator bring less ΔRESCAP.

Four dummy variables measured the level of RES share in the estimation. Two of them (RESLEVEL_10-20, RESLEVEL_20-30) are significant. The dummy variable for the lowest and the higher levels does not have any effect.

5. DISCUSSION

Both higher import dependency and less total capacity results in more new RES investments. This outcome fits the conclusions of Lipp (2007) and Fodor (2013) who state that energy security is a strong motivating factor in case of RES development.

The results of the dummy variables indicating the level of the share of RES in electricity generation are highly unusual. According to the results, countries between 10% and 30% of RES share in electricity generation could raise significantly more new RES capacities than others. It is not surprising and also does not raise concerns that countries with higher RES share than 50% did not have significantly higher new RES development than others. However, RESLEVEL is also not significant for countries beyond 10% share of RES electricity generation. This result is unusual especially since none of the MSs 2020 RES target is under 10% (European Parliament, 2009a). (All non-MS countries – Iceland, Norway, Switzerland – in the sample of this analysis already have higher RES penetration.) This may indicate the danger that some countries remain stalled on a low level of RES and they do not intend to make efforts for RES development. It would be crucial and urgent to find the motivation for RES in these countries as well to reach 2020 RES targets.

In line with other papers (Markard and Truffer, 2006; Hast et al., 2015; Mulder and Zomer, 2016), the results of this analysis indicate that consumer commitment does not affect RES development for the time being. Furthermore, an important added value of this analysis compared to those papers is that this could be the first paper that verifies this opinion with empirical data. Although the European Commission (European Commission, 2016) intends to give a major role to GOs in motivating RES development, such change will hardly occur even on medium term. However, scientific research shall continuously bring attention to the question in what ways GOs could contribute to a more sustainable energy mix in electricity.

With regards to the fact that RES technologies are still not competitive on a free market and neither GOs have been able to give a competitive advantage to RES so far, the most important motivating factors for new RES electricity investors still seem to be support schemes. However, the effect of quantity based support scheme existence is not significant in the model. Nevertheless, this does not prove that quantity based support schemes do not have any positive effect at all. Since almost every country in the sample has had a support scheme within the examined time period – with the exception of those that already have reached a heavy penetration of RES: Iceland and Norway – non-significance does not mean that they would have had the same pace of RES development in an alternative scenario without any support mechanism. In contrast to quantity based support, it is proved by the estimation that price based support scheme existence do have a significant and positive effect on new RES capacities. Thus, the results of the model show that price based support schemes bring more new RES capacities than quantity based support – corresponding to the conclusions of Fouquet and Johansson (2008). However, this still does not mean that quantity based support is not as effective as price based methods, for two reasons. First, the model did not include more detailed information on support schemes. While in case of price based schemes, the amount of regulated tariff or premium is determining, in quantity based schemes, a minimum price of TGC may be set and this can have a dominant effect on the development. Second, in case of a quantity based support scheme quantity is a result of policy decision. While it has not been proven which support scheme is more efficient proportionally, it seems to be certain that price based support schemes provide more RES capacities.

The significance of per capita GDP unambiguously indicates that countries of higher welfare have more opportunities to boost investments in RES developments or to tolerate higher household costs triggered by RES penetration. As investor decisions are directly motivated by support opportunities, welfare might be closely linked to expenditures undertaken by countries to finance support schemes. However, this assumption is beyond the scope of this analysis. As RES technologies will become more mature and their unit costs will decrease in the future, the significance of income may decrease. On the other hand, GDP growth is not significant. In the examined period, countries with lower per capita GDP values could achieve a higher growth in GDP. According to the results, these countries did not turn their higher growth into a more expansive development of RES.

Retail electricity price for households has a significant and positive effect on the dependent variable in the model. It fits to our expectations. However, the cause behind this effect is not revealed by this estimation and that could prove to be an interesting area of further investigation. Neither the other price variable for gas, nor the dummy variable indicting nuclear electricity generation do have a significant effect on RES development.

Indicators measuring solar and wind energy generating potential both do have a strongly significant effect. Both significant effects suit to prior expectations: having all other factors fixed, longer coastline and lower latitude value bring more new RES capacities. Apparently, better endowments enable to develop RES electricity generation on lower unit costs in some countries. Therefore, policy measures can be more efficient in these countries.

At the end of this section, limitations of the analysis are summarized. For one thing, as mentioned above, support schemes were modelled only using dummy variables. The details of these support schemes were not modelled, therefore results do not enable to make more sophisticated conclusions on them. Moreover, natural endowment was measured for the potential of two energy sources only: wind and photovoltaic. Although these have been the leading sources among RES in the past years covered by our analysis, integrating such proxies for other renewable sources (e.g., bioenergy, geothermal, hydro) might have brought additional results.

6. CONCLUSIONS

Finally, conclusions are summarized and some proposals are collected for future studies. The objective of this analysis was to identify factors influencing the development of new RES electricity generating capacities. According to the results, import dependency, total capacity, electricity price, per capita GDP, support schemes and natural endowment are those factors that affect RES development. According to the results, price based support schemes have brought more RES capacities. Results suggest that decision makers should focus on those energy sources that fit to the local natural endowments.

Beside these, the analysis has drawn some other important conclusions too. For the first time, empirical evidence verifies in this analysis that consumer commitment still does not have any effect on RES development in European countries. Further studies may scope the question how could consumer commitment, GOs or green electricity products become a tool to promote RES development. Marine coast length and latitude was used as proxy variables for natural endowment for wind and photovoltaic electricity generation and they proved to be good proxies. The advantage of them is that data are easily available and are applicable for any country and continent universally. Further studies may use these proxy variables for control in estimations on the development on specific RES technologies separately (e.g. wind, solar). As natural endowment probably also affects the effectiveness of support schemes and other policy measures, further analyses might focus on the effects on policy measures, as Vachon and Menz (2006) have already tried this before.

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