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ANALYSIS OF THE PROMOTION OF ONSHORE WIND ENERGY IN THE EU: FEED-IN TARIFF OR RENEWABLE PORTFOLIO STANDARD?

ABSTRACT

This paper provides an empirical evaluation of feed-in tariff and renewable portfolio standard policies applied to onshore wind power in the EU-28 over the period 2000-2014. It allows policy-makers to know: a) if these policies have actually increased onshore wind generation capacity compared to a scenario without regulatory supports, b) which policy led to most onshore wind generation capacity, c) the impact of policy design elements on onshore wind generation capacity. The results suggest that only feed-in tariff policies and their main policy design elements (contract duration and tariff price) have significant impacts in terms of installed capacity. The establishment of a more risk-free framework would be necessary in renewable portfolio standard policies in order to increase investor confidence.

Keywords: wind energy, feed-in tariff policy, renewable portfolio standard, empirical assessment

1. Introduction

Solar and wind energy play a very important role in climate change and energy security issues, therefore in the development pathway transition [1,2]. Wind energy is considered the most mature technology among new renewable technologies and is now a prominent player in the European Power System. It is able to supply 10.2% of European electricity needs [3]. Indeed, the EU wind energy industry was an early-mover which is now quite active outside Europe. According to the European Commission [4] over 48% of European wind energy companies do business outside the EU.

Regulatory options to encourage deployment of renewable energies (RES-E) may be divided into two large schemes: price-driven and quantity-driven [5]. *Price-driven mechanisms* include the feed-in tariff, which establishes a fixed payment per KWh of electricity produced from renewable energy. So, producers of renewable energy obtain remuneration based on a pre-set price per kilowatt-hour (feed-in tariff) or on the price of electricity established in the wholesale electricity market plus an incentive. On the other hand, *quantity-driven mechanisms* include bidding systems and tradable certificate systems. Through bidding systems, a call for renewable energy projects is made by governments for defined capacities. With this mechanism, the winners of contracts obtain a guaranteed tariff for a specific time period. In the case of negotiable green certificates, producers of renewable electricity receive a certificate for each pre-defined unit of electricity produced. Certificate prices are given by the market.

Notwithstanding, Glachant and Henriot [6] recognise that the role of RES-E in the European electricity markets is evolving in two directions: either they are isolated from market prices so are receiving feed-in-tariffs, or they are integrated in the spot market and receive a premium on top of the spot price set by this market. To date, these price-based regulatory options have become far more popular than quantity-based strategies where renewable energy price is the outcome, not the assumption, of the RES-E support scheme.

In this context, previous studies have mainly analysed the influence of price-based RES-E support policies (feed-in tariff) on RES-E development [7,8]. This paper tries to contribute to the empirical evidence by studying not only the effect of the feed-in tariff policy but also of quantity-based policies (quota system, also known as renewable portfolio standard) on RES-E development.

Therefore, this paper makes a double contribution. Firstly, the two main RES-E polices are considered together in the case of onshore wind power. This production technology is chosen because it has the largest installed base of any RES-E source [9]. Likewise, the feed-in tariff (FIT) and renewable portfolio standard (RPS) are chosen as the research focus because they represent the main policies for promoting RES-E in the EU [10,11]. However, other aspects that may influence RES-E development –the main policy design elements in both policies– are analysed in this paper. As far as we know, they have hardly been subject to quantitative analysis, with the exception of Jenner *et al.* [8] who only focus on FIT policies. Although the choice of design elements in each policy is at least as important for promoting RES-E as the choice of specific policies, the literature has focused on the study of RES-E support policies [12]. Secondly, our paper analyses these issues over a long and recent period of time in the EU-28, 2000-2014, and also allows for testing of a possible endogeneity problem, which is not taken into account in most of the previous studies. This approach offers robust and quantitative evidence in this research field.

2. Literature review

Few studies have assessed the effectiveness of RES-E policies [8,13]. Table 1 shows an overview of the literature that analyses this issue. Initially, the literature has mainly centred on both qualitative and theoretical approaches. In this context, Menanteau *et al.* [14] analysed the efficiency of RES-E support policies based on prices and quantities in the EU from a theoretical approach. Their results showed that the FIT was more efficient than bidding systems in the development of RES-E resources. Wüstenhagen and Bilharz [15] developed a qualitative analysis, for the German case, over the period 1990-2003, whose results indicated that the FIT was effective in new RES-E capacity as well as in cost reduction. Gan *et al.* [16] studied qualitatively the cases of Germany, the Netherlands, Sweden and the United States, over the period 2002-2005. They concluded that the success of RES-E support policies comes from the establishment of clear and coherent policies that involve an increase in the market share of RES-E in electricity generation and a reduction in RES-E costs –even when government intervention is eliminated.

By means of case study methodology, Frondel *et al.* [7] found that the RES-E policy adopted in Germany (FIT) prevented the necessary market incentives from ensuring the development of cost-effective RES-E. Patlitzianas and Karagounis [17] studied the progress of RES-E in the new EU member states (Bulgaria, Cyprus, Czech, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia), over the period 2005-2009. The results of their case study showed that FIT seemed to be an effective instrument for developing RES-E in those member states. Liao [18] concluded that governments have to adopt flexible policies to achieve RES-E targets in different RES-E market phases (undeveloped, developing and developed markets) and therefore there was not an optimum RES-E support policy. Mignon and Bergek [19] showed that different investors are influenced by different institutional demands in Sweden and concluded that the design of a mix policy is essential in order to stimulate RES-E investment.

The main conclusion obtained from the qualitative and theoretical literature is that RES-E policies are a main driver in the development of clean production technologies. Nevertheless, empirical assessment of the effectiveness of RES-E policies is still scarce. Carley [20] studied the impact of RES-E support policies on the contribution of RES-E to energy supply in 50 US states over the period 1998-2006 by means of a fixed-effect panel data methodology. The results indicated that RES-E support policies were not a significant predictor of the percentage of RES-E generation. Jenner *et al*. [8] analysed the effectiveness of FIT in developing onshore wind and photovoltaic solar power in 26 EU countries over the period 1992-2008. Using the same kind of methodological approach, they concluded that the interaction of electricity prices and production costs as well as policy design were the most effective elements for developing RES-E.

Likewise, there is scarce empirical literature analysing the impact of specific RES-E support policies (price versus quota mechanisms) on the development of these clean production technologies. Johnstone *et al*. [21] studied the effects of different public policies on innovation in RES-E in 25 OECD countries over the period 1978-2003. Their results showed that different policies are effective for developing different types of RES-E. Specifically, FIT tended to encourage innovation in more costly technologies, while quantity-based policies were needed to encourage innovation in more competitive technologies. Shrimali and Kniefel [22] analysed the effect of public policies on the development of various RES-E sources in 50 US states over the period 1991-2007. By means of a fixed-effect panel data model, they found that clean energy funds and required green power options were the most effective instruments for developing all types of RES-E.

In the case of the EU, Marques and Fuinhas [23] studied the effect of public policies supporting RES-E in 23 member states on the use of RES-E over the period 1990-2007. Using a panel corrected standard errors estimator, their results showed that policies of incentives/subsidies (including FIT) were significant drivers of the use of clean production technologies. Similar results were obtained by Dong [11] using a panel data for 53 countries over the period 2005-2009. Polzin *et al.* [24] analysed the influence of public measures on RES-E investments made by institutional investors in a variety of OECD countries over the period 2000-2011. Using panel data methodology, they found that FITs were especially relevant because they provided a more long-term and reliable signal to invest than quota policies.

[Insert Table 1.Overview of the effectiveness of RES-E support policies in the EU. Source: Drawn up by the authors]

Finally, the majority of the previous empirical literature does not consider policy design features that influence the strength of RES-E support policies. Some studies used qualitative analysis, such as Masini and Menichetti [25], who used surveys to analyse behavioural factors influencing RES-E investment. Their results showed the relevance of FIT policies as well as their design features –tariff price and contract duration– for investment in RES-E. Similarly, Iychettira *et al*. [26] studied the design elements of different RES-E policies in the EU by means of three learning methods and concluded that these attributes needed to be harmonised at EU level. As an exception, Jenner *et al*. [8] considered tariff price, contract duration and digression rate in the FIT policies of 26 EU countries. Their results showed the importance of these variables for explaining the development of RES-E, but they do not consider RPS in their analysis. Our paper goes beyond this by quantifying and testing the significance of the two main RES-E support policies and their attributes in the EU.

The literature shows that there are important differences in both RES-E development and the characteristics of RES-E policies between countries and over time. Therefore, key issues for policy-makers are to know: a) if RES-E policies have actually increased RES-E generation capacity compared to a scenario without regulatory supports, b) which RES-E policy (based on quantities or prices) led to most RES-E generation capacity, c) the impact of policy design on RES-E generation capacity. Our contribution to the literature is an empirical assessment of those three questions in the case of onshore wind power for a long period of time in the EU-28.

2.1. Statement of hypotheses

With the aim of promoting the development of wind energy, governmental intervention has been essential to protect this clean production technology from competition by conventional production technologies. Menanteau *et al*. [14], Patlitzianas and Karagounis [17] and Marques and Fuinhas [14], among others, show the importance of FIT policies to promote RES-E –including wind energy– in the EU in terms of installed capacity and electricity generation. On the other hand, Shrimali and Kniefel [22] and Ederer [27] emphasize the importance of RPS based on its effectiveness to incentivise RES-E in the form of profit and certainty.

Taking into consideration the above-mentioned arguments, both FIT and RPS would provide incentives to develop innovative technological solutions in wind energy that can be economically viable. Thus, the following first hypothesis is presented:

Hypothesis 1. *Wind support policies (FIT and RPS) result in the installation of onshore wind capacity*.

However, there may be remarkable differences in policy design elements within the same RES-E promotion policy. Therefore, the success or failure of a specific policy might stem from its particular design elements [13]. Masini and Menichetti [25] and Iychettira *et al*. [26] indicate that a positive impact of tariff price and contract duration is expected on RES-E installed capacity (including wind energy) as enough incentives in terms of remuneration and maintenance of contract duration are essential for ensuring expansion. Thus, a positive relationship between tariff price and contract duration was found by Jenner et al. [8] in FIT policies, using panel data methodology.

Considering this argument, the following hypotheses are proposed:

Hypothesis 2. *The higher the tariff price in* FIT*, the greater the onshore wind power installed capacity*.

Hypothesis 3. *The longer the contract duration in* FIT, *the greater the onshore wind power installed capacity*.

Scarce empirical evidence is also found regarding policy design elements in RPS, again based on qualitative analysis. Masini and Menichetti [25] and Iychettira *et al*. [26] identify certificate prices and certificate validity lifetime as the main design elements of this policy. They show that these variables should involve a positive impact on RES-E installed capacity as they reduce risk and therefore increase the profitability of these generation plants. In addition, Fischlein and Smith [28] also indicate the importance of considering the certificate award rate as this positively affects the expected profitability of wind generation plants.

Thus, the following hypotheses are tested:

Hypothesis 4. *The higher the certificate prices in RPS, the greater the onshore wind power installed capacity*.

Hypothesis 5. *The higher the award rates in RPS, the greater the onshore wind power installed capacity*.

Hypothesis 6. *The longer the certificate validity lifetime in RPS, the greater the onshore wind power installed capacity*.

3. Methodology

This section discusses the sample, the variables and the methodology used in the empirical assessment.

3.1. Sample

In order to carry out the empirical analysis, the Eurostat database was examined as well as reports about the state of RES-E support policies in the EU [29,30] over the period 2000-2014 (28 countries, 449 observations). The analysis starts in 2000 as most of RES-E support policies in the EU were adopted in the first years of that decade. In order to avoid missing values in the estimates and to have the same sample size in all models, those cases for which there was not information on any of the variables were not considered. As a result, an unbalanced panel of 27 countries and 284 observations was obtained.

3.2. Variables

The literature shows RES-E installed capacity and contribution of RES-E energy to electricity supply as the main dependent variables for measuring RES-E development [23,31]. In this study, wind installed capacity is considered as the dependent variable because a key issue for policy-makers is to know if wind energy support policies have actually increased wind capacity beyond what would have happened in their absence [8]. More specifically, this variable is measured as the electricity capacity of onshore wind generators (in Mw) (WIND_CAPACITY).

As RES-E support policies may influence wind installed capacity, this effect is taken into account by creating three dummy variables: RES-E promotion policy1 (the non-existence of a specific promotion policy in wind energy) (RES-E_POL1), RES-E promotion policy2 (RPS in wind energy) (RES-E_POL2), and RES-E promotion policy3 (FIT in wind energy) (RES-E_POL3) [11,13].

Likewise, the effects of the main policy design elements are considered in FIT and RPS policies. Regarding FIT policies, tariff price and contract duration variables were included in the model. Tariff price refers to the price obtained by a wind producer for electricity sold to the grid (in Euros/MWh) in FIT observations and 0 otherwise (TARIFF_PRICE): in the case of premium tariffs, it is the bonus; for fixed-price tariffs, it is the amount of the tariff. Contract duration is the duration of a FIT contract in years and 0 otherwise (TARIFF_DURATION).

Certificate prices, award rate and validity lifetime are considered the main design elements in the model for RPS policy. Certificate prices are the prices that are generally obtained through a market mechanism (in Euros/MWh) in RPS policy for wind energy and 0 otherwise (QUOTA_PRICE). Award rate refers to the number of certificates awarded for wind generators (in MWh) (QUOTA_AR). Certificate validity lifetime is the duration of a RPS contract in years and 0 otherwise (QUOTA_DURATION).

Control variables are grouped in two categories: (i) political factors and (ii) socioeconomic factors.

(i) Political factors. Empirical literature shows that the institutional framework as well as the manner in which policy-makers operate have an impact on environmental policy adoption and on the achievement of their expected results [20,23,31,32]. In this context, the variables of dependency on energy imports and government commitment toward environmental policy are introduced.

Dependency on energy imports refers to the extent to which an economy relies upon imports in order to meet its energy needs (information obtained from Eurostat). It is calculated as net imports divided by gross inland energy consumption (in %) (IMPORTS). It is expected that a country's dependency on energy imports results in higher investment in its own renewable sources in order to substitute energy imports with local resources [33, 34].

Regarding government commitment toward environmental policy, environmental investment made by the government (in Euros per capita) (GOV_POLICY) is considered. This variable is expected to involve a greater green energy commitment and therefore higher wind energy deployment [20,35].

(ii) Socioeconomic factors. These factors are possible explanatory variables for the type of energy sources [36]. In this context, we introduce price of oil, contribution of oil to electricity generation, carbon dioxide emissions per capita, and electricity energy consumption.

Price of oil is the Brent crude petroleum price by barrel obtained from the BP Statistical Review of World Energy (Euros/barrel) (PRICE_OIL). Higher prices of conventional production technologies, such as oil, are expected to lead to greater use of RES-E [37,38] and therefore to greater wind energy development.

The variable contribution of oil to electricity generation shows the percentage of oil in total gross electricity supply (in %) from Eurostat (CONTRIBUTION_OIL). In order to determine the impact of this variable on RES-E development, it is necessary to consider that the power of interest groups associated with fossil energy sources may be an obstacle for the development of RES-E [39]. Therefore, the contribution of oil to electricity generation is expected to have negative effects on wind energy development.

Regarding carbon dioxide emissions per capita, this variable includes total emissions related to the Kyoto Protocol (carbon dioxide -CO_2-, methane -CH_4-, nitrous oxide -$N2_O$-, and the F-gases hydro fluorocarbons, per fluorocarbons and sulphur hexafluoride -SF6-) divided by population (tonnes of CO_2 equivalent per capita) from Eurostat (EMISSIONS). Greenhouse gas emissions are largely responsible for climate change. Therefore it is expected that greater amounts of greenhouse gas emissions means more incentives for RES-E investments and therefore more wind energy development [40,41].

Finally, electricity consumption per capita (MWh per capita) obtained from Eurostat was considered (ELECT_CONSUMPTION). Electricity consumption shows the energy needs of a country. As these needs can be met either by RES-E or by traditional fossil fuel sources or a mix of traditional and clean production technologies, electricity consumption may have a positive or a negative impact on RES-E (and particularly wind) development [36,39].

3.3. Model

In order to test the hypotheses proposed in the theoretical background, pooled OLS regressions clustered at firm level are used with the STATA12 program[1]. In addition, in order to control for endogeneity problems in the models proposed, explanatory and control variables are lagged by one year. Initially, the possibility of employing a panel data methodology, such as the two-step difference GMM model drawn up for dynamic panel data models by Arellano and Bond [43], was considered. However, as our number of countries is

[1] The cluster option also implies the estimation of robust standard errors.

not so large, this methodology was not applied because the results would not be reliable as the number of instruments would be larger than the number of countries.

The two proposed models are as follows:

$$\text{Wind\_Capacity}_i = a_0 + \beta X_i + \sum_{t=2000}^{2014} D_t + \varepsilon_i \qquad \text{[Model 1]}$$

$$\text{WIND\_CAPACITY}_i = a_0 + \beta_1 \text{ TARIFF\_PRICE}_i + \beta_2 \text{ TARIFF\_DURATION}_i + \beta_3 \text{QUOTA\_PRICE}_i + \beta_4 \text{ QUOTA\_AR}_i + \beta_5 \text{QUOTA\_DURATION} + \sum_{t=2000}^{2014} D_t + \varepsilon_i \qquad \text{[Model 2]}$$

where $\sum_{t=2000}^{2014} D_t$ is a set of time dummy variables and ε_i is the error term.

4. Results

Table 2 shows the descriptive statistics while Table 3 lists the correlation coefficients of the variables used in the regression analyses. Although some of the variables show a statistically significant correlation, analysis of the variance inflation factors (VIF) revealed no evidence of multicollinearity as all of them remained under 10 [44].

[Insert Table 2.Descriptive statistics. Source: Own elaboration]

Table 3 summarises the results of the regression analyses. Model 1 considers the effect of RES-E promotion policies on the contribution of wind energy to electricity supply, while Model 2 focuses on different policy design elements. As explained in the variables section, RES-E_POL is a qualitative variable that places RES-E support polices in three possible categories; thus, to make it operative, three dummy variables are defined. However, in the regression models it is only possible to add k-1 dummies (in our case 2) because in the other case the parameters cannot be estimated. Therefore, the results are presented by combining the dummies in pairs to understand what their coefficients really mean. It is sufficient to state the results of the combination of dummy RES-E_POL2 (RPS in wind energy) and RES-E_POL3 (FIT in wind energy) because the results of the remaining combinations can be deduced from the previous one.

[Insert Table 3.Correlation matrix. Source: Own elaboration]

The results of Model 1 support Hypothesis 1 that establishing that wind power support policies (FIT and RPS) result in the installation of onshore wind capacity. Feed-in tariff

(RES-E_POL3) significantly increases onshore wind capacity in comparison to the non-existence of a specific promotion policy for wind energy (RES-E_POL1). These findings are in line with other previous studies [11,17,23] that indicate greater RES-E development with FIT. However, the pairwise comparisons suggest that there are no significant differences between RPS (RES-E_POL2) and the non-existence of a specific promotion policy (RES_POL1). RPS (RES-E_POL2) increases but the increase in onshore wind capacity is not statistically significant in comparison with the non-existence of a specific wind energy promotion policy (RES-E_POL1). An explanation might lie in the higher risk for investors as they do not have fixed payments so might refrain from investment [20,24,45]. Thus, this first hypothesis is only confirmed partially.

However, contrary to Hypothesis 2 which states that the higher the tariff price in FIT, the greater the onshore wind power installed capacity, the results suggest that a higher tariff price obtained by an onshore wind generator when power is sold to the grid (TARIFF_PRICE) reduces onshore wind capacity (β= -0.477; p = 0.002). The explanation might lie in the regulatory uncertainty concerning this design element [5,19]. Tariffs are frequently changed in the annual legislation of member states on climate change and energy efficiency issues. In addition, if wind power is considered a mature production technology in the EU, investors may have lower expectations in terms of maintaining high tariff prices.

On the other hand, the results support Hypothesis 3 which establishes that the longer the contract duration in FIT, the greater the onshore wind power installed capacity. Thus, longer duration of a FIT contract (TARIFF_DURATION) favours onshore wind capacity (β= 0.454 p = 0.000). Although not shown, this policy design element is more stable with a duration between 15 and 20 years for this production technology in the EU. Similar results are obtained using qualitative approaches [25,26].

Finally, the results do not support Hypothesis 4 (the higher the certificate prices in RPS, the greater the onshore wind power installed capacity), Hypothesis 5 (the higher the award rates in RPS, the greater the onshore wind installed capacity nor Hypothesis 6 (the longer validity lifetime for certificates in RPS, the greater onshore wind installed capacity). They must be rejected as certificate prices (QUOTA_PRICE), award rate (QUOTA_AR) and the duration of an RPS contract (QUOTA_DURATION) are not statistically significant. These results suggest that RPS design might not reduce investor risk or increase investor confidence in the expected income stream [45].

Regarding control variables, political factors such as IMPORTS and GOV_POLICY do not seem to significantly influence the capacity of onshore wind generators. However, some socioeconomic factors seem to matter. More specifically, in line with other studies [37,39], the results indicate that PRICE_OIL is positively associated with onshore wind energy capacity (in Model 1 and 2, respectively, $\beta = 0.045$ $p = 0.023$; $\beta = 0.054$ $p = 0.057$). Therefore, the analysis suggests that higher oil prices provide incentives to substitute this traditional energy source with onshore wind energy.

In addition, the findings indicate that electricity consumption per capita (ELECT_CONSUMPTION) has a negative impact on onshore wind installed capacity (in Models and 1 and 2, $\beta = -7.028$ $p = 0.063$; $\beta = -6.828$ $p = 0.005$). This result suggests that larger electricity energy consumption needs are not supplied by wind energy but by other alternative resources.

The analysis also indicates a negative effect of the percentage of oil in total gross electricity supply (CONTRIBUTION_OIL) on wind capacity but only in Model 2 and at a 10 per cent level ($\beta = -0.032$ $p = 0.063$). Therefore, the existence of industrial lobbying (especially relevant in the case of oil) might make it difficult to develop onshore wind energy [23].

In addition, the Model 1 suggests that the higher the carbon dioxide emissions per capita (EMISSIONS), the larger the capacity of onshore wind generators ($\beta = 0.336$ $p = 0.097$). This result is in line with Jenner *et al*. [8]. Greenhouse gas emissions might encourage wider use of cleaner production technologies, such as onshore wind energy.

Finally, regarding annual effects, dummy proxies for years 2001 (in both models) and 2007 (in Model 1) are negative and significant. This means that, *ceteris paribus*, in those cases the specific year influenced the dependent variable in a different and negative way in comparison with the situation existing in the reference year 2000.

[Insert Table 4. Linear regression analysis. Source: Own elaboration]

Robustness of model results

In order to establish the robustness of our results, our estimations are repeated using additional measures, considering the FIT and RPS sub-samples separately, and additional estimations.

First, Hypothesis 1 was tested by considering individually the FIT and RPS, respectively. It must be emphasized that the number of observations in both *sub-samples* is not large and consequently it is necessary to be cautious when interpreting the results. In any case, the results are quite similar to those shown in Model 2 in Table 4 for the whole sample of countries.

Second, the models proposed (summarised in Table 4) were estimated by considering the contribution of wind energy to electricity supply, as a percentage of total gross electricity supply (WIND_CONTRIBUTION), as the *dependent variable*, instead of the installed capacity of wind energy. The results are similar.

Third, when the estimations (summarised in Table 4) are repeated by considering IMPORTS, CONTRIBUTION_OIL, and EMISSIONS only as *endogenous variables* (in which the endogeneity problem is clearer), the results did not vary significantly.

Fourth, as it might be necessary to consider all remuneration in order to analyse the expansion of onshore wind energy [27], the estimations were repeated defining TARIFF_PRICE as electricity market price plus bonus in the case of premium tariffs and QUOTA_PRICE as electricity market price plus certificate prices. The new variable related to TARIFF_PRICE turns out to be negative and significant at the 5 percent level (β= -0.155, p-value = 0.046), while the new variable related to QUOTA_PRICE presents a positive coefficient (β= 0.066) but is not statistically significant (p-value = 0.445). Thus, the results are the same as those shown in Table 4 concerning policy prices.

Fifth, as the expansion of wind farm development might involve delays, two lags instead of one were considered for the explanatory and control variables in order to have a longer period of time. The results remained the same.

Finally, the initial models were repeated by considering alternatively different *proxies for the control variables* and, in all three cases, for the main explanatory variables the results remained the same. More specifically, the oil price and oil contribution variables were substituted by the price of imported natural gas in Europe (average import border price) according to the World Bank (Euros/million BTU) (PRICE_GAS), and the contribution of gas to electricity generation variable that shows the percentage of gas in total gross electricity supply (in %) (CONTRIBUTION_GAS), respectively. Moreover, regarding government commitment toward environmental policy, the GOV_POLICY variable was changed to environmental protection expenditure that considers not only environmental investments but also environmental current expenditure and subsidies (in Euros per capita) (GOV_POLICY2). Finally, household electricity prices referring to electricity prices charged to final consumers (in Euro/MWh) were considered instead of electricity consumption (ELECT_PRICES).

5. Discussion

RES-E is an essential concept for promoting a low carbon economy in the EU. In this context, Directive 2009/28/EC [47] sets an overall policy for the production and promotion of energy from clean production technologies. It establishes as its objective that at least 20% of total energy needs in the EU can be fulfilled by RES-E by 2020. In order to reach this target, each member state has to meet individual national targets that are established by the Directive in terms of the starting-point and overall potential for RES-E. Likewise, this legislation allows member states to choose the RES-E support policy that they consider most suitable (price mechanisms –FIT– or quota mechanisms –RPS, among others) depending on their characteristics.

In this paper, the relative effectiveness of the two main RES-E support policies (FIT and RPS) for promoting wind capacity in the EU is compared. The results show that FIT would give better results than RPS policy in terms of installed wind capacity. FIT seems to involve a more stable governmental commitment than RPS policy, resulting in higher reductions in price and volume and a less framework involving less risk, with the consequent incentive to invest in onshore wind energy [48].

However, any support policy can fail if it does not have certain design elements. In this context, the relative effectiveness of these issues in both policies is studied. The results of this paper suggest the importance of tariff price and contract duration in FIT for developing wind energy capacity. A consistent commitment by government in the long-term is essential for successful development of wind energy.

Nevertheless, the results indicate that neither RPS nor its policy design elements are significant for the development of wind energy capacity. Uncertainty about the certificate value affects the financial situation of investors who might refrain from investments [45].

Some strategic issues related to RES-E still need to be solved in the EU: the harmonisation of national support policy, and infrastructure limits. In this context, the success of RES-E support policies largely depends on the credibility of these instruments for potential investors. A first action to promote such credibility might be the establishment of a stable regulatory framework to secure continuity of development in both promotion schemes. This would require the same contract duration and certificate validity in FIT and RPS respectively in each member state [49]. Therefore, joint efforts for similar framework conditions might allow the convergence of the different RES-E support policies into an optimal strategy based on the best element design.

Another possible option might be to harmonise FITs as they are effective and cost-efficient instruments for increasing RES-E generation and for achieving environmental and security targets [45]. Taking the successful factors of this support policy as their basis, Muñoz *et al*. [50] identify the incorporation of a modular premium that provides information and transparency as an essential concept for creating policy robustness and eliminating political uncertainty.

Finally, a certain tendency towards "bottom-up" convergence is being seen in the EU related to how policy-makers design RES-E support policies [51]. However, specific considerations are necessary regarding not only the RES-E potential of each country but also their infrastructure limits. Various member states do not have the required grid infrastructure to correctly allow RES-E to develop and compete on fair terms with conventional power sources. Grid infrastructures have to consider the special characteristics of some RES-E plants compared to traditional plants, such as intermittent power output (as with wind power), decentralisation or smaller plant size [52].

6. Conclusions

The development of RES-E is relevant for meeting energy security, energy efficiency and greenhouse gas emission reduction targets in the EU. Therefore, it is essential to establish suitable RES-E support policies in the member states to achieve the overall aims laid out in the 2020 and 2050 EU Strategies.

This paper provides an empirical evaluation of FIT and RPS applied to onshore wind power in the EU which might be useful for policy-makers when designing RES-E support policies.

Our results suggest that FIT gave better results in terms of onshore wind installed capacity in the EU-28 over the period 2000-2014. The analysis indicates that its main policy design elements (contract duration and tariff price) have significant impacts on the development of that clean production technology. However, policy-makers should consider reducing regulatory uncertainty about the tariff price when enacting such policies.

RPS and its main design elements (certificate prices, award rate and validity lifetime) do not seem to have a significant impact on the development of onshore wind energy in our analysis. Policy-makers should consider establishing a more risk-free framework to increase investor confidence in their expected income stream.

Therefore, the EU should encourage the use of FIT in the development of onshore wind energy as it seems to be the most successful method for achieving RES-E targets. Another alternative would be to make a thorough, urgent review of the design elements of RPS as onshore wind technology is already mature in the EU. It is essential to detect the main weaknesses of this policy and correct them in order to achieve energy efficiency and security targets.

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