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Electricity Prices in the European Union Region: The Role of Renewable Energy Sources, Key Economic Factors and Market Liberalization

George E. Halkos * and Apostolos S. Tsirivis

Department of Economics, University of Thessaly, 38333 Volos, Greece
* Correspondence: halkos@econ.uth.gr; Tel.: +30-2421074920

Abstract: Electricity is by far the most valuable energy commodity for households; hence, it is of the utmost importance for national regulatory authorities and the European Commission (EC) to guarantee affordable and unimpeded access for European citizens to this vital social good. The existing academic literature mainly focuses on the effect of specific renewable energy resources (RES), such as solar, wind, etc., on electricity prices, thus neglecting the crucial impact of the electricity market structure. In an effort to fill this gap, the present paper attempts to clarify whether the real effect of the share of total renewable energy production in the generation scheme and certain electricity market liberalization indices constitute key determinants of household electricity prices. The study is further innovative on the grounds that the empirical analysis utilizes both static and dynamic panel methodologies for a dataset including several variables introduced for the first time in academia. The dataset consists of yearly observations regarding 26 EU countries for a time horizon from 2003 until 2019. The econometric outcomes revealed the complex relationship between RES deployment and generation concentration with the level of household electricity prices. In contrast, the deregulation of the retail market and especially the presence of many retailers with a market share exceeding 5% can benefit European consumers by reducing electricity prices. Additionally, the relative costs concerning the outward-orientation of the economy and the power system's upgrade were found to be transferred to the final electricity price. The opposite applies to environmental taxes, allowing European governments to accumulate considerable funds for ecological and environmental protection actions. Lastly, due to the estimated slow adjustment rate of electricity prices, policymakers are advised to develop long-term strategic energy planning.

Keywords: electricity price; renewables; market liberalization; competition; SDG 7; energy policy; JEL classifications

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1. Introduction

Electricity is an essential energy commodity both for households and the industrial sector. The quality of life and economic prosperity of millions of people depend to a high degree on their ability to uninterruptedly access an affordable and high-quality power grid. The backwash from the recent military conflict and escalating geopolitical tension in Eastern-Europe shone a spotlight on the European Union's (EU) high dependency on imported fossil fuels to ensure the security of the electricity supply [1]. The entire European economy, governments, and citizens were suddenly exposed to potential energy shortages and extreme price risks. This development highlighted more than ever the importance of enhancing energy resource autonomy while, in parallel, eliminating any current market distortions that delay the transition towards a deregulated electricity market.

The EU was one of the leading forces in incorporating the United Nations' (UN) sustainability goals for low-cost and clean energy production (SDG 7), which intended to mobilize countries on a global scale to take precautionary measures against the phenomenon of climate change and energy poverty. Since 2015, when the UN first endorsed the relative directive [2], the EU has developed an innovative energy policy emphasizing environmental protection and market openness [3]. This ambitious strategy was based on two main pillars. The first is trying to mitigate carbon emissions and, at the same time, improve the EU's energy self-sufficiency, including stringent environmental restrictions concerning electricity generation and multiple incentives for the rapid expansion of RES [4]. Likewise, the second one intensified efforts for electricity market liberalization, targeting monopoly and oligopoly conditions in power production, distribution, and retail sales [5]. The EU's strategic energy planning aimed to encourage the entrance of new market participants by progressively repealing any bureaucratic obstacles and potential disincentive legal framework in all country members [6]. In this way, any existent market barriers would be permanently removed, boosting competition and allowing the free determination of electricity prices. Nevertheless, according to [7–9], reaching the desired levels of competition and market openness in the consolidating European energy market remains a very long and arduous process, requiring targeted reforming policies of the existing market structure, which will make it more attractive and accessible to new entrants.

Numerous pieces of research, among which are [10,11], have praised the role of electricity as a valuable social good while at the same time highlighting the significance of electricity as the primary energy commodity for European households. Yet, combining environmental protection with affordable energy and sustainable development of the electricity sector composes a major challenge and an extremely complicated task for national regulatory authorities and the EC. Considering the complexity of electricity markets, the present research attempts to shed light on how the percentage contribution of renewables in the generation fuel mix, key economic factors, and market liberalization influence consumer electricity prices in many European countries.

The great majority of academic papers focus on the effect of renewable energy production from specific sources, most commonly solar and wind, on electricity prices. The recent works of [12–14] analyze the multiple consequences to the spot and futures market from the accelerated transition to green electricity production in the EU area. A more content group of research papers, such as [15–17], examine the effect of the European electricity market structure on prices by examining certain market liberalization indices, such as the number of retailers and the concentration of market power in electricity generation.

The current study is quite novel on the grounds that it offers a more spherical view of the investigated subject of European electricity prices by employing two separate models. The basic model examines the impact of total RES production, including solar, wind, hydropower, and biofuels, and certain economic parameters on household electricity prices. In addition, a second model is specified, which is intended to unveil the real effect of generation and retail market competition on electricity price levels. For this purpose, the econometric analysis of the two models was conducted by utilizing both static panel Fixed-Effects and dynamic panel System-GMM methodologies, as well as a unique panel dataset that has never been used by any other relevant academic paper so far. Specifically, to the best of the authors' knowledge, it is the first time that an economic globalization index is used to represent a country's level of economic outward-orientation. Furthermore, the research provides energy policymakers with a comprehensive assessment of the role of market liberalization, taking into account several aspects of the European electricity market. Except for generation concentration and the total retail sellers, two extra and rather interesting variables are incorporated. These variables refer to the amount of electricity generation from non-primary activity producers and the number of retailers with a market share exceeding 5%. In detail, the basic model consists of variables representing the percentage RES share, the GFCF concerning the power sector solely as proposed by [18], the total amount of environmental taxes, and the economic globalization index rating. Likewise, the competition model comprises the percentage market share of the largest generator, the amount of electricity from secondary activity producers, the number of large electricity retail companies, and the total number of retailers.

Besides exploring the relationships and possible interactions between the proposed model variables and household electricity prices, the present research will further scrutinize whether the effect of RES participation in the production fuel mix changes after a certain point. Based on the outcomes of the econometric analysis, a number of essential policy adjustments will be proposed in an attempt to moderate the latest high electricity price levels. Moreover, a set of crucial initiatives and incentive measures will be recommended in order for European authorities to intervene successfully in the deregulation process of the electricity market and ensure the desired outcomes for the benefit of both the power sector's investors and household consumers. Finally, there will be an approximation of the required time frames until the full convergence of electricity prices with respect to any policy adaptations concerning the parameters of the two processed models.

The paper is organized as follows: Sections 1 and 2 consist of the introduction to the research topic and state of the art, respectively. Section 3 presents the analyzed panel dataset, the two models' specifications, statistical diagnostic tests, and the implemented methodology. Section 4 contains detailed commentary on the econometric analysis and outcomes. Section 5 contains a complete summary of the most valuable economic and environmental conclusions and a series of potential policy implications. Lastly, Section 6 summarizes the main findings and contributions of the paper.

2. State of the Art

The vital role of electricity in the quality of life, technological progress, and economic prosperity of modern societies has led a plethora of researchers to try to identify the main determinants of electricity prices. The impact and potential costs of RES expansion are, at the moment, one of the most popular topics in academia, as renewable electricity manages to combine supply security and energy resource autonomy with CO_2 abatement. Due to the EU's global lead in RES deployment, the vast majority of relative studies focus on wholesale and retail price adjustments as a consequence of RES's penetration in the European electricity market. As the largest national electricity market, the epicenter mostly lays the German market together with the EU market as a whole. Refs. [19–21] support that renewable electricity production was a positive driver in Germany's drop in electricity price levels. Similarly, Ref. [22] the repercussions of the rise of RES participation in the generation scheme of Spain, the principal electricity market in the Iberian Peninsula, are explored. The research demonstrated a net reduction in retail electricity prices despite the cost of RES feed-in tariffs. The studies of [23,24] validated this outcome for the Spanish wholesale electricity price, with [25] arguing that renewable electricity not only reduced prices but also moderated the likelihood of potential upward spikes. Ref. [26] affirm the beneficial effect of RES's penetration into the Danish electricity market, while [27,28] further verified this outcome for the entire EU region. The latter further claimed that the decline in the average electricity price gets steeper for higher levels of RES installed capacity. In contrast, investigating country-specific cases, Refs. [29–31] allege that the rising adoption of RES increased final consumer electricity prices in Denmark, Israel, and Germany, respectively. Ref. [32], based on dynamic panel analysis of a dataset containing information for seven major OECD economies, including Germany, France, Italy, and the United Kingdom, found that the share of RES in the generation scheme does not affect electricity price in a statistically significant way. However, Refs. [15,33,34] examining the influence of RES on the electricity markets of almost the entire group of EU member states declared that RES deployment overall creates a direct and increasing effect on household electricity prices.

Compared to the amount of research for RES, little work has been done with respect to the impact of capital investments on European electricity prices. Relative studies, such as that of [35,36], show that electricity market reform is associated with a decline in private investments in the power sector, while high electricity prices reduce the ability of EU countries to attract foreign investments. Yet, the opposite relationships were not analyzed.

Nonetheless, due to the EU's intensified efforts to accelerate the integration of European electricity markets and create a single and unified market, a large group of academics conducted research on the implications of market liberalization and competition level in electricity generation and distribution. Refs. [32,34,37] concluded that the EU's dedicated policy for market deregulation and stimulation of competition benefited European citizens by lowering consumer prices. Conversely, in the papers of [33,38], no statistically significant effect was discovered between the progress of market reform and electricity prices. Furthermore, Refs. [39,40] highlight that contrary to expectations for electricity market openness, there was a tendency for retail prices to rise in several cases.

A competitive electricity market with high supplier diversification and a regulatory framework that separates generation and distribution services is theoretically better able to provide lower consumer prices. Ref. [37] argue that electricity supply markets under perfect competition conditions lead to notable price reductions. In line with this view, Refs. [34,41] report that moderating generation concentration brings more affordable electricity prices. On the contrary, a vast array of research finds strong evidence against all aforementioned notions. According to [42,43], unbundling in electricity generation resulted in higher average electricity prices for a large number of OECD countries. Focusing explicitly on market conditions and the competition level of power production within the EU, Refs. [15,33] concluded that in contradiction with perfect competition theory, decreasing the market share of the largest generator can adversely affect household electricity prices. Consistent with the previous outcome, Ref. [16] further claims that the entrance of supplementary individual power producers in the supply market did not succeed in reducing final consumer prices.

Providing consumers the option to choose among various electricity sellers is expected to prevent potential market abuse by one or a small group of large retailers, thus avoiding any price implications from monopoly and oligopoly market conditions. In agreement with this view, Ref. [44] supports that regardless of whether it is a public or privately owned retail company that acts as a regional monopolist, this causes considerable welfare losses and increases consumer prices. Refs. [19,42] propose liberalization efforts to intensify, as expanded retail access is likely to lower electricity prices, yet [43] argues that retail competition is unable to significantly affect the electricity price.

3. Methodology and Data

3.1. Data Summary

The paper focuses on the key drivers of household electricity prices in Europe. As a result, the following econometric analysis relies on a panel dataset consisting of multiple annual observations for a group of 26 European countries. In detail, the dataset contains information for the average yearly electricity price (per MWh) [45], the percentage of total RES participation in the total generation fuel mix including solar, wind, hydropower, and biofuel electricity production [46], the power sector's GFCF (%GDP) [47], the economic globalization index rating [48,49], the total amount paid in environmental taxes [50], the percentage market share of the largest generator [51], the amount of generated electricity by secondary activity producers (GWh) [52], the number of retailers covering at least 5% of the total national electricity consumption [53] and the total number of electricity retailers [54] for a time horizon from 2003 to 2019 (The dataset for competition model contains observations for 24 countries as the annual values for the percentage market share of the largest electricity generator concerning Austria, and the Netherlands were not available (confidential) in Eurostat's dataset.) The data sample was obtained from the databases of Eurostat, the World Bank, the OECD statistical library, the U.S. Energy Information Administration, and the Quality of Government.

Table 1 presents the descriptive statistics of the entire dataset, including electricity price and all other 8 explanatory variables. The statistical values in Table 1 provide a quick but pretty clear picture of Europe's overall electricity market conditions. Even before the recent energy crisis, the price range for household electricity suffers from great instability and fluctuations, with the cost for domestic electricity use varying from 50.5 to the skyrocketing level of 213 euros per MWh. The largest part of Europe's power generation undoubtedly comes from conventional fossil fuel power plants. The mean and median values for RES are approximately 30%, which implies a great dependency on traditional energy commodities such as natural gas, coal, and oil. Nevertheless, the statistical results for the examined countries reveal a great imbalance relative to RES dependency, as in the same sample, co-exist countries that cover 99.47% of their total demand from renewable electricity, with countries where RES's contribution is practically insignificant. Similarly, capital investments in the power sector and the imposed environmental taxes considerably differ among the countries included in the study. The amounts of electricity GFCF and environmental taxation deviate from almost zero to several billions of euros. Yet, the median values of 0.85% GDP and 5.79 billion euros signify that for most European governments, environmental protection and upgrading their power system's infrastructure becomes a priority. Likewise, statistics for the economic globalization index confirm the previous findings, with the majority of European states characterized by economic outward-orientation and high investment and financial freedom.

Table 1. Descriptive statistics of total panel dataset (Years: 2003–2019).

	Electricity Price (Euro Per MWh)	Renewables (% Total Fuel Mix)	Electricity GFCF (% GDP)	Environmental Tax (Billion Euro)	Economic Globalization Index	Market Share Largest Generator (% Total)	Secondary Autopro-ducers (GWh)	Main Electricity Retailers (≥5% Total Market Share)	Total Electricity Retailers
Mean	112.36	31.13	1.06	12.77	78.25	50.01	1.92	3.97	142.55
Median	110.00	24.28	0.85	5.79	78.28	45.10	0.68	4.00	47.00
Std. dev.	30.16	24.67	0.67	19.07	7.11	23.86	2.53	2.06	244.37
Minimum	50.50	0.48	0.00	0.16	51.66	3.00	0.00	1.00	1.00
Maximum	213.00	99.47	4.27	61.12	92.85	97.00	11.99	9.00	1485.00
Skewness	0.62	1.03	1.79	1.72	−0.33	0.33	1.76	0.43	3.21
Kurtosis	3.55	3.34	7.13	4.60	2.81	1.80	5.49	2.53	14.26
Jarque-Bera	33.57 ***	79.69 ***	550.8 ***	8.85 **	8.84 ***	30.51 ***	317.00 ***	16.16 ***	2859.00 ***

Note: *** Denotes significance at the 1%, and ** at 5% level, respectively.

Nonetheless, the statistical outcomes for the variables comprising the electricity market competition model show that the goal for a common deregulated European electricity market remains far from being achieved in the near future. Specifically, the mean and median values for the market share of the largest generator, the contribution of non-main activity producers, and the number of main retailers highlight that there is a low degree of market competition in a large group of countries. The zero supplementary power generation, the presence of only one primary retailer, and a market power concentration of the largest producer reaching 97% show strong evidence of a lack of competition. Yet, the median and mean values for the above variables mainly describe oligopolistic market conditions, with probably one large public company playing the leading role in power generation and only a few main electricity retailers. What is more, the low 3% market concentration of the largest generator, in conjunction with the maximum values for electricity generation from secondary producers as well as for the number of main retailers, indicate a content group of countries with highly liberalized electricity markets. Most likely, this set of countries refers to the Nordic market, where market barriers regarding electricity production and transmission networks have been lifted, allowing consumers' easy access to multiple producers and retailers located either in their own country or generally in the region of Scandinavia. Lastly, in harmony with the values for skewness and kurtosis, the Jarque–Bera normality test null hypothesis is rejected for both the dependent and all independent variables, verifying their non-normal unconditional distributions.

3.2. Causality Analysis

3.2.1. Pearson Correlation Test

Tables 2 and 3 portray the coefficients of Pearson's correlation test for the variables of the two processed models. For the basic model, a low but statistically significant correlation between all explanatory variables and electricity price except for renewables is notable, with the highest correlation concerning the relationship between electricity price and the economic globalization index. Similarly, for the competition model, there is a low statistically significant correlation between electricity price and three out of four independent variables. Moreover, the market share of the largest generator seems to be negatively connected with non-primary activity producers, the number of main retailers, and total retailers, yet the strongest statistical connection concerns secondary electricity production and total retailers with a correlation coefficient of 0.8083.

Table 2. Pearson's correlation coefficients.

Variable	Electricity Price	Renewables	Renewables ^{2}	Electricity GFCF	Environmental Tax	Economic Globalization
Electricity Price	1.0000					
Renewables	0.0701 (0.1411)	1.0000				
Renewables ^{2}	0.0218 (0.6475)	0.9527 *** (0.0000)	1.0000			
Electricity GFCF	−0.2900 *** (0.0000)	−0.0757 (0.1118)	−0.0839 * (0.0781)	1.0000		
Environmental Tax	0.2298 *** (0.0000)	0.0425 (0.3731)	−0.0137 (0.7732)	−0.2083 *** (0.0000)	1.0000	
Economic Globalization	0.3643 *** (0.0000)	−0.0464 (0.3308)	−0.0199 (0.6760)	−0.2303 *** (0.0000)	−0.1875 *** (0.0001)	1.0000

Note: *** Denotes significance at the 1% and * at the 10% level respectively. Renewables ^{2} is the Renewables variable in second power.

Table 3. Pearson's correlation coefficients.

Variable	Electricity Price	Market_Share Largest Generator	Secondary Autoproducers	Main Electricity Retailers	Total Electricity Retailers
Electricity Price	1.0000				
Market_Share Largest Generator	−0.2279 *** (0.0000)	1.0000			
Secondary Autoproducers	0.3739 *** (0.0000)	−0.2858 *** (0.0000)	1.0000		
Main Electricity Retailers	−0.0175 (0.7251)	−0.4462 *** (0.0000)	−0.1316 *** (0.0078)	1.0000	
Total Electricity Retailers	0.2660 *** (0.0000)	−0.2937 *** (0.0000)	0.8083 *** (0.0000)	−0.0626 (0.2067)	1.0000

Note: *** Denotes significance at the 1% level. Numbers in parentheses show the test corresponding *p*-Values.

3.2.2. Dimitrescu-Hurlin (2012) Causality Test

Specifying suitable econometric models requires a prior investigation of the potential causal relationships between the examined sample variables. For this reason, a causality analysis was carried out by utilizing the Dumitrescu and Hurlin (2012) test [55]. Tables 4 and 5 highlight the statistically significant causality relationships among the variables of the proposed models for two lagged periods. In the first table, containing the results for the basic model, electricity price seems to affect both renewables and environmental taxes in a unidirectional way, while economic globalization seems to solely affect the electricity price. Similarly, renewables affect electricity GFCF and economic globalization, respectively. Interestingly, the test reveals a bidirectional relationship between renewables and environmental taxes.

Table 4. Basic model Dimitrescu-Hurlin (2012)—Causality testing (lag order: 2).

Null Hypothesis:	Obs	Test-Statistic	*p*-Value
Electricity Price does not Granger Cause Renewables	438	2.5687	0.0102
Electricity Price does not Granger Cause Environmental Tax	438	2.7679	0.0056
Economic Globalization does not Granger Cause Electricity Price	438	3.0238	0.0025
Renewables do not Granger Cause Electricity GFCF	438	4.5606	0.0000
Renewables do not Granger Cause Environmental Tax	438	2.0831	0.0372
Environmental Tax does not Granger Cause Renewables	438	3.1718	0.0015
Renewables do not Granger Cause Economic Globalization	438	2.6687	0.0076

Note: For estimating the Dimitrescu-Hurlin (2012) causality test, the analysis used the *xtgcause* command with two "STATA" software lags.

Table 5. Competition model Dimitrescu-Hurlin (2012)—Causality testing (lag order: 2).

Null Hypothesis:	Obs	Test-Statistic	*p*-Value
Electricity Price does not Granger Cause Market Share	404	2.8923	0.0038
Market Share does not Granger cause Electricity Price	404	2.4870	0.0129
Secondary Autoproducers does not Granger cause Electricity Price	404	3.8407	0.0001
Electricity Price does not Granger Cause Total Retailers	404	3.0426	0.0023
Secondary Autoproducers does not Granger cause Market Share	404	7.7739	0.0000
Market Share does not Granger Cause Total Retailers	404	3.3445	0.0008
Total Retailers does not Granger cause Market Share	404	3.3490	0.0008
Secondary Autoproducers does not Granger Cause Total Retailers	404	3.9646	0.0001
Total Retailers does not Granger Cause Main Electricity Retailers	404	7.6239	0.0000

Note: For estimating the Dimitrescu-Hurlin (2012) causality test, the analysis used the xtgcause command with two "STATA" software lags.

With regard to the electricity market competition model, there is evidence for a two-way connection of generation concentration with electricity price and total retailers. Likewise, a unidirectional causality effect appears to be running from non-primary activity producers towards electricity price, market share of the largest generator, and total retailers. Finally, electricity price alone affects total retailers, and total retailers affect the number of main retailers.

3.3. Model Specification

The latter outcomes of the causality analysis verified several interactions between the variables included in the panel data sample. Relying on these findings, two proposed model specifications are formed, with the basic model exploring the influence of renewables and all four economic variables. In contrast, the competition model will try to identify the actual impact of retailers and concentration in power generation on household electricity prices.

Basic Model:

$$\textbf{\textit{Electricity Price}} = \beta_0 + \beta_1 \textbf{\textit{Renewables}}_{i,t} + \beta_2 \textbf{\textit{Electricity GFCF}}_{i,t} + \beta_3 \textbf{\textit{Environmental Tax}}_{i,t} + \textbf{\textit{Economic Globalization}}_{i,t} + \varepsilon_{i,t} \quad (1)$$

Competition Model:

$$\textbf{\textit{Electricity Price}} = \beta_0 + \beta_1 \textbf{\textit{Market\_Share\_Largest\_Generator}}_{i,t} + \beta_2 \textbf{\textit{Secondary\_Autoproducers}}_{i,t} + \beta_3 \textbf{\textit{Main\_Retailers}}_{i,t} + \beta_4 \textbf{\textit{Total\_Retailers}}_{i,t} + \varepsilon_{i,t} \quad (2)$$

where β_1, β_2, β_3 and β_4 denote the coefficients of the independent regression variables, representing the elasticity of electricity price relative to changes in the independent variables ceteris paribus. β_0 and $\varepsilon_{i,t}$ symbolize the constant and the error terms, respectively, of the relative regressions.

3.4. Cross-Sectional Dependence Tests

Following the model specification, it is essential to conduct a series of statistical tests that will guide researchers through selecting the most appropriate econometric methodologies to successfully process the two proposed models and produce reliable and robust outcomes. Testing for cross-sectional correlation within and between country panels is a crucial step, as failing to consider this aspect when dealing with panel datasets may lead to ill-founded conclusions and poor policy implications. The presence of cross-sectional dependence in the error-terms may cause severe distortions in the approximation of variable coefficients and standard errors unless a suitable estimator is employed.

To detect any possible signs of cross-sectional dependence, the analysis utilizes the Pesaran (2015) CD test [56] for weak cross-sectional dependence and the Pesaran (2004) CD test [57], which relies on the average and pairwise correlation of the OLS residuals that derive from separable panel regressions. Table 6 emphatically proves the existence of cross-sectional dependence among the models' variables. The null hypotheses (H_0) of both tests are rejected at a 1% significance level, implying that the investigated variables, which refer to various EU member states, are influenced by the common energy strategy and the implemented fiscal and environmental policies.

Table 6. Cross-Section dependence of panel time series.

Variable	Pesaran (2004) CD_{test}	Correlation (Average)	Correlation (Absolute)	Pesaran (2015) Weak CD_{test}
Electricity Price	30.46 *** (0.000)	0.410	0.518	73.309 *** (0.000)
Renewables	49.18 *** (0.000)	0.662	0.757	69.584 *** (0.000)
Renewables ^{2}	47.42 *** (0.000)	0.638	0.717	64.828 *** (0.000)
ElectricityGFCF	6.36 *** (0.000)	0.086	0.375	68.832 *** (0.000)
Environmental Tax	53.16 *** (0.000)	0.715	0.718	73.359 *** (0.000)
Economic Globalization	36.41 *** (0.000)	0.490	0.612	74.280 *** (0.000)
Market Share	17.05 *** (0.000)	0.251	0.480	9.919 *** (0.000)
Secondary Autoproducers	10.04 *** (0.000)	0.147	0.471	13.265 *** (0.000)
Main Electricity Retailers	2.11 *** (0.035)	0.031	0.413	5.937 *** (0.000)
Total Electricity Retailers	16.00 *** (0.000)	0.234	0.493	18.763 *** (0.000)

Note: *** Denotes significance at the 1%. Numbers in parentheses show the test corresponding *p*-values. The null hypothesis (H_0) of the Pesaran (2004) CD test assumes strict cross-sectional independence. The null hypothesis (H_0) of the Pesaran (2015) CD test assumes weak cross-sectional independence. For the Pesaran (2004) CD and the Pesaran (2015) CD tests, the *xtcd* and the *xtcd2* commands of the "STATA" software were utilized. Correlation and Absolute (correlation) are the average (absolute) value of the off-diagonal elements of the cross-sectional correlation matrix of residuals. Renewables ^{2} is the Renewables variable in second power.

After the assumption of cross-sectional independence for the panel time series is rejected, the analysis explores the likelihood that the different panel units of the dataset are cross-sectionally dependent. Table 7 depicts the relative results for the non-parametric Friedman (1937) [58] and Frees (1995) Q-distribution [59] tests and the Pesaran (2004). The outcomes for the test statistics in Table 7 signify the presence of strong cross-sectional dependence between the various country panels as the null hypotheses (H_0) of all three tests is rejected at a 1% significance level for the basic model, while the same applies for the Pesaran (2004) and Frees (1995) tests for the competition model. This is quite a reasonable conclusion since all the countries included in the study either belong to the "central core" of the EU or have very close political relationships and special trade agreements with the EU, indicating a high level of integration. As a result, the consequences of a potential economic and environmental shock in one country are transmitted up to a degree to all other country panels of the dataset.

Table 7. Cross-Section dependence among groups.

	Basic Model	Competition Model
Pesaran's test of cross-sectional independence	10.034 *** (0.000)	12.371 *** (0.000)
Friedman's test of cross-sectional independence	67.913 *** (0.000)	19.500 (0.671)
Frees' test of cross-sectional independence	3.589	1.669
Critical values from Frees' Q distribution:	Alpha = 0.10 0.1521 Alpha = 0.05 0.1996 Alpha = 0.01 0.2928	Alpha = 0.10 0.3169 Alpha = 0.05 0.4325 Alpha = 0.01 0.6605

Note: *** Denotes significance at the 1%. Numbers in parentheses show the test corresponding P-values. For the Pesaran, Friedman, and Frees group cross-sectional dependence tests, the xtcsd Pesaran abs, Friedman xtcsd, Frees xtcsd post commands after xtreg POLS regression in the "STATA" software were utilized.

3.5. Panel Unit Root Tests

The standard panel data econometric techniques, often used in academia for processing similar datasets, presuppose stationary model variables. Realizing the importance of this aspect, the present research employs two first-generation and one second-generation panel unit-root tests to examine the stationarity of all variables included in the dataset both at levels and first differences. The LLC test is a basic unit root test that can be quite reliable for datasets with observations for numerous time periods, yet the ADF-Fisher test relaxes the restrictions of the LLC test allowing lag lengths to differ across panels, making it superior. Nevertheless, a weakness of the ADF-Fisher test is that it depends on Monte Carlo simulations to estimate the corresponding *p*-values. Therefore, the CIPS unit root test introduced by Pesaran (2007) is additionally included in the analysis as its basis for its outcomes on a non-standard distribution while simultaneously managing to account for cross-sectional dependence.

The statistical results for the three unit root tests are illustrated in Table 8. What is evident from the table is that at levels, the null hypothesis (H_0) for unit roots in the dataset's panels fails to be rejected for most variables independent of the trend option. In contrast, when applying the first differences to the dataset, all three tests confirm variable stationarity at a 1% significance level both for trend and without trend, implying that the models' variables are stationary and integrated at order one I(1).

Table 8. Unit root tests.

	Level						First-Difference					
	Intercept			Intercept and Trend			Intercept			Intercept and Trend		
Variable	**LLC**	**ADF-Fisher**	**CIPS**	**LLC**	**ADF-Fisher**	**CIPS**	**LLC**	**ADF-Fisher**	**CIPS**	**LLC**	**ADF-Fisher**	**CIPS**
Electricity Price	−7.337 *** (0.000)	59.698 (0.216)	−2.125	5.791 *** (0.000)	38.629 (0.915)	−2.617	−10.625 *** (0.000)	89.476 *** (0.000)	−3.933 ***	−8.18 *** (0.000)	91.496 *** (0.000)	−4.021 ***
Renewables	3.231 (0.999)	18.104 (1.000)	−2.397 ***	−3.115 *** (0.009)	37.613 (0.933)	−2.640	−11.149 *** (0.000)	157.601 *** (0.000)	−3.710 ***	−7.652 *** (0.000)	136.259 *** (0.000)	−3.864 ***
Renewables ^{2}	7.911 (1.000)	18.813 (1.000)	−2.445 ***	2.720 (0.996)	31.248 (0.990)	−2.641	−5.386 *** (0.000)	130.804 *** (0.000)	−3.478 ***	−2.668 *** (0.000)	121.289 *** (0.000)	−3.709 ***
Electricity GFCF	−1.764 (0.038)	61.258 (0.177)	−2.053	−3.991 *** (0.000)	82.796 *** (0.004)	−2.916 ***	−10.415 *** (0.000)	248.007 *** (0.000)	−4.110 ***	−3.025 *** (0.000)	203.299 *** (0.000)	−3.999 ***
Environmental Tax	1.651 (0.950)	20.647 (1.000)	−1.976	−2.297 ** (0.011)	31.237 (0.990)	−1.858	−12.109 *** (0.000)	146.501 *** (0.000)	−3.556 ***	−6.112 *** (0.000)	114.260 *** (0.000)	−3.786 ***
Economic Globalization	−5.075 *** (0.000)	41.533 (0.850)	−2.875 ***	−4.568 *** (0.000)	45.183 (0.736)	−3.536 ***	−15.455 *** (0.000)	195.996 *** (0.000)	−4.421 ***	−8.591 *** (0.000)	129.593 *** (0.000)	−4.488 ***
Market Share	−1.170 (0.177)	53.273 (0.000)	−2.794 ***	0.957 (0.830)	142.990 *** (0.000)	−2.706 **	−16.734 *** (0.000)	269.910 *** (0.000)	−5.376 ***	−2.846 *** (0.002)	190.979 *** (0.000)	−5.315 ***
Secondary Autoproducers	3.668 (0.000)	42.058 (0.713)	−1.663	−10.066 (0.000)	96.315 *** (0.000)	−1.791	−18.026 *** (0.000)	102.580 *** (0.000)	−3.087 ***	−13.879 *** (0.000)	97.070 *** (0.000)	−3.339 ***
Main Electricity Retailers	0.193 (0.576)	96.737 (0.000)	−1.646	−2.172 ** (0.014)	79.598 ** (0.014)	−2.487 **	−5.851 *** (0.000)	97.359 *** (0.000)	−3.731 ***	−7.693 *** (0.000)	149.959 *** (0.000)	−3.816 ***
Total Electricity Retailers	−0.567 (0.285)	37.416 (0.576)	−2.069	−2.689 *** (0.003)	47.788 (0.481)	−2.624	−15.921 *** (0.000)	145.572 *** (0.000)	−3.800 ***	−1.148 (0.000)	56.855 *** (0.000)	−3.938 ***

Note: *** Denotes significance at the 1% and ** at 5%. Numbers in parentheses show the test corresponding *p*-values. The null hypotheses (H_0) of the tests assume non-stationary variables. For the ADF–Fisher, LLC, and CIPS unit root tests, the *xtunitroot* and *xtcips* commands of the "STATA" software were utilized. Critical values for the CIPS test of Pesaran (2007) are −2.07 (10%), −2.15 (5%), and −2.32 (1%) for constant and −2.58 (10%), −2.67 (5%) and −2.83 (1%) for trend, respectively. The optimal lag selection was made based on the Akaike Information Criterion, while the Bartlett kernel was selected with the maximum number of lags being determined by the Newey and West bandwidth selection algorithm. Renewables ^{2} is the Renewables variable in second power.

3.6. Panel Cointegration Tests

After verifying the absence of unit roots, the two proposed models should be checked further for co-integration. Table 9 depicts the statistical results of the Kao (1999) [60] and Pedroni (1999, 2004) panel cointegration tests [61,62]. In Table 9, the *p*-values for the test-statistics suggest panel cointegration for the basic and competition model in three out of five Kao (1999) tests. To confirm panel cointegration in the two models, the analysis further employs the Pedroni (1999, 2004) test with the recommended adjustment of Levin, Lin, and Chu (2002) so that the test accounts for cross-sectional dependence. The statistical outcomes in Table 10 categorically reject the null hypothesis for joint non-co-integration at a 1% significance level.

Table 9. Kao panel cointegration test.

	Basic Model		**Competition Model**	
	Statistic	***p*-Value**	**Statistic**	***p*-Value**
Modified Dickey-Fuller-t	−1.0789	0.1403	−0.1684	0.4331
Dickey-Fuller-t	−2.0437	0.0205	−1.6596	0.0485
Augmented Dickey-Fuller-t	−0.5699	0.2844	−0.9023	0.1834
Unadjusted modified Dickey-Fuller-t	−2.7615	0.0029	−1.9163	0.0277
Unadjusted Dickey-Fuller-t	−2.9947	0.0014	−2.7776	0.0027

Note: For the Kao (1999) panel cointegration test, the *xtcointtest kao* command of the "STATA" software was utilized, with *kernel (bartlett)* option. The optimal lag length was selected automatically based on the Akaike Information Criterion. All other bandwidth orders are set according to rule $4(T/100)^{2/9} \approx 3$. The test's null hypothesis (H_0) assumes no cointegration in the examined models, while the alternative hypothesis (H_a) assumes that all panels are cointegrated.

Table 10. Pedroni Panel Cointegration Test.

	Basic Model		**Competition Model**	
	Statistic	***p*-Value**	**Statistic**	***p*-Value**
Modified Phillips-Perron-t	5.6727	0.0000	3.7857	0.0001
Phillips-Perron-t	−13.1729	0.0000	−8.0833	0.0000
Augmented Dickey-Fuller-t	−22.1789	0.0000	−17.6723	0.0000

Note: For the Pedroni (1999, 2004) panel cointegration test, the *xtcointtest pedroni* command of "STATA" software was utilized, with *kernel (bartlett)*, *trend,* and *demean* options. The optimal lag length was selected automatically based on the Akaike Information Criterion (AIC). All other bandwidth orders are set according to rule $4(T/100)^{2/9} \approx 3$. The test's null hypothesis (H0) assumes no cointegration in the examined models, while the alternative hypothesis (Ha) assumes that all panels are cointegrated. The test's null hypothesis (H0) assumes no cointegration in the examined models, while the alternative hypothesis (Ha) assumes that all panels are cointegrated. Demean option: Stata computes the mean of the series across panels and subtracts this mean from the series. Levin, Lin, and Chu (2002) suggest this procedure to mitigate the impact of cross-sectional dependence.

3.7. Heteroskedasticity, Serial-Correlation, and Omitted Variable Tests

Before proceeding to the main econometric analysis and to be properly guided through the selection of the most suitable panel methodologies and estimators, a series of diagnostic tests must first be conducted. The two proposed models are inspected for heteroskedasticity and serial-correlation by employing a group of relative tests generally acknowledged in academia as the most statistically robust. Table 11 illustrates the P-values of the test-statistics for the Breusch-Pagan (1979) [63], Glejser (1969) [64], Harvey (1976) [65], and White (1980) [66] heteroskedasticity tests and the Breusch-Godfrey/Wooldridge (2010) [67] serial correlation test. It is noteworthy from the table that four out of five heteroskedasticity tests confirm the presence of heteroskedasticity in the models, while the Breusch-Godfrey/Wooldridge (2010) test emphatically rejects the null hypothesis for no-serial correlation at a 1% significance level for both models.

Table 11. Model diagnostic tests.

	Basic Model		Competition Model	
	Statistic	*p*-Value	Statistic	*p*-Value
Breusch-Pagan Heteroskedasticity test	21.08	0.0000	30.81	0.0000
Glejser Heteroskedasticity test	8.83	0.0000	17.56	0.0000
Harvey Heteroskedasticity test	1.50	0.1753	5.47	0.0001
White Heteroskedasticity test	4.46	0.0121	0.23	0.7924
Breusch-Godfrey/Wooldridge Serial Correlation test	242.43	0.0000	218.68	0.0000

Note: The null hypothesis (H_0) of the Breusch-Pagan (1979), Glejser (1969), Harvey (1976), and White (1980) tests assumes no-heteroskedasticity in the models. Similarly, the null hypothesis (H_0) of the Breusch-Godfrey/Wooldridge (2010) test assumes no-serial correlation (pbgtest {plm} from "R" software).

3.8. Econometric Methodology

Considering the verification of cross-sectional dependence, heteroskedasticity, and serial correlation by the exhibited statistical test results in the previous sections, it is critical to implement suitable panel econometric techniques, which will ensure the accuracy and robustness of the produced outcomes. Tables A1 and A2 in the Appendix A consist of a set of econometric tests concerning the most appropriate static econometric modeling for the current analysis, showing a clear indication in favor of utilizing the Fixed-Effects methodology. Considering the outcomes of the preceding diagnostic tests, the study, to improve the predictability of the standard Fixed-Effects model, will further adopt a Driscoll-Kraay standard-error correction as suggested by Driscoll and Kraay (1998) [68] and Hoechle (2007) [69].

Despite the plethora of merits of the qualified static panel methodology, this may lead to biased estimates and under-or-over-estimation of the actual effect of the explanatory variables in case of a long-term underlying relationship. Dealing with this contingency requires further dynamic analysis of the two proposed models. For this purpose, the System-GMM model of Blundell and Bond (1998) [70] is employed. The System-GMM approach, among other advantages, is very effective in dealing with any potential unobserved effects relative to both dependent and explanatory variables. By developing and incorporating into the initial model a series of instruments based on differenced and lagged levels of the examined variables, the System-GMM method manages to overcome the lack of external instruments. Nevertheless, ensuring the precision and robustness of the produced outcomes demands strict orthogonality. Additionally, the validity of the System-GMM model further depends on the absence of second-order serial correlation and non-overidentified instrumental variables. These conditions are checked by the AR(1) and AR(2) serial correlation tests of Arellano and Bond (1991) [71], as well as the Hansen-J and Sargan-J overidentification tests, respectively. The dynamic analysis in the present research will primarily rely on the two-step System-GMM model with Windmeijer's (2005) [72] correction robust standard errors (WCSE) and orthogonal deviations, an econometric approach widely acceptable in academia for its accurate and endogeneity, autocorrelation and heteroskedasticity consistent outcomes.

4. Empirical Analysis and Results

4.1. Static Analysis

Table 12 summarizes the final results obtained from both static and dynamic panel regression analysis. The P-values for the coefficients of all variables of the basic model are statistically significant at a 1% level except for economic globalization, which is significant at 5%. Similarly, all independent variables of the competition model are significant at a 1% level apart from the number of main retailers, which is found to be statistically insignificant. In harmony with the findings for static modeling of [15,32,33] renewables have a positive estimated coefficient; hence it is implied that a rise in the share of RES electricity increases household prices in the 26 investigated EU member states. However, the fact that the coefficient for renewables^2 is also statistically significant but negative reveals the complexity of RES's impact on electricity price. Based on this outcome, renewable's initially increasing effect is reversed beyond 49.27% of RES participation in the generation scheme as depicted in Figure 1. Concerning the effect of electricity GFCF, it is noteworthy that the high investment costs for the power system's upgrade are passed into a high degree into final consumer prices, as a 1% increase in electricity GFCF ceteris paribus causes an increase of 8.2735% in the short run. The same applies to environmental taxes, with a 1% rise to the level of the relative taxation leading to 0.6855% higher electricity prices. Similarly, economic globalization creates an effect of analogous size in electricity prices.

Table 12. Empirical findings under different specifications.

	Static-Analysis		Dynamic-Analysis	
	Basic Model	Competition Model	Basic Model	Competition Model
Variable	**Fixed Effects Driskoll-Kraay (S.E)**	**Fixed Effects Driskoll-Kraay (S.E)**	**System-GMM (2-Steps)**	**System-GMM (2-Steps)**
Electricity Price$_{(t-1)}$	-	-	0.8681 *** (0.000)	0.8283 *** (0.000)
Renewables	1.8428 *** (0.000)	-	−0.1957 *** (0.005)	-
Renewables ^{2}	−0.0187 *** (0.000)	-	-	-
ElectricityGFCF	8.2735 *** (0.000)	-	6.7119 *** (0.003)	-
Environmental Tax	0.6855 *** (0.010)	-	0.1379 * (0.100)	-
Economic Globalization	0.5963 ** (0.040)	-	1.2539 ** (0.016)	-
Market Share	-	−0.4851 *** (0.004)	-	−0.1612 * (0.067)
Secondary Autoproducers	-	5.4711 *** (0.000)	-	1.9501 ** (0.044)
Main Electricity Retailers	-	0.3583 (0.746)	-	−0.7942 * (0.059)
Total Electricity Retailers	-	−0.0432 *** (0.004)	-	−0.0207 *** (0.002)
Constant	-	131.0176 *** (0.000)	-	31.3733 *** (0.000)
Observations	442	390	416	369
AR(1) (*p*-Value)	-	-	0.001	0.000
AR(2) (*p*-Value)	-	-	0.619	0.839
Number of instruments	-	-	21	24
Sargan test (*p*-Value)	-	-	0.291	0.490
Hansen-J test (*p*-Value)	-	-	0.605	0.384

Note: *** Denotes significance at the 1%, ** at 5%, and * at the 10% level, respectively, with the numbers in brackets indicating the corresponding *p*-values. The Fixed Effects function of Hoechle's (2007) xtscc command for the "STATA" software was applied for the static analysis. For the dynamic analysis and System-GMM models, the corresponding statistical functions of Roodman's (2009) *xtbond2* command for the "STATA" software were utilized. Specifically, the two-step System-GMM models were estimated by applying the relative options for robust estimators (*robust*) and strict orthogonality (*orthogonal*). The *twostep robust* option in the *xtbond2* command of "STATA" requests Windmeijer's finite-sample correction for the two-step covariance matrix. AR(1) and AR(2) are tests for first- and second-order serial autocorrelation. The Sargan and Hansen-J denote the tests of overidentifying restrictions of the instruments in System-GMM models. Renewables ^{2} is the second power of variable Renewables.

In addition, the outcome for the concentration of electricity generation is again in line with that of [15,33], as the increasing market share of the largest producer appears to be able to reduce electricity price. In contrast, the impact from the generation of non-main activity producers, contrary to what suggested by [16], is positive and statistically significant. Finally, allowing the market entrance of additional electricity retailers is proved to create a slightly decreasing effect in household prices.

4.2. Dynamic Analysis

The econometric outcomes for the dynamic panel analysis show that none of the processed two-step System-GMM models fail to pass the required specification tests. The null hypothesis (H_0) of the AR(1) test for no-autocorrelation is rejected by both models, hence indicating that the correct specification is indeed a dynamic model. Next, the results for the AR(2) tests confirm that no additional autocorrelation is observed in the models after incorporating the lagged dependent variable. Likewise, the null hypotheses (H_0) of the Sargan and Hansen-J overidentification tests cannot be rejected by either of the two models, verifying the validity of the implemented instrumental variables.

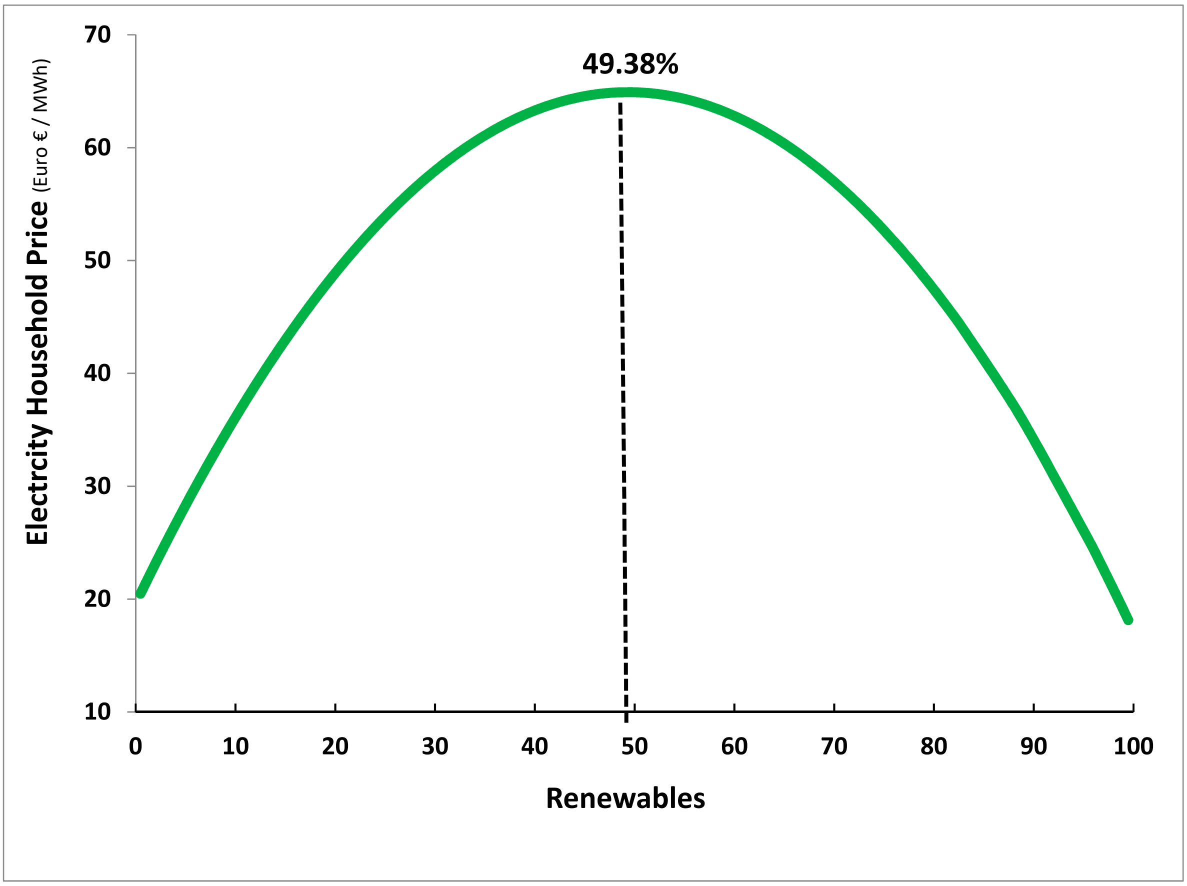

Figure 1. Household Electricity Price (Euro €/MWh) VS polynomial function of %RES usage (authors' elaboration).

Focusing on the variable estimations for the basic and the competition model, the statistical significance of the lagged electricity price shows strong path dependency, with the latest value of the variable being correlated with its former ones. In contrast with the outcomes of [32,34] for the overall dynamic effect of RES generation, the coefficient for the renewables parameter is negative and statistically significant at a 1% level. Specifically, a 1% further increase of RES's contribution to electricity production fuel mix is expected to ceteris paribus reduce household electricity prices by −0.1957%. This finding is consistent with the work of [28], in which the author claims that the continuously rising RES deployment could drop electricity prices at an ever-increasing rate. With respect to the basic model, it is worth noticing that the impact of electricity GFCF, although remaining equally statistically significant it is lower than that estimated in the static model, with a 1% rise in the expenditure (%GDP) for the power system's upgrade increasing consumer price by 6.7119%. Likewise, improving the economic globalization index by 1% influences a price increase in the region of 1.25%, while only 0.1379% from a potential 1% raise in environmental taxes seems to be passing into the final household price in the long run.

In agreement with the conclusions of [15,33] for the role of generation concentration, the coefficient of percentage market share of the largest generator is negative and statistically significant at 10%. However, the magnitude of this effect is considerably lower than that estimated by the static model. Against expectations from perfect competition theory, a 1% increase in market concentration, holding constant all other explanatory variables, drives a −0.1612% fall in household electricity prices. Furthermore, a rise of supplementary generation by 1% is anticipated to create an upward trend in electricity consumer prices of roughly 1.95%. Nevertheless, in accordance with [19,42], progressive retail market openness is proved to be an essential step for lowering electricity prices. Both the number of main retailers and total retailers show strong statistical significance, yet the impact of retailers with market power exceeding 5% is multiple times higher. Concretely, the addition of 1% more retailers into the market is estimated to drop electricity prices by −0.0207%, while increasing the number of large retailers leads to a notable decrease of −0.7942%. Lastly, the statistically significant coefficient for the lagged electricity price in both examined dynamic models allows for approximating the variable's convergence rate relative to changes in the explanatory variables of the two models. Hence, the adjustment of electricity price proceeds at a pace of nearly 14% (1–0.86) per year for the basic model and 17% (1–0.82) per year for the competition model, respectively. These outcomes basically signify that it practically requires 7 years for the full convergence of electricity prices with respect to changes in RES generation and the other three economic variables, while almost 6 years would be needed until the competition level in the electricity market fully affects household prices.

5. Discussion and Policy Implications

In an effort to thoroughly scrutinize the actual effect of RES on household electricity prices, the present study utilized advanced panel econometric methodologies, which revealed the complexity of the connection between the two factors. The empirical analysis showed a relationship of quadratic form between RES and electricity price, best described by an inverted U-shape curve. This outcome clearly indicates that the initial phase of the positive influence of renewables on electricity price is reversed after the turning point of 49.27% of renewable generation and is then followed by a gradually growing price pressure, as suggested by [28]. Nevertheless, the overall effect of RES, as estimated by the dynamic model, is found to be negative and significant for the 26 EU countries included in the dataset. Considering that the marginal cost for electricity production from RES tends to be zero, the previous results are quite reasonable providing key answers to the debate and the plethora of contradicting academic papers regarding the real effect of RES on electricity prices.

Combining the outcomes of the econometric analysis with the finding of [18] that excessive RES deployment can lead to adverse environmental consequences in terms of CO_2 production, an optimal range of percentage RES participation in the generation fuel mix can be approximated by state authorities in each country. Within this optimal range of RES usage, CO_2 abatement could be combined with lower consumer prices, enabling a specific country or region to comply with the UN's goal for affordable and clean energy production (SDG 7). However, the extended development of the RES market and the transition towards a "green" and sustainable energy future requires governments and organizations like the EU to set strict environmental rules and provide financial incentives to promote firm green and sustainable innovation. According to [73–76], sustainable entrepreneurial innovation and environmental performance rely on corporate responsibility and on employees with high environmental awareness; hence targeted policies and information and education campaigns should be built to enhance these vital characteristic features of private firms.

With regard to the role of electricity GFCF, it is evident that to avoid potential price increases from the high investment costs concerning the power system's upgrade requires these costs to be at least partially moderated by implementing targeted subsidy policies. Moreover, in the long run, the moderate effect that environmental taxes seem to have on electricity prices allows the European Commission to encourage its country members to increase the relative taxation and raise substantial funds vital to promoting environmental protection and other ecological actions. Conversely, potential rating improvement in the economic globalization index comes at the cost of higher household electricity prices. An extended level of economic outward-orientation creates a series of benefits, such as enhanced trade openness and financial and investment freedom. Extensive interaction with other economies boosts economic growth and attracts foreign investments; however, in case electricity prices are higher in neighboring countries, power suppliers may choose to export electricity through a unified transmission and distribution grid. Under such a scenario, domestic electricity prices would be dragged to rise until matching the export price.

The econometric analysis proved the liberalization of the electricity market to be of immense importance for the level of household electricity prices. In contrast with the finding of [34] for the insignificant dynamic effect of generation concentration, the market power of the primary electricity generator was found to be statistically significant and negatively associated with electricity price. This outcome implies that the presence of a large supplier is beneficial for preserving a lower price level. Although seemingly a paradox, this discovery is quite reasonable since, in most European countries, there is one public owned generation company in which profitability does not constitute its main objective, hence supplying the market with low-cost electricity, usually from conventional carbon-intensive production units. Under such market conditions, new entry power generators are forced to operate with a very limited profit margin, discouraging potential new investments in the power sector, especially new investments involving novel and eco-friendly production lines, which require considerable high amounts of capital. Similarly, despite theoretical expectations for supplementary electricity production from non-main activity generators, the econometric results in Section 4 show that this extra electricity supply is a positive driver for more expensive household prices. A possible explanation lies in the fact that this group of generators merely relies on sophisticated and relatively expensive small-scale RES units with only limited capacity. Consequently, in order to avoid passing these initial investment costs to final consumers, it necessitates the EU's energy strategy to foresee the provision of affordable funding to such investment plans, as well as to subsidize the production of "green" electricity.

Finally, the deregulation of the retail electricity market and gradual repeal of all legal framework and bureaucratic matters related to market entrance barriers can lead to lower household prices; as a result, the European Commission is advised to act accordingly. The ability of retailers to hold a market share of over 5% in reducing electricity prices was proven to be far greater than that of retailers with limited market power. Therefore, it is reasonable that the EU should put more emphasis on forming the necessary conditions in the retail electricity market, which will promote and trigger an M&A process while simultaneously attracting new investment plans for the creation of influential retail companies.

6. Conclusions

Considering that electricity constitutes the most valuable energy commodity for households, it is of the utmost importance for governments and international organizations like the EU to guarantee affordable and unimpeded access of their citizens to this vital social good. Complying with the UN's sustainable development goals and particularly SDG 7 for clean and low-cost energy production, the present study scrutinizes how household electricity prices are influenced by renewable energy, specific economic parameters, and the liberalization of the electricity generation and supply market. The research is based on both static and dynamic panel analysis of a dataset consisting of 26 EU countries for a time horizon from 2003 to 2019.

Realizing the importance of electricity prices for European consumers, the study, except renewables, market share of the largest generator, and total retailers, further examines for the first time the effect of a series of variables, which account for the role of the national economy and electricity market structure. This set of variables includes the power sector's GFCF, the total amount paid in environmental taxes, the economic globalization index rating, the electricity generation from non-primary activity producers, and the number of retailers with market power exceeding 5%. Additional novelties concern the utilization of both linear and squared forms of the renewables variable, as well as the approximation of the necessary time for the convergence of electricity price to policy changes with respect to the examined models' parameters.

The obtained econometric outcomes revealed the complexity of the relationship between renewables and electricity prices. Results showed that low levels of RES participation in the generation fuel mix tend to increase consumer electricity prices, yet this effect is progressively reversed for higher shares of RES. Constantly increasing RES deployment is expected to reduce electricity prices at a brisk pace, as suggested by [28]. However, such a development might hide adverse market and environmental implications. Therefore, before employing measures that promote RES expansion, national energy policymakers should first explore whether the intended level of RES reliance produces the anticipated economic and environmental benefits in this particular country. In contrast, the EU as a whole is advised to subsidize investments for the power system's upgrade and sustainable development, as these high costs are very likely to be incorporated into the final consumer price. The fact that potential environmental tax increases are gradually absorbed to a high degree by electricity producers and retailers allows EU countries to increase relative taxation and accumulate essential funds for ecological actions. Lastly, improving the rating of the economic globalization index implies enhanced financial and investment freedom and economic growth, though increased market openness enables electricity exporting, which is possible to raise the domestic electricity price.

Likewise, the liberalization of the electricity market is a complicated process in which several aspects must be first taken into consideration. The econometric analysis showed that lowering the market share of the largest generator can become an aggravating factor for household electricity prices. Even though against expectations from perfect competition theory, this finding aligns with the previous works of [15,33] regarding the European supply market. This negative connection of market concentration with electricity price can be explained by the presence of a primary public owned producer in several European countries, which serves as a regulatory pillar. These public companies are not driven by profit. Instead, their principal goal concerns maintaining a low consumer price level. Consequently, to moderate household electricity prices, European governments may either rely on an oligopoly built around a leading public supply company or proceed to the full liberalization of market generation with the privatization of the public-owned generators and complete dependency on free competition conditions of an open market economy. With reference to supplementary producers, the EU should subsidize their activity whenever this involves employing RES. Additionally, extending the deregulation policy for the retailers market can benefit European household electricity prices.

Finally, the low convergence rate of electricity price relative to policy adjustments concerning the investigated parameters indicates that both European Commission and individual state authorities are necessitated to develop long-term strategic energy planning. Nevertheless, all suggested policies should be modified by taking into account the individual country-specific characteristics. This limitation of the present paper, which provides an overall picture of the investigated parameters for the entire EU area, could become the main topic for future research incorporating panel FMOLS and PDOLS econometric methodologies.

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Abbreviations and Acronyms

RES	Renewable Energy Sources
EU	European Union
EC	European Commission

GDP	Gross Domestic Products
GFCF	Gross Fixed Capital Formation
GWh	Giga Watt hour
MWh	Mega Watt hour
UN	United Nations
SDG	Sustainable Development Goal

Appendix A

Table A1. Tests for static econometric analysis.

	Basic Model		Competition Model	
	Statistic	***p*-Value**	**Statistic**	***p*-Value**
Poolability test	7.033	0.0000	6.227	0.0000
Breusch-Pagan LM test	994.6	0.0000	1025.9	0.0000
Joint significance F-test (FE)	31.13	0.0000	27.16	0.0000
Time-Effects test (FE)	67.368	0.0000	71.39	0.0000
Hausman test	50.02	0.0000	48.82	0.0000

Note: For the Poolability test, the *Pooltest* of the *plm* package of "R" software was applied. The null hypothesis (H_0) of the *Pooltest* assumes the stability of the POLS model and robustness when compared to a Fixed Effects model. The Breusch-Pagan LM (1980) test (1980) [77] of the plm package of "R" software was utilized to examine the existence of a panel effect in the data. The null hypothesis (H_0) of the Breusch-Pagan LM test (1980) assumes no panel effect, implying that the POLS model is more effective than a Random Effects model. The joint significance F-test (u_i = 0) in Table A1 is the one reported in the statistics table of a Fixed Effects model using the *xtreg* command of "STATA" software. To investigate whether it is necessary to implement the Time-Fixed-Effects model relative to the basic Fixed-Effects model with individual effects, the *pFtest* of the *plm* package of "R" software was used. The null hypothesis (H_0) of the *pFtest* assumes the presence of significant time effects, implying the superiority of the Time-Fixed-Effects model relative to the basic Fixed-Effects model. Finally, the Hausman (1978) test [78] of the "STATA" software with the *sigmamore* option and year variables was applied to select between the dummy control of time-invariant heterogeneity and its potential random disperse in the error term, as implied by the Fixed Effects and the Random Effects methodology, respectively.

Table A2. Variance Inflation Factor Test.

Basic Model			Competition Model		
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
Renewables	1.12	0.8896	Market Share	1.48	0.6753
Electricity GFCF	1.08	0.9272	Secondary Autoproducers	3.00	0.3332
Environmental Tax	1.06	0.9400	Main Electricity Retailers	1.37	0.7276
Economic Globalization	1.01	0.9896	Total Electricity Retailers	2.89	0.3464

Note: For the variance inflation factor test, the *estat vif* command of the "STATA" software was utilized, which calculates the centered variance inflation factors (VIFs) for the independent variables specified in a linear regression model.

Research Highlights

- The impact of RES and economic outward-orientation on electricity prices is assessed;
- Optimal RES participation in electricity generation fuel mix is approximated;
- The role of market liberalization in European electricity prices is investigated;
- The importance of the deregulation process in energy policy-making is evaluated;
- Time horizon until the convergence of electricity prices in policy changes is estimated.

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