The Impact of Renewable Energies and Electric Market Liberalization on Electrical Prices in the European Union. An Econometric Panel Data Model.

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Abstract— **A controversial debate has arisen about the effects on household electricity prices of electricity generation from Renewable Energy Sources and regulatory reforms in the European Union Electricity Market. In this paper we propose to use panel data models with the aim of explaining the household electricity prices as a function of several economic variables related to renewable energy sources and electricity market regulation. More specifically we use a panel data set provided by Eurostat and covering 27 European Union countries during the period 1998–2009. Our results suggest that electricity prices increase with the deployment of Electricity from Renewable Energy Sources.**

Keywords-renewable energy, electricity market, panel data model.

I. INTRODUCTION

There is a controversial debate about the effects of the promotion of renewable energy and electric power sector reforms on electricity prices.

The European Union has emphasized the need to control climate change and then it has assumed a binding unilateral greenhouse gas emission reduction target for 2020, according to which the EU is committed to reducing emissions to at least 20% below 1990 levels. In order to achieve this target the European Union is working on the development of renewable energy industries, the implementation of energy efficiency measures and saving energy technologies.

More specifically, the Community Directive 2009/28/EC [1] on the promotion of the use of energy from renewable sources has agreed European targets for 2020: European Union should achieve by 2020 a 20% share of Renewable Energy Sources (RES) in the Community's gross final consumption of energy and a 10% share of energy from renewable sources in transport energy consumption.

The EU sustainable development strategy [2] recognises that environmental investments as well as technological innovation are the prerequisites for long-term competitiveness and better environmental protection.

Therefore, the development of renewable energy industries and energy-saving technologies provides several positive effects, mainly with reference to the expected increase in energy self-sufficiency, employment, investment and production[1], but it also has some costs related to the adjustments in production, prices and transportation systems

Regarding the effects on prices, the majority of renewable energy technologies increase electricity generation costs with regard to conventional generation so they are expected to increase the electricity price paid by final consumers. In fact, there are three principal components of extra costs: the generation costs, the costs of distribution and transmission system reinforcements and, in the case of the intermittent renewals, the extra balancing costs.

In the European Union the largest part of the investments for electricity production was devoted to new wind power stations and Photovoltaic and Solar thermal systems as we can see in Table I.

The generation of Electricity from Renewable Energy Sources (RES-E) especially from wind and photovoltaic power, can increase generation costs when compared with conventional generation. A number of recent studies have sought to quantify the costs associated with large-scale renewable generation by wind ([6], [7] and [8] among others).

Moreover, the majority of renewable energy technologies are not profitable at current energy prices so their development is mainly driven by different public renewable support schemes: feed in tariffs, quota obligations, green-certificate trading, fiscal measures as tax benefits, investment grants, etc. Some important classification criteria are whether policy instruments address to price or quantity, and whether they support investment or generation. A classification of the existing promotion strategies for renewals is provided in [9].

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[1] Several studies have reviewed the effects of the introduction of renewable energies at EU country level. This is the case of [3] for the United Kingdom or [4] for Germany. Other studies as [5] have analysed the macroeconomic RES impact at local level.

TABLE I. EU INFRASTRUCTURE FOR ELECTRICITY PRODUCTION. NET INSTALLED CAPACITY (MEGAWATT)

Infrastructures	Percentage of change 2000-2007
Thermal power stations	10.31
Nuclear power stations	-3.25
Hydro power stations	2.08
Pumped storage plants	5.10
Wind-turbines	**339.75**
Geothermal plants	15.56
Steam turbine power plants	:
Gas turbine power plants	:
Combined cycle power plants	:
Internal combustion engine plants	:
Public power plants	12.18
Autoproducer power plants	24.65
Photovoltaic systems	**2540.56**
Solar thermal systems	1200.00
Municipal solid wastes	141.13
Biogas	218.22
Industrial wastes	-20.79

Source of data: Eurostat, http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database: Statistics data base/Energy Statistics/infrastructure/electrical infrastructure.

Most RES-E support systems are financed via the electricity market, which increases the retail electricity price. Therefore promotion systems have costs for the final consumers. For example, [10] shows that Quota-based Tradable Guarantee-of-Origin Certificates systems as well as Feed-in tariff systems create an artificial market and cause policy costs (¼ additional costs to be usually paid by electricity customers).

In Table II we summarise the main promotion mechanism implemented in specific EU countries. Quota-based systems are now in place in the UK, Sweden, Italy, Belgium, and Poland. Moreover, as each country has different targets set in Directive 2009/28/EC [12], the dimension of policy support can be different thus following in different effects on electricity prices.

In addition, environmental costs related to CO_2 emissions in electricity generation usually have a significant negative effect on energy costs as a CO_2 emission trading scheme (ETS) exists. The substitution of conventional electricity generation by renewable energies could reduce the cost derived from environmental emissions and the electricity price. Support systems for Electricity from Renewable Energy Sources (RES-E) can reduce electricity prices that have also been influenced by a CO_2 Emission Trading Scheme (ETS): Additional RES-E substitute electricity from fossil fuels, and thus CO_2-emissions are reduced. The demand for emission reductions is lowered; as a result the CO_2 price is also reduced and consequently the wholesale price for electricity decreases [13].

TABLE II. RES-E PROMOTION MECHANISM IMPLEMENTED IN EUROPEAN UNION COUNTRIES

EU members	Feed in Tariff	Quota-based Tradable Guarantee-of-Origin Certificates	Fiscal incentives
Austria	X		
Belgium		X	
Bulgaria	X		X
Cyprus	X		
Czech Republic	X		
Denmark	X		
Estonia	X		
Finland			X
France	X		
Germany	X		
Greece	X		
Hungary	X		
Ireland	X		
Italy		X	
Latvia	X		
Lithuania	X		
Luxembourg	X		
Malta	X		
Netherlands		X	
Poland		X	
Portugal	X		
Romania			
Slovak Republic	X		
Slovenia	X		
Spain	X		
Sweden		X	
United Kingdom		X	

Source [11]

It is also necessary to consider that a higher use of renewable energies could reduce even the electricity final prices because its promotion stimulates the generation of renewable energy which is characterized by variable costs lower than fossil conventional technologies [14].

Regarding the legislative aspects, the regulatory reforms in the EU Electricity Market could also have effects on electricity prices. In fact the liberalization of generating and retailing activities could increase competition thus reducing electricity prices.

Following the EU Directives 96/92/EC [15] and 2003/54/EC [16] the electricity markets in Europe were fully liberalized the 1st of July 2007. Since then all electricity users are able to choose their own suppliers, and electricity network service providers are separated from generating and/or supply companies.

This liberalization of the European electricity markets aims to increase efficiency by competition, thus decreasing electricity prices for final consumers.

However, as [17] points out, market liberalization does not necessarily imply effective competition and competitive prices. Achieving competitive prices depends on the number

 ISBN: 978-1-61208-138-0

of enterprises and the nature of consumer to switch. The combination of low elasticity to prices and a small number of competitors means that market prices can easily deviate from competitive levels.

Regarding the production market structure, the liberalization in many of the EU countries in the generation sector has not provided a less concentrated market structure.

In Figure 1 we can see that the market share of the largest generator in the electricity market has not a significant decrease for the majority of the EU countries from 1999 to 2008. This lack of competition may allow electricity prices on the wholesale markets to increase, thus leading to higher retail electricity prices, especially for household consumers.

Therefore, there are several economic variables related to renewable energy sources and electricity market regulation affecting the electricity prices. During the last years several studies have been developed in order to explain the effect of several variables on electricity prices using cross-sectional, temporal or panel data. Some of them include explanatory variables related to energy use or technology [18] and [19] or liberalization market [20] [21]. In this paper we propose an empirical study including all the potential effects together and therefore we propose panel data models with the aim of explaining the household electricity prices as a function of variables related to renewable energy sources and electricity market regulation. The main objective of our empirical work is to explain some differential aspects of the European Union member countries in the electricity prices.

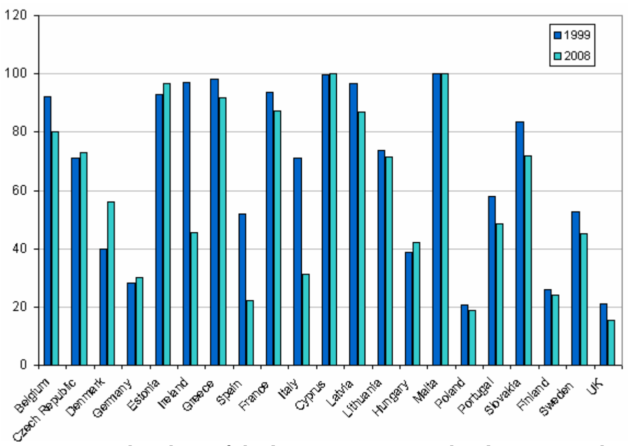

Figure 1. Market share of the largest generator in the electricity market. Percentage of the total generation.
Source of data: Eurostat.
http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

II. MODELLING THE IMPACT OF RENEWABLES ON ELECTRICITY PRICES. PANEL DATA MODELS

The European Union is working in the development of renewable energy industries, the implementation of energy efficiency measures and saving energy technologies. Within this framework countries pledge to make substantial efforts in their energy policy. However, each country tries to effectively implement renewable energies according to its own characteristics such as energy consumption, energy diversity or composition of electricity generation.

Moreover, the RES-E policy support and dimension of each EU member can vary, leading to different effects in electricity prices. With regard to the market liberalization each country has particularities in its market structure, size (number of enterprises) and consumer demand.

All these differences lead to a wide range of household electricity prices in the EU countries as we can see in Figure 2.

In this section we propose panel data models with the aim of explaining the household electricity prices as a function of several economic variables related to renewable energy sources and electricity market regulation. More specifically we use a panel data set provided by Eurostat and covering 27 countries of the EU during the time period 1998–2009.

The basic country-level time series data for the period 1998–2009 were taken from Eurostat (available at the web site http://epp.eurostat.ec.europa.eu).

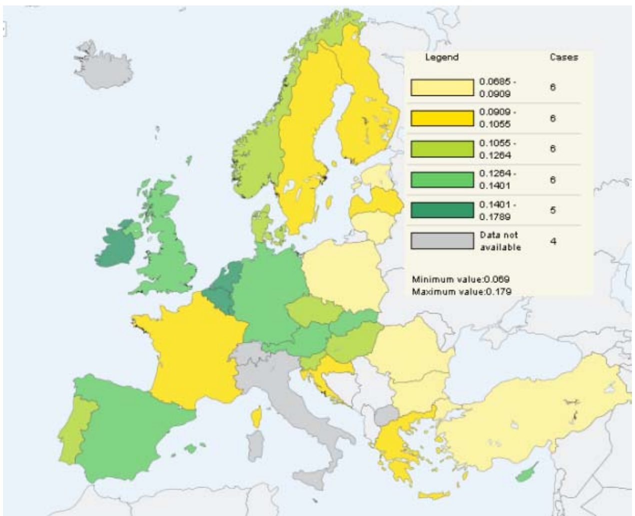

Fig. 2. Electricity prices for household consumers €/kWh (year 2009).
Source of data: Eurostat.
http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

The considered dependent variable is *Electricity prices for household consumers*. This indicator measures electricity prices charged to final consumers, which are defined as follows: Average national price in Euro per kwh without taxes applicable for the first semester of each year for medium size household consumers (Consumption Band Dc with annual consumption between 2500 and 5000 kwh). Until 2007 the prices are referring to the status on the 1st of January for medium size consumers.

We propose the following explanatory variables related to renewable energy sources and electricity market regulation:

- Electricity generated from renewable sources - % of gross electricity consumption (RES-E). This indicator is computed as the ratio between the electricity produced from renewable energy sources and the gross national electricity consumption for a given year. Electricity produced from renewable energy sources comprises the electricity generation from hydro plants (excluding pumping), wind, solar, geothermal and electricity from biomass/wastes. We expect a positive estimated effect of this variable on electricity prices as the generation of Electricity from Renewable Energy Sources (RES-E) increases generation costs and their development is mainly driven by different public renewable support schemes.
- Percentage of Greenhouse gas emissions (GHG) by Energy industries as a total of Greenhouse gas emissions (Energy Industries Emissions). We expect a positive estimated effect of this variable on prices as emission trading schemes exist.
- Market share of the largest generator in the electricity market- Percentage of the total generation (Electricity Generation Competition-ECG). This indicator shows the market share of the largest electricity generator in each country. To compute this variable, the total net electricity production during each reference year is considered, meaning that the electricity used by generators for their own consumption is not taken into account. Then, the net production of each generator during the same year is considered in order to calculate the corresponding market shares, and only the largest market share is reported under this indicator. As a result a positive effect of this variable on electricity prices is expected, since market share increases also increment the market power thus leading to higher electricity prices.
- Gross Domestic Product, GDP per capita, measured in Purchasing Power Standards PPS- (GDPpps). This variable aims to study the effect of the general economic activity on electricity prices. Besides the convenience of considering the general economic context, the inclusion of this indicator is particularly interesting in some European Countries (as in Spain) where part of the electricity price is paid by the government through state budgets.

In the described situation the use of panel data techniques could be advisable if significant country effects exist, allowing us to determine if there are differences at country-level among the European Union member states.

We specify the following panel regression model:

$$y_{i,t} = \alpha_i + \beta_1 \, RESE_{it} + \beta_2 EGC_{it} + ... + \beta_4 GDPpps_{it} + u_{it}$$

where i=1,…,27, *t*=1998,…,2009.

Parameters α_i denote country effects and they are included in the model with the aim of capturing the specific effects related to the different EU countries, since the omission of these terms might lead to biased estimates. The disturbances of this model are denoted by u_{it} and are assumed to be independently and identically distributed random variables with mean zero and variance σ_u^2.

In order to identify the most suitable specification, the proposed model has been estimated considering both fixed and random effects[2]. According to the fixed effects model α_i is considered as a regression parameter while the random effects model treats it as a component of the random disturbance. In order to establish whether the fixed or the random effects estimator is more appropriate a Hausman test is performed [26].

If the effects α_i are correlated with the explanatory variables, then the random effects model cannot be consistently estimated, and the Hausman test can be used to test for inconsistency in the random effects estimation by comparing the fixed-effects and random-effects estimated coefficients (a significant difference indicates that the random effects model is estimated inconsistently). In other words, the null hypothesis of the Hausman test is that individual country effects are uncorrelated with the other explanatory variables and thus the random-effects model is the most appropriate estimator.

The obtained value for the Hausman test statistic is 39.81 and the related *p*-value (approximately 0) leads to a rejection of the null hypothesis of strict exogeneity. Therefore, we conclude that the fixed effects model is better than the random effects option.

Further, the existence of country specific effects has been checked though the F test (whose null hypothesis is the existence of equal α_i for all the countries). If the individual country effect α_i is assumed to be equal across all countries, then the pooled Ordinary Least Square are consistent and efficient.

The obtained results are summarized in Table III confirming the existence of country-specific effects (The F test statistic leads to the rejection of the null hypothesis at the 1% level). As a result, different α_i are assumed in order to control for unobserved heterogeneity of EU-27 members as significant differences between countries in electricity prices exist.

[2] The details about panel data econometrics can be seen in [22], [23], [24] and [25], amongst others.

 ISBN: 978-1-61208-138-0

TABLE III. ESTIMATED FIXED PANEL DATA MODEL FOR HOUSEHOLD ELECTRICITY PRICES (PANEL DATA SET COVERING 27 EU COUNTRIES DURING THE PERIOD 1998–2009).

Explanatory Variables	Estimated parameters
RES-E (%)	0.00167^{***}
Electricity Generation Competition (%)	-0.000559^{**}
Energy Industries Emissions (%)	0.00181^{**}
GDPpps	0.001^{**}
R^2	0.80
Hausman test	39.81^{***}
F test (country-specific effects)	$24{,}175^{***}$

(1) **significant at 5%; ***significant at 1%.
(2) Robust regression is used to adjust the results for heterokedasticity

The fixed effects estimated model has a good explanatory power (the overall goodness of fit is 80%).

The panel regression results indicate that, according to the t-test, the overall considered variables are statistically significant at 5% level. The variable Electricity generated from RES has a positive estimated coefficient, showing that a 1% increasing in RES-E, holding constant all other explanatory variables, causes an increases of 0.00167 Euro per kwh in the household electricity prices.

Moreover, Energy Industries Emissions and GDPpps have also estimated positive effects on electricity prices. More specifically, by increasing 1% the Green Gas Emissions produced by Energy Industries the electricity price would increase in 0.00181 Euros per kwh (holding constant all other variables). The positive estimated effect of the GDP per capita on electricity prices could indicate that the RES-E promotion expenditures in countries with higher income are usually supported by increasing electricity prices paid at the end by the consumers (in stead of state budgets).

Lastly, the variable related to the liberalization of electricity generation (Electricity Generation Competition) has a negative impact on household electricity prices. This result does not fulfil our initial expectations as it is generally expected that liberalization of generating activities increase competition thus reducing electricity prices.

In fact, when market share of the largest generator in the electricity market decreases 1% (holding constant all other variables) the household electricity prices are expected to increase in 0,00056 Euro per kwh, Therefore, Electricity market liberalization does not necessarily imply effective competition and competitive prices. Achieving competitive prices depends on the number of players, the nature of electricity supply and the nature of consumer demand.

Since the largest part of the EU electricity generation by RES is devoted to wind power and hydro, we estimate the model including the explanatory variables *Electricity generated from wind power* and *Electricity generated from hydroelectricity*, obtaining the results summarized in Table IV. In this new model, the Hausman test for the null of random effects versus fixed effects leads to a chi-squared statistic with a value of 10,56 and therefore random components can not to be rejected at 5% of significance.

TABLE IV. ESTIMATED RAMDOM PANEL DATA MODEL FOR HOUSEHOLD ELECTRICITY PRICES (PANEL DATA SET COVERING 27 EU COUNTRIES DURING THE PERIOD 1998–2009).

Explanatory Variables	Estimated parameters
RES-E from Wind (%)	0.0025^{***}
RES-E from Hydro (%)	-0.0001
Electricity Generation Competition (%)	-0.0003^{***}
Energy Industries´ Emissions (%)	-0.0004
GDPpps	0.0003^{**}
Log-likelihood	400.74
Hausman test	10.56^{*}
Breusch-Pagan test (country-specific effects)	354.96^{***}

(1) **significant at 5%; ***significant at 1%.
(2) Robust regression is used to adjust the results for heterokedasticity

According to the estimated t statistics, the RES-E for hydro and Energy Industries´ Emissions are not significant explanatory variables.

Regarding Electricity generated from wind, the estimated coefficient suggests that an 1% increasing in this variable (holding constant all other variables) leads to an increase of 0.0025 euros per kwh in household electricity prices.

III. MAIN FINDINGS AND CONCLUDING REMARKS

The liberalization of electricity markets in Europe aims to increase competition, thus decreasing electricity prices for the final consumers. However, the promotion of European electricity generation from renewable energy (RES-E) could have an opposite effect on electricity prices.

In the framework of a controversial debate about the effects of RES-E on household electricity prices, this paper explores the impact of several economic variables on household electricity prices in the European Union.

With this aim, panel data models are estimated trying to explain the household electricity prices as a function of several economic variables related to renewable energy sources and electricity market regulation: Electricity generated from renewable sources, Greenhouse gas emissions produced by Energy industries and Market share of the largest generator in the electricity market. The panel data set is provided by Eurostat covering 27 EU countries during the period 1998–2009 and the obtained results indicate that electricity prices increase with the deployment of RES-E and also with the increased emissions of energy industries.

Regarding the liberalization of electricity generation, our findings suggest that when the market share of the largest generator in the electricity market decreases 1% the household electricity prices increases in 0,00056 euro per kwh. Therefore, the liberalization of Electricity markets does not necessarily imply effective competition and competitive prices.

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 ISBN: 978-1-61208-138-0