Chapter 3

On the Public Policies Supporting Renewables and Wind Power Overcapacity: Insights into the European Way Forward

António Cardoso Marques,
José Alberto Fuinhas and Rui Flora

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1. Introduction

The debate about the depth and characteristics of public policy intervention in encouraging renewable energy is more urgent than ever. Some of the literature has started to cast doubt on the strategies being pursued by countries to encourage renewables. These criticisms have been varied with regard to the costs of intervention and the consequences for the economy as a whole. The need to guarantee a continuous supply of electricity requires the existence of backup power, which is essentially based on fossil sources. Marques and Fuinhas (2012a) point out that the increase in renewables has been predominantly based upon direct public subsidies and intervention. Market-driven policies have been deprecated in favor of policy-driven measures. Fossil sources are often identified as beneficiaries of subsidies, so renewable sources should also be stimulated by these policy instruments. However, the way in which this argument is presented can lead to confusion. In fact, a substantial part of these subsidies for fossil fuels is a consequence of the strategy to develop renewables. Fossil fuels are used to provide backup power, such as that from coal plants or combined-cycle gas-fired plants, but they are turned off for long periods. Consequently, overcapacity and economic inefficiency arise, which is the primary reason for the current subsidies for fossil fuels. Some literature, such as Liao et al. (2011), sustains that all incentives/subsidies should be removed, both for fossil fuels and renewables. The authors then propose applying fees to fossil-based products in order to pay for the emission of greenhouse gases. Despite being pragmatic and objective, this perspective is not easy to apply considering the current state of renewable energy technology. In fact, several challenges remain, such as the problem of intermittent generation, which will continue to require the use of fossil sources to offset it.

The deployment of new energy sources is inevitable, which is why alternative energy sources have emerged, resulting from the use of natural resources such as water, wind, sun, tides and heat from the earth. In the meantime, the international community has made several commitments to promoting greater deployment of renewable energy sources. Examples include the Kyoto Protocol in 1997 or the recent European directive for climate and energy measures, known as the 20-20-20 targets. This directive aims to reduce greenhouse gas emissions by 20%, increase the share of energy consumption from renewable energy sources to 20% and promote energy efficiency by reducing primary energy use by 20%. Nevertheless, while the need to develop the use of new energy sources has been consensual, in view of the long-term depletion of fossil fuels and the issue of climate change, there has been no extensive evaluation of the consequences of renewable energy use. The continuous support for renewables, particularly in Europe, has raised the debate about the levels of wind power installed capacity. It is well known that there is no kind of power plant that operates at 100% of its maximum capacity, particularly renewables due to their intermittent nature. Hence, a problem of structural inefficiency arises, which leads to high economic costs associated with the existence of idle capacity.

It is widely accepted that renewables, such as solar and wind, are at the heart of common instruments in reaching European goals of reducing energy dependence, as well as the reduction of greenhouse gases. However, the growth in wind energy magnifies the problem of intermittency. As stated by Holttinen et al. (2009), it is crucial to properly estimate the costs of wind energy in the system as a whole when planning high wind power penetration. Furthermore, the analysis of renewables' intermittent generation is important for policymakers due to the great support for renewables in Europe, in the context of long-term energy goals. Faced with the problem of renewable intermittency, two possible solutions can be considered: (i) energy storage for later use; and (ii) backup electricity generation with fossil fuels. However, the literature (e.g. Beaudin et al., 2010) suggests that energy storage costs are still very high, so upgrading the energy grid in this way is not yet attainable. As a consequence, it would seem more appropriate to combine other energy sources to backup power. Fossil fuel plants can startup and shut down in a short time to keep a secure energy supply and are an effective way of mitigating renewable intermittency (Isla, 1999; and Luickx et al., 2008). A consequence of the divergence between maximum capacity in full-time operation and the electricity actually generated in a given period of time is the idle capacity phenomenon. Idle capacity is noticeable both for renewables, due to their intermittent nature, and for other energy sources since they are turned off more frequently.

We shall focus only on wind power overcapacity. The scarce research on this subject arouses curiosity about the high levels of idle capacity in wind power. Indeed, Boccard (2009), Fiedler and Bukovsky (2011) and Yang et al. (2012) found that wind energy generation is rarely more than 25% of total capacity. This leads us to believe that there may be overcapacity in wind power. The ratio of the actual electricity output to maximum capacity is referred to as the capacity factor. Electricity demand throughout the day is volatile, especially in off-peak and peak-load periods. This may also influence the amount of idle capacity. This problem can force investment into pumped hydro during periods when there is wind overproduction and low grid consumption and secondly into thermal plants like coal-based or gas-fired to provide backup power for wind power when necessary (Luickx et al., 2008).

The vast literature about renewable intermittency, both theoretical and case studies, has not explored the phenomenon of wind overcapacity in enough detail. Indeed, the empirical assessment of overcapacity in wind power merits much more attention. On the one hand, the phenomenon of overcapacity reflects the path taken by renewables and, on the other, since this phenomenon is a leading indicator, it should back the process of updating public guidance. The aim of this chapter is to provide empirical evidence on the drivers that contribute to explaining wind power overcapacity and, secondly, to identify empirically the causes for a panel of 19 countries. While Boccard (2009) addresses the issue of wind intermittency from the perspective of the capacity factors, this chapter is focused on the importance of intermittency and possible wind overcapacity, but using a non-used wind capacity approach.

The role played by several energy sources in creating wind power overcapacity is assessed, controlling for socio-economic drivers and public energy policies and measures. On the whole, this approach can be useful in highlighting the relevance of the intermittent nature of renewables for policymakers in order to deal with wind overcapacity. Econometric techniques of panel data were applied to deal with the energy and socio-economic characteristics of an economic bloc with environmental concerns and long-term energy targets. In particular, the contribution of conventional energy sources to the wind power overcapacity in Europe is appraised. Some light is shed on the public policies that might mitigate the economic inefficiency.

2. Renewables' intermittency context: The debate

The expansion of renewables is the subject of hot debate in the literature regarding the implications of these energy sources, namely their advantages, consequences and prospects for growth. The implications of the unpredictability and inconstancy of wind energy generation prove relevant. In fact, this intermittency in generation makes it increasingly important to combine different energy sources, including fossil fuels, to backup energy supply. A relevant role is merited not only for conventional energy sources, but also for the mix of renewables. Moreover, it is crucial to understand the role that public policy and measures have played. Wind power installation has been strongly stimulated by public guidance and highly subsidized, namely by guaranteed prices under feed-in tariffs which will last for more than 25 years, as stated by Moreno and Martínez-Val (2011). Together with other drivers that promote renewables on a large scale, this creates distortions and increased costs for consumers (Gómez et al., 2011).

2.1. Intermittency and wind power overcapacity

Although the issue of renewable intermittency is far from new in the literature, the relevance of this topic together with the phenomenon of overcapacity requires much more research. The main reasons and impacts of non-constant generation of wind energy are analyzed by authors such as Albadi and El-Saadany (2010), and Green and Vasilakos (2010). Gonzalez et al. (2004) focus on Ireland, Gül and Stenzel (2005) on Scandinavia, the United Kingdom and the United States, Caralis et al. (2008) on Greece and the Chinese case is targeted by Yang et al. (2012) and Zhang and Li (2012).

Intermittency in renewables can be analyzed by using the capacity factor. This is the ratio, for a certain period of time, of the energy generated to the energy that would have been generated in operation by operating total continuous power during the same period (Denholm et al., 2005). Boccard (2009) summarizes that capacity factor depends on: (i) wind variability; (ii) the shadowing phenomenon; and (iii) the intensive focus on subsidy policies. The shadowing phenomenon comes from installing too many wind turbines in a limited area to save costs on land use. Moreover, the short distance between wind farms compromises the individual performance of each farm. The vast use of public financial support policies may have led to fast, but inefficient, wind energy deployment.

Acker et al. (2007) noted that a seasonal influence in the capacity factor can be observed. Caralis et al. (2008) analyzed the capacity factors in Greece and suggest that spatial dispersion of wind farms benefits the wind power capacity factor. They concluded that the accumulation of too many wind farms is not always the optimal solution because it may impair the efficiency of each individual wind farm. More recently, Yang et al. (2012) and Zhang and Li (2012) assessed wind power growth in China, which was driven by three main factors: (i) the perception that China benefits from large wind resources; (ii) the adoption of incentives and subsidies that support the investment in wind power; and (iii) the reduction in wind capital costs. The authors note that more attention to the efficiency of wind turbine allocation in China is needed. In fact, one-third of wind turbines were idle, causing a capacity factor of 16.3% between 2007 and 2010 (Yang et al., 2012).

2.2. Backup and energy storage

It is important to seek new ways to deal with wind speed variability, both in the short and long term. Examples could be additional energy sources to backup power in windless periods or energy storage devices (Purvins et al., 2011). To ensure a secure energy supply, it is necessary to mix wind power with other energy sources, including fossil fuels. Pearce (2009) suggests a solar photovoltaic system mixed with combined heat and power to overcome intermittency in California without resorting to energy storage. Moreno and Martínez-Val (2011) argue that thermal power plants are no longer so important in base load energy generation, turning them into backup sources to substitute renewables. These authors support that by 2020, backup with combined cycle gas turbine plants needs to grow to 8 or 9 Gigawatts. The literature (e.g. Archer and Jacobson, 2007) also mentions another method to smooth wind variability. These authors found that by interconnecting multiple wind parks

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through the electricity transmission grid, wind farms behave more similarly over time as a single wind farm with constant wind speed, providing a constant and secure energy supply.

As regards the impact of energy policies and measures on the deployment of renewables, a few studies have provided empirical evidence. Carley (2009) uses the fixed-effect vector decomposition, which is a variant of the fixed-effects model, and finds that the sum total of United States energy policies does not contribute significantly to more electricity from renewables. However, the growth of renewables is promoted by each additional year that a State maintains a policy. A positive relationship between the expansion of wind energy and the adoption of energy policies that promote investment and subsidies is found by Menz and Vachon (2006). Regarding European countries, Marques and Fuinhas (2012a) prove that policies subsidizing the promotion of renewables have been effective in doing so. Overall, they argued that this process is driven by political willingness rather than by economic rationality.

3. Wind capacity, energy sources and European public policies

Wind energy growth in the last decade in Europe was mainly driven by several factors such as: energy demand growth; the commitments made to greenhouse gas reduction under the Kyoto protocol directives; improvements in renewable energy technology; and the reduction of the marginal cost of wind power generation over the past 15 years, approaching the cost of conventional energy sources (Pechak et al., 2011). For these reasons, wind power has registered a strong impulse since the late 1990s and early 2000s. As a consequence, due to the lack of data before 1998 for almost all European countries, this study uses panel data for the time span 1998-2009, for the following countries: Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, the Netherlands, Norway, Poland, Portugal, Spain, Sweden and the United Kingdom. These countries are part of a group that is driven by long-term energy goals under European directives (EU directive, 2009). Not all countries have the same number of observations due to sporadic missing values, which leads to an unbalanced panel. The remaining countries of the EU27 did not provide available data for wind power installed capacity in the considered time span.

Panel data techniques have several advantages, such as: (i) they allow a more accurate statistical inference; (ii) they provide more informative data and variability; (iii) they increase the number of observations and degrees of freedom; and (iv) they allow for controlling individual heterogeneity and unobserved characteristics of errors which are not detectable in time-series or cross-sectional models (Baltagi, 2005 and Hsiao, 2006).

3.1. Wind capacity

For a better approach to the issue of intermittency and overcapacity, it proved necessary to make the concept of overcapacity operational. To do so, a variable which emulates wind overcapacity ($WOCAP_{c,t}$) was created.

$WOCAP_{c,t}$ is the dependent variable and represents the ratio of idle capacity in a year to the hypothetical maximum energy that could be produced in a year, in a continuous full-power operation. This ratio was computed from raw data, and can be done in two different ways: (i) through idle capacity; and (ii) through capacity factor. Accordingly, for option (i) the result is:

$$WOCAP_{c,t} = \frac{IDCAP_{c,t}}{TOTALCAP_{c,t}}. \tag{1}$$

In equation (1) $TOTALCAP_{c,t}$ is the total of wind installed capacity. $IDCAP_{c,t}$ denotes the idle capacity of wind power in a year. In other words, $IDCAP_{c,t}$ represents the difference between maximum possible wind electricity generation during the year (8760 hours) and the amount of electricity actually generated. $TOTALCAP_{c,t}$ and $IDCAP_{c,t}$ are expressed in Megawatts (MW) and this last one is computed as follows:

$$IDCAP_{c,t} = \frac{(WINDCAP_{c,t}*8760) - (TOTELECGEN_{c,t}*1000)}{8760}, \tag{2}$$

where $TOTELECGEN_{c,t}$ is the total electricity generated in a year, in Gigawatts *per* hour (GWh). $TOTELECGEN_{c,t}$ is multiplied by 1000 to convert to same units.

Regarding option (ii) $WOCAP_{c,t}$ can be computed as the difference between 1 and the capacity factor ($CF_{c,t}$) as follows:

$$WOCAP_{c,t} = 1 - CF_{c,t}. \tag{3}$$

The capacity factor is computed as follows:

$$CF_{c,t} = \frac{TOTELECGEN_{c,t}*1000}{TOTCAP_{c,t}*8760}. \tag{4}$$

In expressions (3) and (4) $CF_{c,t}$ is the ratio of actual wind power to maximum capacity in a year. For example, for Germany and Spain, which are the leader countries in terms of wind installed capacity, in 2009 the total installed capacity was respectively 25777 MW and 18988 MW. Electricity output was 38637 GWh and 36851 GWh. From here, following equation (2) for Germany and Spain, $IDCAP_{c,t}$ in 2009 was:

$$\frac{(25777*8760) - (38637*1000)}{8760} \approx 21366.3836\, MW, \tag{5}$$

$$\frac{(18988*8760) - (36851*1000)}{8760} \approx 14781.2648\, MW. \tag{6}$$

In accordance with equation (1), wind overcapacity ratios ($WOCAP_{c,t}$) for Germany and Spain are given as:

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$$\frac{21366.3836}{25777} \approx 0.8289, \quad (7)$$

$$\frac{14781.2648}{18988} \approx 0.7785. \quad (8)$$

For Finland and Latvia, which are the countries with the lowest wind installed capacity (147 MW and 29 MW respectively) with electricity output of 277 GWh and 49 GWh, in 2009 $IDCAP_{c,t}$ was:

$$\frac{(147*8760) - (277*1000)}{8760} \approx 115.3790\, MW, \quad (9)$$

$$\frac{(29*8760) - (49*1000)}{8760} \approx 23.4064\, MW. \quad (10)$$

Hence, wind overcapacity ratios ($WOCAP_{c,t}$) for these two countries respectively are given as:

$$\frac{115.3790}{147} \approx 0.7849, \quad (11)$$

$$\frac{23.4064}{29} \approx 0.\ 8071. \quad (12)$$

Our computations indicate that 82.89 %, 77.85 %, 78.49 % and 80.71 % of the wind installed capacity was idle during the year, i.e., a capacity factor of 17.11 %, 22.15 %, 21.51 % and 19.29 % respectively for Germany, Spain, Finland and Latvia. These values are relatively high. Indeed, it is surprising that this issue has not been addressed earlier with more emphasis in the literature. Average $WOCAP_{c,t}$ values for all countries of our panel for the time span 1998-2009 are presented in Figure 1. Wind overcapacity average values are in line with other authors who addressed capacity factors, like Boccard (2009) and Yang et al. (2012). For example, in Denmark and Portugal, the average $WOCAP_{c,t}$ is 0.7790 and 0.7840 respectively, and according to (4) the capacity factor is 0.2210 and 0.2160. It denotes that Nordic countries (e.g. Norway, Sweden, Finland, Denmark, the United Kingdom and Ireland) as well as southern Europe (e.g. Portugal, Spain and Greece) have less idle capacity and therefore more capacity factors than continental countries. This may be because of higher wind speeds in these regions.

3.2. Variables

Several causes for idle capacity are suggested by the normative literature. Following this closely, the impact of variables with different natures is controlled for, such as: conventional energy sources; other renewable sources; socio-economic drivers; and energy efficiency measures and public policies as follows.

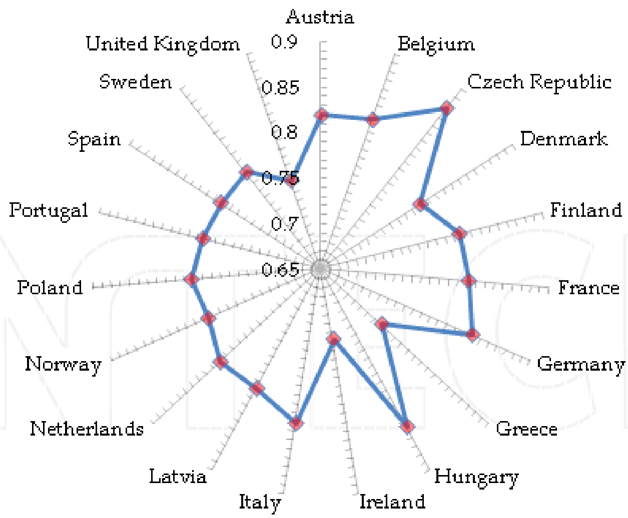

Figure 1. Average $WOCAP_{c,t}$ for the time span 1998 – 2009

3.2.1. Conventional energy sources

To assess the impact of conventional energy sources on wind overcapacity, the shares of fossil energy sources in total electricity generation across European countries were used (see Figure 2 for average values). The variables are for coal-based power plants ($COALSH_{c,t}$), gas-fired ($GASSH_{c,t}$) and oil power plants ($OILSH_{c,t}$). The literature (e.g. Luickx et al., 2008; Østergaard, 2008; Larraín et al., 2010; and Purvins et al., 2011) argues that these variables are the main sources used to backup wind power, especially coal and gas. In fact, gas turbines can be used as a backup source for wind power in windless periods because their startup times are in the order of a few minutes while other conventional power plants may take much longer (Kehlhofer et al., 2009). It is expected that these variables will be highly significant in explaining wind overcapacity. Nuclear power is also part of conventional energy sources. The impact of nuclear capacity factor ($CFNUCL_{c,t}$) in wind overcapacity (computed according to (4)) is controlled. Nuclear power still has great importance in Europe, despite its capacity factor reduction by 7.9% between 1998 and 2009. The toxic waste that comes from nuclear power and the fact that it is difficult to treat as well as risk of disaster have recently brought the debate to Germany to reduce its share of nuclear power in electricity generation.

Figure 2 suggests that the 19 countries included in our study still have a large share of conventional energy sources in total electricity generation, except Nordic countries and Portugal, which have been at the forefront of the support in renewables, namely wind and solar energy.

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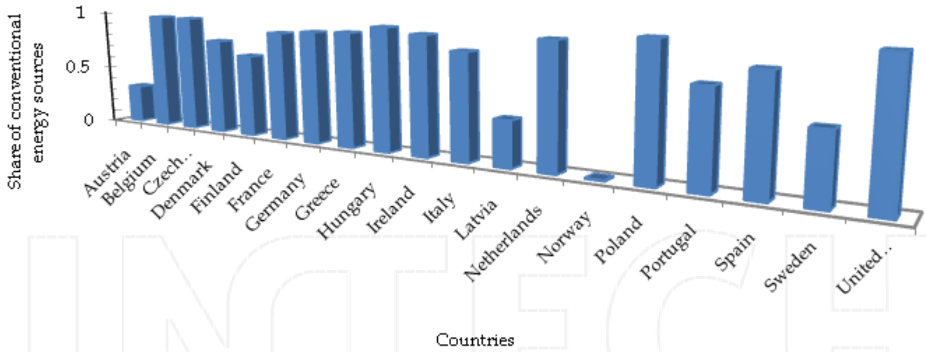

Figure 2. Average conventional energy sources share for the time span 1998-2009

3.2.2. Other renewable energy sources

To assess the impact of renewables on wind overcapacity, our option is to use variables representing the most common renewable energy sources such as hydropower, renewable waste and solar energy. Figure 3 presents the growth rate of renewables' share in the 19 countries under analysis. Regarding hydropower, the effect of the capacity factor of hydropower ($CFHYD_{c,t}$) is controlled. This variable was computed similarly to the nuclear capacity factor, according to expression (4) to avoid multicollinearity problems. In the context of the Europe 20-20-20 targets, renewable waste and solar energy have been increasingly used to generate electricity (Münster and Meibom, 2011). To assess the impact of these two energy sources on wind overcapacity, the effect of the share of waste ($WASTSH_{c,t}$) and solar ($SOLSH_{c,t}$) in the total electricity generated is controlled. We also sought to ascertain the impact of installing more wind power over the years through the growth rate of wind power installed capacity ($WINDGR_{c,t}$). It is expected that the overcapacity of wind power will be positively influenced by more wind power plants.

In Figure 3, values suggest that, in Europe, there has generally been large growth in the share of electricity generated from renewable energy sources. Negative values may indicate that in these countries hydro power is becoming less important in the energy portfolio. For example, Portugal, Germany, Denmark and Ireland have average rates of growth of 10.75%, 9.57%, 10.63% and 11.55% respectively, which indicates huge support in electricity generation from renewables in the early 2000s.

3.2.3. Socio-economic drivers

Potential socio-economic drivers such as population density or economic development were controlled for in order to assess their effect on wind overcapacity (see Figures 4 and 5 for average values). According to Caralis et al. (2008) and Boccard (2009), the spatial dispersion of wind farms may be an important driver for a greater or lesser capacity factor. To control for the effect of spatial dispersion of wind farms, a proxy, the variable $POPDENS_{c,t}$ is used.

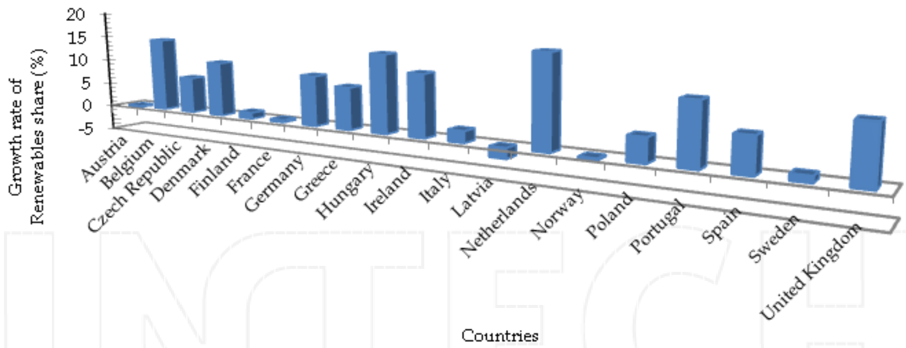

Figure 3. Average rate of growth in renewables' share in total electricity generation (including Hydro) for the time span 1999-2009

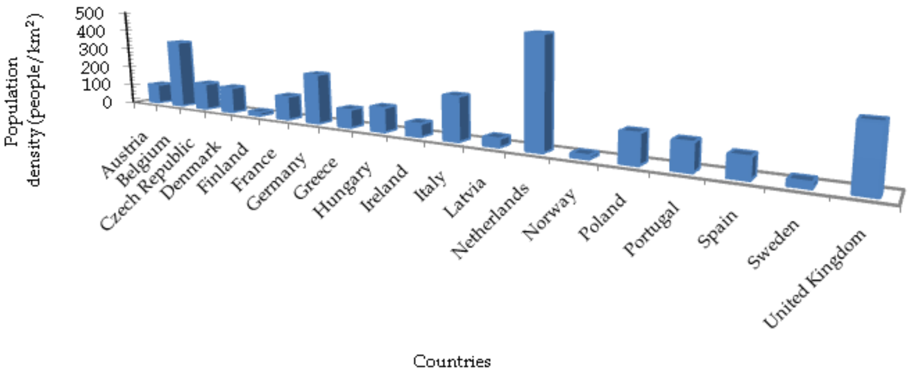

Figure 4. Average population density for the time span 1998-2009

This variable assesses the effect of available and suitable land area for wind park installation in countries with greater or lesser population density. The Netherlands, followed by the United Kingdom, reveal the largest population density in the panel.

Regarding economic development, the natural logarithm of Gross Domestic Product (GDP) *per capita* ($LNGDPPC_{c,t}$) is used to measure the capacity of European countries to invest in more efficient energy generation technologies. It is expected that more developed countries will have greater available financial resources to invest in more efficient energy sources, such as offshore wind parks.

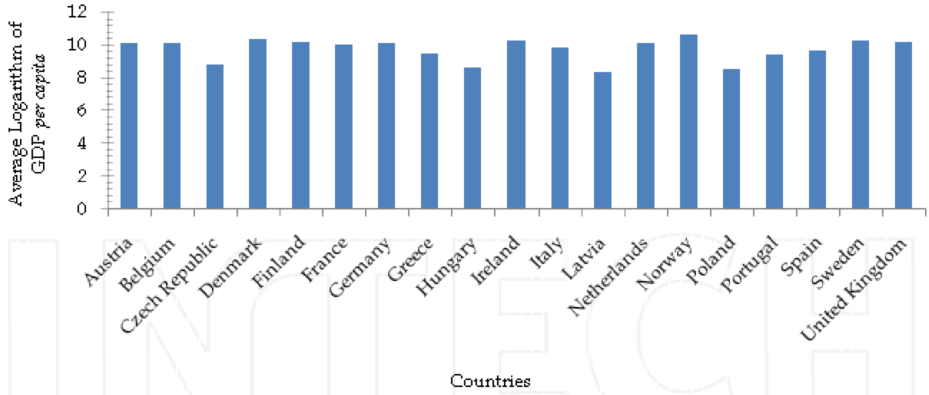

Figure 5. Average natural logarithm of GDP *per capita* for the time span 1998-2009

Latvia is the country with the smallest average natural logarithm of GDP *per capita*, while Norway holds the largest value for this indicator.

3.2.4. Energy efficiency measures and public policies

Energy policies and measures have been widely used to promote and support the deployment of renewables. Data from the Mesures d'Utilisation Rationnelle de l'Energie (MURE) database was collected, which provides information concerning the amount and the impact of these measures in order to control for the influence of energy policies on overcapacity. The variables are the cumulative amount of measures taken per household and in the industrial and tertiary sectors, as presented in Figure 6. Firstly, the total energy policies and measures carried out in a year ($ALLPOL_{c,t}$) were considered. It is expected that the total measures may have a positive impact on wind power overcapacity. For a deeper analysis of public policies, the total energy policies are divided into seven individual types to assess the influence of each type individually: (i) Legislative/normative ($NORMPOL_{c,t}$) stands for mandatory standards for buildings, regulations for heating systems and hot water systems, regulations in the field of building and mandatory standards for electrical appliances; (ii) legislative/informative ($INFOPOL_{c,t}$) aims to inform about energy efficiency, mandatory standards in buildings and electrical appliances; (iii) fiscal/tariff ($FISCPOL_{c,t}$) measures include tax exemptions/reductions in retrofitting investments; (iv) incentives/subsidies ($FINPOL_{c,t}$) includes feed-in tariffs, grants and loans. A positive effect of these measures on $WOCAP_{c,t}$ is expected, due to their contribution to renewables' deployment which may positively influence wind overcapacity; (v) information/education ($EDUPOL_{c,t}$) measures aim to provide campaigns by energy agencies and energy suppliers; (vi) co-operative measures ($COOPPOL_{c,t}$) include voluntary programs; and (vii) cross-cutting measures ($CUTPOL_{c,t}$) are the eco-tax on energy consumption or CO2 emissions and other eco-taxes.

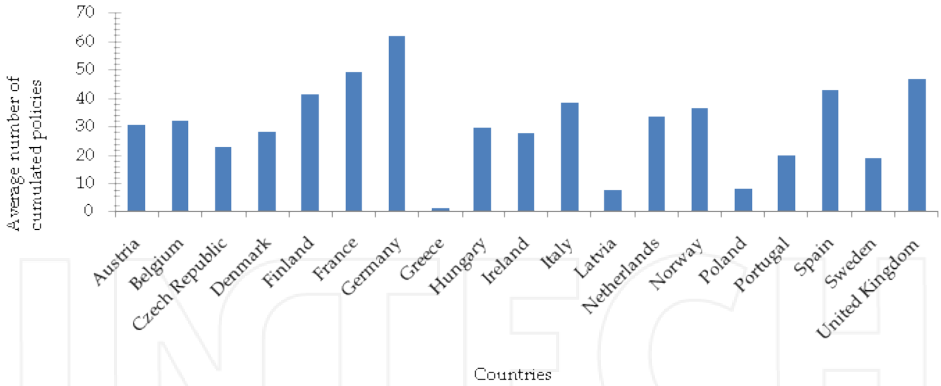

Figure 6. Average number of accumulated energy policies and measures for the time span 1998-2009

Variable	Definition	Source	Obs.	Mean	SD	Min.	Max.
$WOCAP_{c,t}$	Ratio of non-used output to the maximum possible output over a year	EUROSTAT	221	0.7956	0.0543	0.5947	0.9912
$COALSH_{c,t}$	Ratio of elect. gen. to coal (TWh)/total elect. gen. (TWh)	IEA	227	0.2940	0.2483	0	0.9636
$GASSH_{c,t}$	Ratio of elect. gen. to gas (TWh)/total elect. gen. (TWh)	IEA	227	0.2161	0.1761	0.0015	0.6339
$OILSH_{c,t}$	Ratio of elect. gen. to oil (TWh)/total elect. gen. (TWh)	IEA	227	0.0564	0.0770	0.0001	0.4243
$CFNUCL_{c,t}$	Ratio of average plant output to the maximum possible output over a year	IEA	228	0.4324	0.4164	0	0.9659
$CFHYD_{c,t}$	Ratio of average plant output to the maximum possible output over a year	IEA	228	0.2884	0.1231	0.0948	0.6223
$WASTSH_{c,t}$	Ratio of elect. gen. to waste (TWh)/total elect. gen. (TWh)	IEA	227	0.0308	0.0348	0	0.1486
$SOLSH_{c,t}$	Ratio of elect. gen. to solar (TWh)/total elect. gen. (TWh)	IEA	227	0.0004	0.0018	0	0.0210
$WINDGR_{c,t}$	Yearly growth rate of wind installed capacity	EUROSTAT	223	50.5234	98.1664	-7.1429	1000
$POPDENS_{c,t}$	Population density (people/km2)	World Bank, World Development Indicators Database	228	139.6083	115.6765	14.5655	489.6442

Variable	Definition	Source	Obs.	Mean	SD	Min.	Max.
$LNGDPPC_{c,t}$	Logarithm of Gross Domestic Product per Capita	World Bank, World Development Indicator Database	228	9.7194	0.6774	7.9737	10.6431
$ALLPOL_{c,t}$	Total of Accumulated Number of Renewable Energy Policies and Measures	MURE DATABASE	228	29.8553	18.9586	0	82
$NORMPOL_{c,t}$	Accumulated Number of Renewable Energy Policies and Measures – Normative/Legislative	MURE DATABASE	228	6.9035	6.0468	0	36
$FISCPOL_{c,t}$	Accumulated Number of Renewable Energy Policies and Measures – Tariff/ fiscal	MURE DATABASE	221	1.0905	1.8367	0	7
$INFOPOL_{c,t}$	Accumulated Number of Renewable Energy Policies and Measures – Legislative/informative Legislative/ informative	MURE DATABASE	228	3.2807	3.2434	0	13
$FINPOL_{c,t}$	Accumulated Number of Renewable Energy Policies and Measures – Incentives/subsidies	MURE DATABASE	228	8.6754	7.0079	0	26
$EDUPOL_{c,t}$	Accumulated Number of Renewable Energy Policies and Measures – Educational	MURE DATABASE	228	5.5526	4.7159	0	22
$COOPPOL_{c,t}$	Accumulated Number of Renewable Energy Policies and Measures – Co-operative	MURE DATABASE	218	2.7456	3.0511	0	16
$CUTPOL_{c,t}$	Accumulated Number of Renewable Energy Policies and Measures – Cross-cutting	MURE DATABASE	228	1.6404	3.5199	0	16

Notes: MURE DATABASE stands for Mesures d'Utilisation Rationnelle de l'Energie (MURE II Database); co-ordinated by the Institute of Studies for the Integration of Systems and the Fraunhofer Institute for Systems and Innovation Research ISI. IEA stands for International Energy Agency Data Services and EUROSTAT stands for Eurostat Statistics Database available at http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database with the code nrg_113a.

Table 1. Variables definition, sources and summary statistics

Figure 6 indicates that there has been major support for renewables through energy policies and measures especially in Germany, France, Finland and the United Kingdom.

3.3. Data

In this chapter data from several sources such as the Eurostat database, International Energy Agency (IEA), World Bank and MURE Database is used. Table 1 presents the variables, their definition, sources and summary statistics for the time span 1998-2009.

3.4. Methods

To make a proper empirical analysis the panel dataset structure was analyzed, which generally has a complex nature of term error composition. Several methods were applied: (i) visual analysis of data; (ii) test for first-order autocorrelation in panel data; (iii) test for the presence of groupwise heteroskedasticity; and (iv) test for contemporaneous correlation. Stata v11.2 econometric software was used.

The correlation matrix (Table 2) values suggest that correlation coefficients are low and do not suggest the existence of collinearity among the variables.

	$WOCAP_{c,t}$	$COALSH_{c,t}$	$GASSH_{c,t}$	$OILSH_{c,t}$	$CFNUCL_{c,t}$	$CFHYD_{c,t}$	$WASTSH_{c,t}$	$WINDGR_{c,t}$	$SOLSH_{c,t}$
$WOCAP_{c,t}$	1								
$COALSH_{c,t}$	-0.0365	1							
$GASSH_{c,t}$	-0.1244	-0.1455	1						
$OILSH_{c,t}$	-0.2115	0.071	0.2375	1					
$CFNUCL_{c,t}$	0.2218	-0.1512	-0.0172	-0.4296	1				
$CFHYD_{c,t}$	0.0557	-0.4607	-0.2358	-0.2613	0.1269	1			
$WASTSH_{c,t}$	0.0412	-0.0863	0.0188	-0.2497	0.2778	0.4466	1		
$WINDGR_{c,t}$	0.4853	-0.0079	-0.1081	-0.0593	-0.0462	-0.0219	-0.1532	1	
$SOLSH_{c,t}$	0.0203	-0.0003	0.0637	-0.0357	0.1309	-0.088	0.0184	-0.0723	1
$POPDENS_{c,t}$	0.1344	0.1529	0.5052	-0.0721	0.3865	-0.33	-0.0177	-0.0968	0.0592
$LNGDPPC_{c,t}$	-0.1772	-0.3668	0.0691	-0.0704	0.1725	0.3844	0.301	-0.2477	0.0294
$NORMPOL_{c,t}$	0.0936	-0.2008	0.2193	0.1654	0.0503	-0.1347	-0.0908	-0.109	0.4542
$FISCPOL_{c,t}$	-0.0087	-0.1839	0.2779	-0.2763	0.4015	-0.1103	0.0589	-0.0683	-0.068
$FINPOL_{c,t}$	-0.1705	-0.1179	-0.027	-0.3426	0.5317	0.169	0.088	-0.0178	0.1358
$EDUPOL_{c,t}$	-0.0832	-0.2672	0.0633	-0.3603	0.1555	0.3154	0.252	-0.0749	0.0879
$COOPPOL_{c,t}$	-0.008	-0.1613	0.2452	-0.2366	0.4922	0.3567	0.5535	-0.1681	0.0922
$CUTPOL_{c,t}$	0.0634	0.0865	-0.0564	-0.2202	0.2274	0.175	-0.0224	-0.082	0.249

	$POPDENS_{c,t}$	$LNGDPPC_{c,t}$	$NORMPOL_{c,t}$	$FISCPOL_{c,t}$	$FINPOL_{c,t}$	$EDUPOL_{c,t}$	$COOPPOL_{c,t}$	$CUTPOL_{c,t}$
$\boldsymbol{POPDENS_{c,t}}$	1							
$\boldsymbol{LNGDPPC_{c,t}}$	0.1445	1						
$\boldsymbol{NORMPOL_{c,t}}$	0.1375	0.2511	1					
$\boldsymbol{FISCPOL_{c,t}}$	0.557	0.3284	0.1434	1				
$\boldsymbol{FINPOL_{c,t}}$	0.215	0.2488	0.3877	0.3986	1			
$\boldsymbol{EDUPOL_{c,t}}$	-0.0983	0.3927	0.1509	0.2376	0.4939	1		
$\boldsymbol{COOPPOL_{c,t}}$	0.2422	0.4507	0.1037	0.3808	0.3564	0.3814	1	
$\boldsymbol{CUTPOL_{c,t}}$	0.275	0.3259	0.0897	0.1559	0.4795	0.3185	0.2131	1

Notwithstanding, the Variance Inflation Factor (VIF) test for multicollinearity among variables was performed. Individual values are below 5 for all individual tests and 2.36 for mean VIF (Table 3), which reinforces that multicollinearity among variables is not a problem.

Table 2. Correlation Matrix

Variables	VIF	1/VIF
$COALSH_{c,t}$	2.33	0.4292
$GASSH_{c,t}$	2.42	0.414
$OILSH_{c,t}$	1.81	0.5522
$CFNUCL_{c,t}$	2.76	0.363
$CFHYD_{c,t}$	2.92	0.3423
$WASTSH_{c,t}$	1.95	0.5131
$WINDGR_{c,t}$	1.11	0.8993
$SOLSH_{c,t}$	1.64	0.6092
$POPDENS_{c,t}$	3.47	0.2881
$LNGDPPC_{c,t}$	2.22	0.4514
$NORMPOL_{c,t}$	2.37	0.4226
$FISCPOL_{c,t}$	2.41	0.415
$FINPOL_{c,t}$	3.29	0.304
$EDUPOL_{c,t}$	2.19	0.4556
$COOPPOL_{c,t}$	2.66	0.3758
$CUTPOL_{c,t}$	2.16	0.4621
Mean VIF	2.36	

Table 3. Variance Inflation Factor (VIF)

As part of the empirical research using panel dataset techniques, several tests to detect common panel phenomena in errors structure were performed (see Table 4 for results). The Wooldridge test with the null hypothesis of no first-order autocorrelation to detect serial correlation in the idiosyncratic errors of panel-data (Wooldridge, 2002) was performed. This test follows a normal distribution N(0,1) in Ordinary Least Squares (OLS) estimator. Furthermore, a modified Wald test was applied to search for the presence of groupwise heteroskedasticity in the residuals of a fixed effect (FE) regression model, which assumes homoskedasticity across cross-sections. The modified Wald Test has χ^2 distribution and tests the null hypothesis of: $\sigma_c^2 = \sigma^2 \text{for} c = 1, \ldots, N$ whereσ^2 is the variance of the $c$country (Greene, 2000). As stated by Marques and Fuinhas (2012b), if one considers that European countries are guided by common energy guidelines, one might expect the presence of contemporaneous correlation in our panel. In order to detect this phenomenon, or rather, test the null hypothesis of cross-section independence, Pesaran (2004), Frees (1995 and 2004), and Friedman (1937) tests were performed. While Pesaran follows a standard normal distribution, the Frees statistic test uses Frees Q-distribution and Friedman uses Friedman's chi-square distributed statistic. Frees and Friedman perform only with available data for all cross-sections. Hausman's statistics test the null hypothesis that the difference of coefficients between fixed-effects and random-effects is not systematic.

	Pooled OLS	Fixed Effects (FE)	Random Effects (RE)
Wooldridge test F(N(0,1))	3.48		
Modified Wald test (χ^2)		749.41***	
Pesaran test		-1.717	-2.061**
Frees test		0.744	1.191
Friedman test		7.053	4.605

Note: ***, ** denote significance at 1 and 5% significance levels

Table 4. Specification tests and statistics

According to table 4 results, the Wooldridge test value (3.48) does not reject the null hypothesis of no first-order autocorrelation. Accordingly, the autoregressive (AR1) estimator is not suitable. The modified Wald test value (749.41) suggests rejection of the null hypothesis of errors homoskedasticity within cross-sections. Therefore, the presence of groupwise heteroskedasticity is confirmed. As far as the presence of contemporaneous correlation is concerned, with the exception of the Pesaran test for random effects (-2.061), generally the null hypothesis of no contemporaneous correlation was not rejected, suggesting that there is spatial independence across European countries. This is not surprising given the technical nature of our research into the interaction of conventional sources and renewables with wind overcapacity instead of common policy guidelines.

The OLS estimator proves to be consistent when there is no presence of multicollinearity among the explanatory variables and when the regressors are exogenous. It is optimal when there is no serial auto-correlation following $V(\varepsilon)=\sigma_{\varepsilon}^{2} \mid NT$ and when the errors are homoskedastic following $E(\varepsilon)=0$. Therefore, in our case it may be useful to benchmark results of our panel estimation. Moreover, we apply the panel fixed-effects (FE) and random-effects estimators (RE). Using the fixed-effects estimator appears to be appropriate in studying the impact of variables that vary over time. It explores the different variables within groups that have their own characteristics, in our case European countries. The fixed-effects estimator assumes that something time-invariant within groups can affect the dependent variable and cannot be correlated with other groups. In turn, random effects assume that variation across groups is random and not correlated to the dependent and independent variables.

The generic model to estimate is:

$$WOCAP_{c,t} = \alpha + \sum_{k=1}^{k} \beta_k X_{k,c,t} + d_t + \varepsilon_{c,t} , \tag{13}$$

where the error term is $\varepsilon_{c,t}=\alpha_c + u_{c,t}$ with α_c uncorrelated with the regressors and $\varepsilon_{c,t}$ homoskedastic with no serial correlation. The dummy for time is denoted by d_t.

4. Empirical evidence of the drivers of wind overcapacity

The estimation results are shown in Table 5. Conventional standard errors (CSE) are provided, as are robust standard errors (RSE) to deal with the presence of heteroskedasticity. Models *I* and *II* represent pooled OLS; models *III* and *IV* are panel fixed-effect estimators (FE); and models *V* and *VI* stand for random-effect estimators (RE). The error term is $\varepsilon_{c,t}=\alpha_c + u_{c,t}$.

A battery of diagnostic tests was applied to test the quality of the estimators. The Breusch-Pagan Lagrange multiplier (LM) is provided to test whether the RE estimator is more suitable than the OLS estimator. The results show that the null hypothesis of variances across groups being equal to zero is rejected, so there is a significant difference across groups. Accordingly, the RE estimator is more suitable than Pooled OLS. The Hausman test to choose the most appropriate estimator between FE and RE was applied. The null hypothesis assumes that the difference in coefficients is not systematic, thus accepting RE over FE estimator (Greene, 2008). The Hausman test accepts the null hypothesis, thus the errors α_c are uncorrelated with the regressors. As a consequence, the discussion will be based on RE estimator with RSE (*VI*). In other words, it seems that differences across countries influence $WOCAP_{c,t}$, so the panel RE estimator is more appropriate than FE to our analysis.

	OLS		FE		RE	
Ind. Variables	***CSE(I)***	***RSE(II)***	***CSE(III)***	***RSE(IV)***	***CSE(V)***	***RSE(VI)***
$COALSH_{c,t}$	-0.0402** (0.0161)	-0.0402** (0.0182)	-0.0696 (0.1264)	-0.0696 (0.0651)	-0.0381** (0.0177)	-0.0381** (0.0192)
$GASSH_{c,t}$	-0.0768*** (0.0234)	-0.0768*** (0.0255)	-0.1174 (0.1330)	-0.1174 (0.0660)	-0.0692*** (0.0253)	-0.0692*** (0.0253)
$OILSH_{c,t}$	-0.0442 (0.0479)	-0.0442 (0.0739)	-0.2819** (0.1382)	-0.2819*** (0.0673)	-0.0646 (0.0508)	-0.0646 (0.0731)
$CFNUCL_{c,t}$	-0.0086 (0.0101)	-0.0086 (0.0137)	0.0893 (0.0785)	0.0893 (0.0619)	-0.0070 (0.0110)	-0.0070 (0.0142)
$CFHYD_{c,t}$	0.0118 (0.0362)	0.0118 (0.0402)	-0.1466 (0.0825)	-0.1466** (0.0621)	0.0049 (0.0386)	0.0049 (0.0415)
$WASTSH_{c,t}$	0.2878*** (0.1084)	0.2878*** (0.0836)	-0.1588 (0.3438)	-0.1588 (0.3102)	0.2666** (0.1174)	0.2666** (0.0849)
$WINDGR_{c,t}$	0.0002*** (0.0000)	0.0002*** (0.0001)	0.0002*** (0.0000)	0.0002*** (0.0001)	0.0002*** (0.0000)	0.0002*** (0.0000)
$SOLSH_{c,t}$	1.2293 (1.8236)	1.2293 (1.0963)	1.5059 (2.0191)	1.5059 (0.8716)	1.1403 (1.8146)	1.1403 (0.9527)
$POPDENS_{c,t}$	0.0002*** (0.0000)	0.0002*** (0.0000)	0.0021 (0.0014)	0.0021 (0.0011)	0.0001*** (0.0000)	0.0001*** (0.0000)
$LNGDPPC_{c,t}$	-0.0300*** (0.0063)	-0.0300*** (0.0076)	0.0878 (0.0563)	0.0878 (0.0511)	-0.0290*** (0.0068)	-0.0290*** (0.0081)
$ALLPOL_{c,t}$	0.0008*** (0.0002)	0.0008*** (0.0003)	0.0009** (0.0004)	0.0009*** (0.0003)	0.0008*** (0.0002)	0.0008*** (0.0002)
CONST	1.0650*** (0.0617)	1.0650*** (0.0746)	-0.2911 (0.6436)	-0.2911 (0.6077)	1.0593*** (0.0666)	1.0593*** (0.0805)
N	218	218	218	218	218	218
R^2	0.4316	0.4316	0.3623	0.3623		
Wald (χ^2)					136.63***	
F (N(0,1))	7.09***		4.82***			
LM (χ^2)					11.76***	
Hausman (χ^2)			30.93			

Notes: OLS - Ordinary Least Squares. RE – Random Effects. FE – Fixed Effects. CSE – Conventional standard errors. The F-test has normal distribution N(0,1) and tests the null hypothesis of non-significance of all estimated parameters. The Wald test has χ^2distribution and tests the null hypothesis of non-significance of all coefficients of independent variables. The LM test has χ^2distribution and tests the null hypothesis of non-relevance of individual effects in the RE model. The Hausman test has χ^2distribution and tests the null hypothesis of the difference in coefficients not being systematic between two selected estimators. Standard errors are reported in brackets. All estimates were controlled to include time effects, although they are not reported for reasons of simplicity. ***, **, denote significance at 1 and 5% significance levels respectively for both coefficient estimators and test statistics.

Table 5. Regression results - Dependent Variable $WOCAP_{c,t}$

Globally, the estimation results provided in Table 5 reveal consistency despite some differences between significance levels. By examining the variables in descending order, for fossil fuels, the effect of $COALSH_{c,t}$ and $GASSH_{c,t}$ proved to be negative and statistically significant at 5% and 1% respectively. On the other hand, variable $OILSH_{c,t}$ does not seem to be significant statistically. This result is in line with expectations, revealing that there is backup for wind power using fossil fuels like coal and gas to overcome intermittency. Oil power plants are not generally used for backup, so these results may reveal our model's robustness.

$CFNUCL_{c,t}$, $CFHYD_{c,t}$ and $SOLSH_{c,t}$ coefficients reveal no statistical relationship between the capacity factor of nuclear and hydro or the share of solar energy and wind power overcapacity. The effects of variables $WINDGR_{c,t}$, $POPDENS_{c,t}$, $LNGDPPC_{c,t}$ and $ALLPOL_{c,t}$ are positive and statistically significant. Therefore, it is assumed that they are important drivers in explaining wind overcapacity. Results from disaggregated policies are presented in table A. 1. None of the individual energy policies proves to be significant in explaining wind overcapacity except $NORMPOL_{c,t}$ and $FISCPOL_{c,t}$. However, it is worth noting that there is no inclusion of the legislative/informative policies ($INFOPOL_{c,t}$) due to their identical nature and the fact that they could create collinearity problems. Contrary to expectations, financial policies have no statistical relation to wind overcapacity.

Exclusion tests were run for the explanatory variables ($FINPOL_{c,t}$, $EDUPOL_{c,t}$, $COOPPOL_{c,t}$ and $CUTPOL_{c,t}$), which do not reveal a statistical significance, following the parsimonious principle. The results are shown in Table A.2. In fact, the models maintain robustness among the estimators for all coefficients with or without these individual policies. This set of variables has no influence either on the ratio of non-used wind capacity ($WOCAP_{c,t}$) or on the remaining model. Nevertheless, given that consistency and robustness are crucial properties, a subsection is opened to provide additional analysis on the reliability of results.

5. Consistency and robustness of empirical evidence

According to Huber (1973), as further evidence of the robustness of results, it is appropriate to apply the robust regression (RREG) estimator to cope with possible outliers from our dataset. These outliers can impair the stability and reliability of results. Such as in Marques and Fuinhas (2012b), robustness is analyzed by providing the robust regression with Huber and Tukey weight functions, as presented in table 6.

As shown from this additional assessment of the robustness of results, the variables maintain their signs, though with small differences in significance levels. In general, the robust regression validates the main results of the estimations.

Ind. Variables	**RREG**	**RREG**	**RREG**
	(VII)	**(VIII)**	**(IX)**
$COALSH_{c,t}$	-0.0208 (0.0120)	-0.0130 (0.0115)	-0.0229 (0.0125)
$GASSH_{c,t}$	-0.0755*** (0.0176)	-0.0696*** (0.0159)	-0.0700*** (0.0176)
$OILSH_{c,t}$	-0.0540 (0.0358)	-0.1351*** (0.0346)	-0.1424*** (0.0356)
$CFNUCL_{c,t}$	-0.0120 (0.0075)	-0.0028 (0.0065)	-0.0067 (0.0081)
$CFHYD_{c,t}$	0.0084 (0.0270)	0.0270 (0.0253)	0.0015 (0.0284)
$WASTSH_{c,t}$	0.3199*** (0.0808)	0.3410*** (0.0740)	0.3598*** (0.0827)
$WINDGR_{c,t}$	0.0003*** (0.0000)	0.0003*** (0.0000)	0.0003*** (0.0000)
$SOLSH_{c,t}$	1.6675 (1.3598)	-1.7028 (1.3661)	-2.3226 (1.4871)
$POPDENS_{c,t}$	0.0002*** (0.0000)	0.0002*** (0.0000)	0.0002*** (0.0000)
$LNGDPPC_{c,t}$	-0.0316*** (0.0047)	-0.0276*** (0.0042)	-0.0278*** (0.0047)
$ALLPOL_{c,t}$	0.0007*** (0.0002)		
$NORMPOL_{c,t}$		0.0030*** (0.0004)	0.0030*** (0.0005)
$FISCPOL_{c,t}$		-0.0041*** (0.0016)	-0.0042** (0.0017)
$FINPOL_{c,t}$			-0.0001 (0.0005)
$EDUPOL_{c,t}$			-0.0006 (0.0007)
$COOPPOL_{c,t}$			0.0011 (0.0011)
$CUTPOL_{c,t}$			0.0012 (0.0008)
CONST	1.0712*** (0.0464)	1.0238*** (0.0399)	1.0377*** (0.0457)

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Ind. Variables	RREG (VII)	RREG (VIII)	RREG (IX)
N	218	218	218
R^2	63.59	0.6920	0.7093
F (N(0,1))	15.48***	19.92***	17.93***

Notes: RREG – Robust Regression. The F-test has normal distribution N(0,1) and tests the null hypothesis of non-significance of all estimated parameters. JST - Joint Significance Test. JST is a Wald χ^2 test with the null hypothesis of $H_0=\beta_1=\beta_2=\beta_3=\beta_4=0$, with β_1, β_2, β_3, β_4 representing the coefficient of $FINPOL_{c,t}$, $EDUPOL_{c,t}$, $COOPPOL_{c,t}$ and $CUTPOL_{c,t}$, respectively. LRT - Linear Restriction Test has the null hypothesis of $H_0=\beta_1+\beta_2+\beta_3+\beta_4=0$. Standard errors are reported in brackets. All estimates were controlled to include time effects, but they are not reported for reasons of simplicity. ***, **, denote significance at 1 and 5% significance levels respectively.

Table 6. Results from Robust Regression – Dependent variable $WOCAP_{c,t}$

6. Conventional energy sources and backup

As stated above, renewable energy sources, particularly wind and solar, suffer from the intermittency phenomenon. This phenomenon could cause overcapacity. There are several factors that may influence overcapacity, such as conventional energy sources and renewable energy sources, socio-economic and energy policies. Our results allow us to explore and discuss them individually and suggest some guidance for energy policy and measures.

As shown in the models, the results for conventional energy sources show a negative effect of fossil fuels on overcapacity, more specifically coal and gas power plants. With greater use of coal and gas, the effect of wind overcapacity is reduced. Two main reasons can be at the origin of this effect: (i) intermittency leads to the uncertainty of energy generation and the need to ensure a continuous electricity supply. It requires the existence of fossil fuels like coal and gas to backup power. With more dependence on these sources in peak-load periods, electricity generation is simultaneously based on renewables and fossil fuels in order to meet electricity demand and this implies a reduction in wind overcapacity; and (ii) in line with Marques et al. (2010) the results for fossil fuels sustain a lobbying effect in the electricity generation industry. This effect promotes the growth of fossil fuels to the detriment of renewables due to more stringent energy policies (Fredriksson et al., 2004). The first sites for installation of wind farms are usually the most efficient ones, and, in some countries, the deployment of renewables is still in its early stages because fossil fuels still have high shares in total electricity generation. Therefore, some countries still benefit from better sites with high wind speeds and from better capacity factor and, as a consequence, wind overcapacity tends to be lower, since wind power is installed in optimum sites.

Nevertheless, assuming that fossil fuels could have a positive effect on overcapacity, an increase in the share of coal, gas and oil would provoke a substitution effect in the electricity generation process due to less use of wind energy. In this case, idle capacity would be greater.

Further regarding conventional energy sources, nuclear power is not statistically significant in wind overcapacity, despite its relevance in Europe. Nuclear power is not an intermittent source and its widespread use in Europe is mainly due to its own characteristics: it is cheaper than oil, with a greater capacity to generate power in a single power plant but is inflexible in providing backup for renewables due to its low startup times. Nuclear power works better in full-power operation than on demand (Dittmar, 2012). It is therefore understandable that nuclear is not significant in explaining wind overcapacity. Ultimately, this result can be seen as additional proof of the robustness of the results.

7. Other renewable energy sources

The contributions that renewable energy sources, other than wind, make to explaining wind overcapacity are also discussed. Similarly to results obtained for nuclear, hydropower is not statistically significant. It is a well-developed renewable energy source, with widespread use in Europe for electricity generation (Balat, 2006), which is relatively stable and mature. Its own characteristics imply its use in base load generation. However, recent developments in this source have involved engaging hydropower with wind power. Indeed, wind power combined with pumped hydro power stations can be useful in meeting electricity demand in peak-load periods. In off-peak, wind overproduction can be used to pump water to an elevated reservoir to later be re-used back in the lower reservoir (Dursun and Alboyaci, 2010). This new technology adds storage capacity, not in terms of energy storage but rather in terms of energy generation storage, thereby giving wind energy a new role as a backup to hydropower. In the future, this could help to mitigate overcapacity effects.

Solar energy merits our attention since it is an increasingly common renewable energy source in Europe. The results show that solar energy does not prove to be statistically significant in explaining wind overcapacity. Nevertheless, a popular and advantageous solution, stated by Nema et al. (2009), is the mix of wind and solar considering that their integration makes them less exposed to intermittency. Supporting such systems, more especially in remote areas, may be a solution to reducing overcapacity. It can be followed by European partners, namely in regions where land space and natural resources allow this investment. A case in point is the recent investment in southern Spain in solar thermal plants with a capacity of 300MW at their completion in 2013. Solar thermal power plants use several available technologies such as power towers, parabolic troughs with heat storage, sterling dishes and concentrated/non-concentrated solar power. Consequently, by combining this mix of technologies, the power plants can operate without sunlight at total capacity for 7.5 hours.

When there is more wind installed capacity, the number of intermittent wind power plants also logically increases. Our results support this assumption since the growth rate of wind

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capacity positively influences overcapacity. Regarding the impact of industrial, municipal and renewable waste power, it seems to overlap wind energy due to positive signs in our results. In fact, with more waste processing for energy generation, there appears to be a substitution effect for wind energy. This result is in line with the growing use of waste for electricity generation in recent years, ranging from 2% in 1998 to 5% in 2009.

8. Socio-economic drivers, energy policies and measures

The spatial dispersion and, in other words, the efficient installation of wind parks should be discussed further. Population density was applied as a proxy for spatial dispersion of wind farms to assess the impact of countries with higher or less population density. These countries tend to have less land space to install wind farms properly. Furthermore, continental areas have lower wind speeds than countries with coastlines. Overall, the results support this assumption. Overcapacity is larger in more populated countries. Accordingly, policy makers and players should pay extra attention to this issue in order to support the diversification of wind turbines. To overcome the constraints caused by highly populated countries, offshore technologies can be a better way due to their steadier characteristics mainly driven by higher wind speeds. It also allows the use of higher power generation turbines. In short, offshore wind farms can help to overcome the population density effect on the creation of overcapacity.

In the literature, the role of economic growth as a driver toward renewable energy is far from consensual. Marques et al. (2010) argued that the effect of GDP on renewables depends on the share level of renewables. In their turn, Chang et al. (2009) conclude that economic growth and renewables' development are not directly related. Nonetheless, countries that are in an upward trajectory with high growth rates can support prices of investing in renewables. Despite increased prices for the final consumer, developed countries tend to invest more in renewable energy sources. In this chapter, we focus on the effect of the logarithm of GDP *per capita.* Our results are consistent and reveal that countries with the highest living standards benefit from more advanced and efficient wind power plants which reduce idle capacity.

With the goal of increasing the share of energy from renewable sources, energy policies are stated as an effective instrument for European countries to implement (EU directive, 2009). Several authors (e.g. Gan et al., 2007; and Johnstone et al., 2008) found that incentive taxes, feed-in tariffs, voluntary programs and R&D policy support are the main drivers supporting renewables. Our results allow us to analyze individually and jointly the energy policies adopted in the European context. In our models, the total of accumulated energy policies over the years increases overcapacity, showing that the impact of these policies is sometimes inefficient, taking into account only the players' political will to reach European guidelines. Table A.1 of the appendix shows results from disaggregated energy policies. Normative regulation and efficiency in building policies create wind power overcapacity. Indeed, these policies imply better efficiency and consumption savings. Reducing energy consumption in buildings contributes to aggravating idle capacity. Moreover, fiscal and tariff policies, including tax reduction in retrofitting investments, promote investments in new power plants, replacing old equipment with technologies that generate higher power and are more efficient. Retrofit investments help to upgrade the electricity system and reduce idle capacity.

Overcapacity of renewables is another aspect of the intermittency phenomenon. Wind energy has been a very common and widely accepted instrument in reaching the 20-20-20 targets. It merits a review of the implicit economic consequences. Policy makers should pay more attention to the advantages and consequences of their policies and measures focused on renewables in order to avoid a blindly ill-considered decision-making process. The deployment of wind power installed capacity has implications for the energy grid as a whole and creates economic distortions. To balance conventional energy sources with all renewables is a challenging task that requires enlightened political and scientific intervention. Policy makers should bear in mind that the growth of renewables has to be in line with energy consumption patterns. To mitigate this problem, micro-production incentives seem to be a solution to balancing domestic consumption with network energy supply. Furthermore, installed players should not resist investment in new technologies in order to maximize wind capacity factors. Off-shore sites are a good alternative for countries with coastal areas because in addition to having higher power generation, wind farms can make more efficient use of installed capacity.

Coal-based and gas-fired power plants are actually used to backup wind power. However, this imposes an extra cost on the final consumer since the non-use of conventional power plants is subsidized. Regulatory authorities should be aware and take measures to prevent the price escalation that combines the contribution to investment in renewables with these subsidies for energy industry lobbies. The implementation of mixed systems based on renewable energy in regions with available natural resources can both improve the energy supply economically and supplant the needs of the area (Erdinc and Uzunoglu, 2012). With the opening of energy markets to the private sector, stronger regulation of the market may be an instrument in monitoring immoderate investments.

Generally, there are no incentives to increase the efficiency of renewables' technology. For example, in some countries such as Portugal, there is an incentive based on feed-in tariffs for the solar photovoltaic micro-generation system. The incentive to improve efficiency is non-existent given that the maximum electricity generation that could be sold to the player distributer is bounded. In general, the feed-in tariffs guarantee the price for kWh regardless of whether it is generated by a very efficient device or not. This form of intervention merely ensures income for the players. Policymakers should consider implementing measures that will add competition to the renewables industry, particularly in solar and wind industries, and thus promote patenting and R&D activities.

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9. Conclusion

This chapter is centered on a panel dataset of 19 European countries for the time span 1998-2009 in order to understand and analyze the causes of wind overcapacity that may arise from non-constant electricity generation from renewables. To the best of our knowledge, this approach had never been made through panel data techniques and it is a new method in the renewables' intermittency literature. Some light is shed on overcapacity of wind energy and its interaction with conventional energy sources, other renewables, socio-economic drivers and energy policies in the context of an economic bloc with common long-term energy guidelines.

Results from our models reveal that fossil fuel power plants, such as coal-based and gas-fired, are actually used to backup wind power. Oil and nuclear do not appear to be significant in explaining wind overcapacity. These results may highlight the robustness of our model, considering that oil and nuclear power are generally used for base load energy generation and therefore have no direct effect on wind overcapacity. As further robustness assessment, the robust regression estimator was performed to deal with possible outliers from our panel. Overall, the robust regression supports the main results of the estimations.

Renewables such as hydropower and solar photovoltaic seem to make no apparent contribution to explaining wind power overcapacity, unlike industrial and municipal waste. Moreover, the results indicate that population density is a factor in greater wind overcapacity, while countries with a higher standard of living are associated with less overcapacity. The results for public policies and measures suggest that a positive effect on increased overcapacity may be due to inefficient incentives for deployment of wind power. The promotion of renewable energy is a crucial decision because it deals with one of the central inputs of economies and societies in general. In order to gain a full understanding of the appropriate ways in which to promote the paradigm shift from fossil to renewable sources, objectivity is needed in analyzing both the advantages and disadvantages associated with the path that has already been trodden. This cumulative experience should support the intensification of measures that have had a positive impact on the development of renewables and have not added significant distortions to the economy as a whole. Other measures which do not produce the desired effects, or fail to contribute to an egalitarian distribution of benefits, should be reconsidered or even abandoned and replaced.

Policy measures, particularly incentives, should be largely dependent on the level of efficiency achieved by the players. These measures should be oriented towards the market, avoiding distortions between the different players acting in the energy market. Such measures should not result in costs for the economy that endanger the prosperity levels of society in general. In fact, we are dealing with a non-cooperative game played between international players, including countries or economic blocs, where the competitive advantage of this technology domain is more quickly surpassed than the comparative advantage of the possession of fossil resources, such as coal or oil reserves.

Appendix

Ind. Variables	OLS				FE				RE			
	CSE(X)	CSE(XI)	RSE(XII)	RSE(XIII)	CSE(XIV)	CSE(XV)	RSE(XVI)	RSE(XVII)	CSE(XVIII)	CSE(XIX)	RSE(XX)	RSE(XXI)
COALSH$_{c,t}$	-0.0320**	-0.0380**	-0.0320**	-0.0380**	-0.0614	-0.0739	-0.0614	-0.0739	-0.0317	-0.0380**	-0.0317***	-0.0380**
	-0.0162	-0.0179	-0.0111	-0.0158	-0.1289	-0.1299	-0.0789	-0.0719	-0.0167	-0.0179	-0.0114	-0.0158
GASSH$_{c,t}$	-0.0703***	-0.0676***	-0.0703***	-0.0676***	-0.0767	-0.0996	-0.0767	-0.0996	-0.0692***	-0.0676***	-0.0692***	-0.0676***
	-0.0224	-0.0251	-0.0177	-0.0223	-0.1348	-0.1367	-0.0661	-0.0693	-0.0231	-0.0251	-0.0179	-0.0223
OILSH$_{c,t}$	-0.1247**	-0.1219**	-0.1247	-0.1219**	-0.2299	-0.3022**	-0.2299**	-0.3022***	-0.1267**	-0.1219**	-0.1267**	-0.1219**
	-0.0488	-0.0508	-0.06	-0.0577	-0.1359	-0.1411	-0.0877	-0.0747	-0.0497	-0.0508	-0.0606	-0.0577
CFNUCL$_{c,t}$	0.0034	0.002	0.0034	0.002	0.085	0.0837	0.085	0.0837	0.0037	0.002	0.0037	0.002
	-0.0092	-0.0115	-0.0124	-0.0142	-0.0791	-0.0811	-0.0587	-0.0651	-0.0095	-0.0115	-0.0125	-0.0142
CFHYD$_{c,t}$	0.0335	0.0173	0.0335	0.0173	-0.1241	-0.1599	-0.1241	-0.1599**	0.0315	0.0173	0.0315	0.0173
	-0.0356	-0.0404	-0.0387	-0.0457	-0.0818	-0.0834	-0.0648	-0.0632	-0.0364	-0.0404	-0.0392	-0.0457
WASTSH$_{c,t}$	0.3054***	0.3469***	0.3054***	0.3469***	-0.1836	-0.1975	-0.1836	-0.1975	0.3015***	0.3469***	0.3015***	0.3469***
	-0.1044	-0.1179	-0.0682	-0.0899	-0.3496	-0.349	-0.2983	-0.2968	-0.1075	-0.1179	-0.0692	-0.0899
WINDGR$_{c,t}$	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***
	0.000	0.000	-0.0001	-0.0001	0.000	0.000	-0.0001	-0.0001	0.000	0.000	-0.0001	-0.0001
SOLSH$_{c,t}$	-2.2002	-2.8232	-2.2002	-2.8232	1.1918	0.334	1.1918	0.334	-2.0828	-2.8232	-2.0828	-2.8232
	-1.928	-2.1182	-1.6162	-1.9352	-2.1039	-2.2847	-1.0282	-0.922	-1.927	-2.1182	-1.5621	-1.9352
POPDENS$_{c,t}$	0.0002***	0.0002***	0.0002***	0.0002***	0.0015	0.0022	0.0015	0.0022	0.0002***	0.0002***	0.0002***	0.0002***
	0.000	0.000	0.000	0.000	-0.0015	-0.0016	-0.0012	-0.0012	0.000	0.000	0.000	0.000
LNGDPPC$_{c,t}$	-0.0245***	-0.0264***	-0.0245***	-0.0264***	0.0728	0.0851	0.0728	0.0851	-0.0243***	-0.0264***	-0.0243***	-0.0264***
	-0.0059	-0.0067	-0.0059	-0.0072	-0.0559	-0.0563	-0.0524	-0.0512	-0.0061	-0.0067	-0.006	-0.0072
NORMPOL$_{c,t}$	0.0031***	0.0031***	0.0031***	0.0031**	0.0008	0.0009	0.0008	0.0009	0.0031***	0.0031***	0.0031***	0.0031***
	-0.0006	-0.0007	-0.001	-0.0011	-0.0011	-0.0011	-0.0005	-0.0006	-0.0006	-0.0007	-0.001	-0.0011
FISCPOL$_{c,t}$	-0.0050**	-0.0050**	-0.0050**	-0.0050**	0.0066	0.0017	0.0066	0.0017	-0.0049**	-0.0050**	-0.0049**	-0.0050**
	-0.0022	-0.0024	-0.0022	-0.002	-0.0043	-0.0051	-0.0035	-0.0035	-0.0023	-0.0024	-0.0022	-0.002
FINPOL$_{c,t}$		0.0001		0.0001		0.0001		0.0001		0.0001		0.0001
		-0.0007		-0.0007		-0.0011		-0.0008		-0.0007		-0.0007
EDUPOL$_{c,t}$		-0.0001		-0.0001		0.0004		0.0004		-0.0001		-0.0001
		-0.0009		-0.0007		-0.0013		-0.0011		-0.0009		-0.0007
COOPPOL$_{c,t}$		0.0001		0.0001		0.0015		0.0015		0.0001		0.0001
		-0.0015		-0.0012		-0.0028		-0.0016		-0.0015		-0.0012
CUTPOL$_{c,t}$		0.0012		0.0012		0.0050**		0.0050***		0.0012		0.0012
		-0.0012		-0.0008		-0.0024		-0.0008		-0.0012		-0.0008
CONST	1.0006***	1.0251***	1.0006***	1.0251***	-0.0636	-0.2684	-0.0636	-0.2684	1.0003***	1.0251***	1.0003***	1.021***
	-0.0564	-0.0651	-0.0512	-0.0692	-0.6406	-0.6538	-0.6284	-0.6256	-0.058	-0.0651	-0.0525	-0.0692
N	218	218	218	218	218	218	218	218	218	218	218	218
R^2	0.4772	0.4809	0.4772	0.4809	0.3554	0.375	0.3554	0.375				
Wald (χ^2)									171.31***	176.91***		
F(N(0,1))	8.09***	6.80***			4.44***	3.99***						

Notes: OLS - Ordinary Least Squares. RE – Random Effects. FE – Fixed Effects. CSE – Conventional standard errors. RSE – Robust standard errors. The F-test has normal distribution N(0,1) and tests the null hypothesis of non-significance of all estimated parameters. The Wald test has χ^2 distribution and tests the null hypothesis of non-significance of all coefficients of independent variables. Standard errors are reported in brackets. All estimates were controlled to include time effects, but they are not reported for reasons of simplicity. ***, **, denote significance at 1 and 5% significance levels respectively

Table A.1 Estimation results with disaggregated variables – Dependent variable $WOCAP_{c,t}$

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	OLS	OLS	FE	FE	RE	RE
	CSE (XI)	RSE (XIII)	CSE (XV)	RSE (XVII)	CSE (XIX)	RSE (XXI)
Joint Significance test	0.34	0.76	1.36	10.63***	1.34	3.02
Linear restriction test	0.66	0.85	2.08**	3.78***	0.66	0.85

Notes: JST - Joint Significance Test. JST is a Wald χ^2 test with the null hypothesis of$H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$, with β_1, β_2, β_3, β_4 representing the coefficient of $FINPOL_{c,t}$, $EDUPOL_{c,t}$, $COOPPOL_{c,t}$ and $CUTPOL_{c,t}$, respectively. LRT - Linear Restriction Test has the null hypothesis of$H_0 = \beta_1 + \beta_2 + \beta_3 + \beta_4 = 0$. ***, **, denote significance at 1 and 5% significance levels respectively.

Table A.2. Exclusion tests on $FINPOL_{c,t}$, $EDUPOL_{c,t}$, $COOPPOL_{c,t}$ and $CUTPOL_{c,t}$

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Author details

António Cardoso Marques[1], José Alberto Fuinhas[1] and Rui Flora[2]

1 NECE and University of Beira Interior, Management and Economics Department, Covilhã, Portugal

2 University of Beira Interior, Management and Economics Department, Estrada do Sineiro, Covilhã, Portugal

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