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Sustainable Development of the European Electricity Sector: Investigating the Impact of Electricity Price, Market Liberalization and Energy Taxation on RES Deployment

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Abstract: Replacing conventional CO_2 intensive generation with green electricity from RES constitutes an essential prerequisite of sustainable development. Renewables play a vital role in achieving the UN's goals for clean low-cost energy production and the reverse of climate change process. Based on a comprehensive dataset including observations for 17 European countries between 2003 and 2020, the present research attempts to unveil the fundamental determinants of RES deployment. A panel FMOLS approach was utilized to provide a detailed analysis of the impact of electricity prices, energy taxes and competition level in both power generation and the retail electricity market on each country's RES percentage participation in electricity production fuel mix. The final econometric outcomes verified the strong statistical significance of all examined variables for the vast majority of the countries, constituting them crucial aspects of national energy strategies. However, both the actual effects as well as the impact size were found to differ significantly across Europe, signifying the complexity of the EU's task to develop a unified, autonomous and eco-friendly electricity market based on the principals of a fundamental energy strategy. Contributing to state authorities' and EU's colossal effort to deal with the crucial challenges of RES power generation, the paper proposes a series of targeted individual and groupwise policy implications.

Keywords: RES deployment; market liberalization; retail price; energy tax; SDG 7; SDG 13; energy strategy

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1. Introduction

Extreme weather conditions and climate change are gradually becoming a reality for millions of people worldwide, giving rise to catastrophic consequences for the quality of life and economic prosperity. Air pollution, including the destruction of the ozone layers and the mass concentration of CO_2 into the Earth's atmosphere, is held responsible for triggering the greenhouse gas phenomenon and global warming. The last eight years were reported by [1] to be the warmest in history, since the beginning of official scientific recordings. Annual carbon emissions in 2022 continued to rise by nearly 2.1 ppm, while the average temperature exceeded that of the reference period, 1991–2000, by 0.3 °C despite the cooling La Niña effect, which was evident almost throughout the entire year for the third consecutive time. Putting Europe's environmental distortions under the microscope, Ref. [2] noted that the continent in 2022 experienced the second hottest year after 2020 and the summer with the worst heat wave ever recorded. The same report makes special reference to the fact that Europe was found to be the region in which average annual temperatures have increased at a higher pace than any other on the planet, reaching double the global average. It is indicative that the summer of 2022 in Western Europe was approximately 10 °C warmer than the typical seasonal maximum temperatures and together with the record sunshine duration, led to the largest glacier melts ever observed in European Alps and the second lowest river flow levels in history. Likewise, the combination of prolonged drought periods and extremely high temperatures in southern Europe created ideal conditions for some of the oldest forests in this geographical area to burst into flames. It is estimated that the emitted air pollutants due to the wildfires exceeded all previously documented levels in the last two decades, with the total burnt area being the second largest ever within a calendar year.

Households and industrial production of goods and services heavily rely on mass consumption and constant access to affordable electricity, the most essential energy source, which, according to [3], is accountable for roughly 40% of CO_2 emissions worldwide on year basis. This vital energy input is produced at a great cost of natural resources, inducing a series of environmental consequences. The United Nations (UN) could not have neglected the adverse effects of electricity generation in its effort to mobilize the global community in the joint cause against energy poverty and environmental degradation. The 2015 Paris Agreement and the sustainability goals for affordable clean energy production and tackling climate change (SDGs 7 and 13, respectively), which were endorsed by [4], put great emphasis on the development of a sustainable energy sector that is capable to provide citizens of the countries ratifying the terms of the agreement with green low-cost electricity. These parameters dictate an energy strategy that promotes a shift transition to a liberalized electricity market—-in line with Refs. [5,6]—and towards an era where renewable energy sources (RES) will be the dominant energy source in the generation fuel mix. The decisive role of renewables in mitigating the carbon footprint of electricity generation in the nations comprising the EU and in major economies among with the highest GDPs was highlighted by [7], while [8] unveiled the beneficial effect of RES in moderating the upward price levels of European household electricity prices.

In line with its legal statutes to constantly enhance economic prosperity and its ethical mission to put environmental conditions as well as the quality of life of millions of citizens in the European region at the center of attention, the EU has become the frontrunner in the implementation of R&D and RES deployment strategies. In addition, the European Commission (EC), with its climate [9] and energy [10] directives, embraced the UN's ecological spirit and ideas expressed within the international environmental agreement. This newly established legal framework enabled the EU to align with its provisional commitments, while improving energy autonomy and diminishing import dependency. Nevertheless, the recent energy crisis, triggered by the geopolitical turmoil in Eastern Europe following the Russia–Ukraine conflict in 2022, brought to surface several structural weaknesses of EU's energy plan. The observed inability to effectively handle the energy price rally primarily stems from the lack of a diversified energy fuel mix and the strategic choice for overdependence on imported natural gas. The use of natural gas as the main intermediate fuel and basic instrument for achieving the full transition to green energy production magnified the impact of market shortages and limitations. High reliance on the more eco-friendly and relatively cheap Russian natural gas exposed EU countries to extreme price risk in cases of supply distortions, while increased complacency for technological advancements concerning RES efficiency and development of alternative energy sources, such as hydrogen.

In response to the latest extensive turmoil in the energy market and the lack of supply of natural resources from Russia, which is included in the top 10 countries with the largest natural resource reserves in the world [11], the EC, with its [12,13] directives, implemented several breakthrough energy policy adjustments. Theselegislative interventions and the RePowerEU plan brought fundamental changes—compared to the previously set goals in the Fit-for-55 scenario—, involving a rise of overall RES usage to 45%by 2030 and an increase in the incorporation of new RES technologies from 28% to 32%. Furthermore, specific targets with respect to the reduction of total demand for electricity were established, together with a revenue cap for power generators with lower costs than most expensive sources of electricity production. The chronicle of [14] about the progresses in the European electricity market in 2022 shows that during the last quarter of the year, overall demand for electricity within the EU diminished by 7.9% compared to 2021, with renewables accounting for 22% of total electricity production. This led to an all-time high for RES contribution, overtaking fossil fuel's participation in electricity generation fuel mix—which fell to 20%—yet the total share of fossil fuels still remained significantly large at 39%. However, despite all above actions, precautionary measures and achievements [15] support that the targets set by the RePowerEU plan concerning electricity generation and RES involvement in the transport sector are fairly unrealistic, unless EU member states accelerate the promotion of essential structural changes. Regarding the mitigation of CO_2 [15] underlines that fulfilling the EU's recently revised energy strategy demands the rapid expansion of RES electricity production, such that it approaches a 69% total share of the fuel mix. In order for these gaps to be filled, Ref. [16] proposed an ambitious overhaul of the EU's electricity market structure focusing on the reform of the current electricity pricing mechanism, which is currently mainly driven by short-term fossil fuel prices, in concurrence with strong financial incentives relative to RES deployment. Moreover, it is suggested for the liberalization process of the electricity sector in all member states to advance at a brisk pace, ensuring supply security, empowering consumers, and strengthening market transparency. Similarly, Ref. [17] suggests that strict provisions accompany the political agreement between EU countries about the reduction of the annual amount of emitted CO_2, while the EU is also advised to subsidize and finance the upgrade of the recharging network infrastructure for all types of electric-powered vehicles.

The EU's strategic energy planning, as described in [18], attempts to speed up procedures for a liberalized and integrated electricity market, which will be characterized by intense competition and will set control mechanisms to avoid the development of monopoly and oligopoly phenomena in electricity generation and retail market. The philosophy behind the EU's regulatory framework is to stimulate investments and market entries of new producers and distributors by lifting all legal, bureaucratic, and market barriers. The crucial influence of power sector's liberalization in RES deployment in developed western economies was highlighted by Refs. [19,20], with [21] putting the adverse effects of generation concentration in the epicenter. It is reasonable according to Refs. [22,23] for households in liberalized markets, with a high number of RES power producers and retailers, to choose providers with an ecological profile and at the same time be benefited by lower prices.

Electricity market openness and deregulation compose fundamental prerequisites for attracting and accumulating investments for additional RES projects, yet a series of related studies, among which [24], emphasize on the crucial impact of tax incentives and rational retail prices on maximizing the expected revenue of RES deployment schemes. It is noted by [25], that the announcement by governmental authorities in well-developed economies of RES related tax exemption incentives initiated a rapid response on behalf of private investors and firms, who distributed more of their available capital into projects for alternative electricity sources. Imposing energy taxes, and especially carbon emission taxes, on power production from conventional fossil fuel units was found by [26] to create an upward trend in RES investments.

Depending on the developmental stage, level of energy imports, abundance of natural resource reserves, degree of price stability in domestic electricity market and environmental quality, policymakers in individual countries are devising and modifying their energy strategies appropriately [27]. With respect to EU countries, Ref. [28] indicated that their shift towards renewable electricity varies mainly due to fundamental differences regarding their initial percentage RES usage as well as their dependency on foreign energy sources. The authors observed that European states with low installation capacities and high energy imports are capable of applying a more dynamic RES deployment strategy, since they tend to deal with less repercussions and hurdles from the power sector's stakeholders. Prior extended use of traditional carbon emitting energy sources was characterized by [29] as a critically detrimental factor obstructing the conversion of polluting electricity generation to RES. Several powerful and influential economic groups representing the gas, oil, and nuclear power industries can exert significant pressure on governments and force them to put a halt to their renewable energy strategies. The different paces by which EU member states are heading toward green electricity era were further observed by the recent analysis of [30].The authors highlighted the intense presence of lobbying, which hampers this already complicated procedure, while the opposite applies for stringent environmental rules and increased public awareness relative to the vital importance of RES.

Considering all previously discussed challenges, the present research attempts to clarify the influence of certain key determinants, representing the degree of power market deregulation, retail electricity prices, as well as environmental awareness and the provided investment incentives, onthe development of the European RES market. This research includes several novelties since the individual EU country characteristics are taken into account by utilizing the panel fully modified ordinary least square (FMOLS) econometric methodology. Furthermore, it is to the best of the authors' knowledge, the first time to investigate the effect of energy sector liberalization on RES share fuel mix participation deriving from electricity generation and the retail markets—of several European countries. For this purpose, this analysis will process a dataset comprised of the market shares of the largest electricity producer and the total number of market retail companies. Additionally, to provide a more spherical view of the driving forces of the EU's renewable market, it will be further scrutinized whether the amount of energy taxes imposed on fossil fuel power production and the level of household retail prices are sufficient enough to persuade new private investors and firms to enter the electricity market. These parameters will also be inspected for whether they motivate the existing market stakeholders to proceed to an increase in their RES installation projects. Based on the final outcomes of the econometric process, several suitable policy implications will be proposed accordingly for each country included in the study, in order to assist governmental authorities and the EC in their combined efforts for the transition to carbon neutral electricity generation leading to the alleviation of environmental degradation and the enhancement of the EU's energy autonomy.

Overall, this paper is organized as follows: Sections 1 and 2 contain the introduction and the literature review. Section 3 consists of the data and panel econometric methodology presentation. Sections 4 and 5 present a detailed commentary on the final empirical outcomes and corresponding policy recommendations. Lastly, Section 6 highlights the main findings and contributions of the paper.

2. State of the Art

Despite the plethora of papers in academia scrutinizing the potential implications on retail electricity prices from the delays, inconsistencies and procrastinations of central governments to stimulate the deregulation of the national energy markets, only a confined group of researchers focus on the mechanism upon which market openness affects the expansion of RES. After examining the data for OECD countries from the middle 1970s until the early 2010s, Ref. [31] detected that RES employment policies appear to be far more effective in deregulated electricity markets. Electricity market liberalization was concluded by [32,33] to enhance RES innovations, with [34] finding evidence of a quadratic relationship between the two factors, indicating that the intensity of the deregulation progression can be a decisive parameter of the impact magnitude. Interestingly, Ref. [21] processing long panel datasets on OECD countries, revealed that lifting market barriers for new entrants into the power sector was proved to be almost equally important in boosting RES deployment as consumers' personal available income and public awareness for tackling climate change and environmental depletion. The authors in the latter study further supported that whenever a variety of new actors was allowed to enter the electricity market, it diminished the concentration in power generation and abolished publicly owned monopolies, thereby triggering more progressive initiatives regarding RES sector's enlargement. Analyzing data for 25 developed OECD countries over a 30-year period—between 1985 and 2015—[20] claim that a competitive electricity market produces the necessary conditions under which RES development can flourish. Nevertheless, according to [35], the ability of RES to penetrate a deregulated energy market is not unlimited due to the evident weakness of highly competitive power industries to transparently deliver the proper market signals.

With respect to the impact of active governmental policy, involving tax incentives for the installation of carbon-free generation units and the simultaneous taxation of fossil-fuel-based power production, Ref. [36] underlines the importance of persistent commitment in support of a renewable-centered strategy combined with the willingness on behalf of regulatory authorities to intervene when necessary and impose essential measures (e.g., subsidies, taxes, etc.) to increase installed RES capacity. Exploring the Latin American energy market for a time frame between 2006 and 2015 [37] discovered that countries which adopt active promotion strategies regarding RES deployment accompanied by joint provisions for targeted tax incentives, are better able to cultivate a culture in favor of green electricity among their citizens, thereby increasing the overall contribution of renewables to total power production. By examining the Spanish power industry, Ref. [38] discovered that the most efficient way for the country's public administrators to reinforce RES's share involved establishing a policy mix of added taxes for non-renewable power production and tax discounts concerning investments in new zero-carbon electricity units, creating a competitive advantage over conventional polluting technologies. Likewise, conducting research on 27 EU countries [39] realized that a certain group was applied a dual-purpose tax strategy to intensify national RES usage, which involved financial motives that moderated initial investment budgets and allowed for competitively priced renewable electricity generation. In a similar study that focused on the entire EU electricity market from 2000 until 2015, Ref. [40] claim that imposed taxation on CO_2 emitting electricity production was proved a generally effective measure among all member states for incentivizing the expansion of nationally installed RES capacity. In the most recent relative research examining RES deployment in all EU member states, Ref. [25] highlights the vital significance for European governments to employ a tax incentive strategy that would allow them to achieve a more rapid switch from conventional fossil fuel to eco-friendly electricity production. Utilizing an extended panel dataset, containing information for 27 European countries and the vast majority of US states from 1990 until 2008, Ref. [41] validated the effectiveness of tax incentives to support the progress of green electricity in both regions. Solely referring to the US energy market [42,43] postulate that during the past three decades, tax credit extensions concerning RES electricity production enabled state governments to encourage investments in carbon-neutral power technologies and particularly wind farms. In contrast, the works of Refs. [26,44] examining the drivers behind eco-friendly power generation in China and 118 power markets respectively, determined that power market constraint policies fail to motivate RES investments—especially in regions with rich natural resources—while taxing fossil fuel electricity production results in an insignificant effect.

In spite of the extended number of academic papers found in the literature relative to the possible influence of RES on electricity prices, little research has been done to investigate the opposite effect. The work of [41] is one of the few studies to incorporate the price effect factor, underlying that feed-in tariff strategies increasing the final price received by green electricity producers proved capable of stimulating RES deployment within both the EU and the USA. In harmony with the evidence from the prior study, Ref. [40] recommend the implementation by European regulatory authorities of retail price levies as an effective measure to fund and promote renewable power production. Concentrating explicitly on the impact of electricity prices, Ref. [45] processing a large panel sample of well-developed OECD members unveiled that in countries with high percentage GDP growth, rising prices in the power market trigger an expansion of clean electricity consumption. Likewise, Ref. [46], based on data from 13 major economies from 2008 until 2018, argued that the impact of feed-in tariff policies, as well as the increasing price of electricity itself, is capable of stimulating investments in RES production units. utilizing evidence from 13 northeast US states [47] contend that the desire for higher financial returns generated by higher retail prices influenced investments in new solar photovoltaics, with [48] claiming that a decrease in electricity prices would indeed lead to a reduction of RES installations in the Spanish power market. Contrarily, Ref. [49] analyzing data for 38 of the most wealthy economies worldwide—including several European, OECD, and BRICS countries—from 1990 until 2010; they postulate that industrial electricity prices can negatively affect the rise of renewable electricity capacity, while the outcomes in the paper by [50] suggest that retail prices insignificantly contributed to the penetration of RES in the USA.

3. Methodology and Data

3.1. Data Presentation and Descricptive Statistics

Focusing on the key determinants of RES deployment within EU member states, the present research utilizes a balanced data sample containing yearly observations for a set of 17 countries, including the largest European power markets, during a time period between 2003 and 2020. The panel FMOLS econometric analysis that follows processes data for the total renewables' share in the electricity generation fuel mix [51], the average annual electricity retail price charged to household consumers (EUR/MWh) [52], the proportion of market concentration of the largest producer in the domestic power sector [53], the number of retail electricity providers [54] and the percentage of total national tax revenues corresponding solely to energy taxes [55]. The dataset was created with the use of the free online databases provided by the US Energy Information Administration and Eurostat. Table 1 contains brief and concentrated information of all variable details included in the analysis.

Table 1. Data sources and description.

Variable	Definition	Years	Data Sources
Renewables	Percentage RES participation into a country's electrcity generation fuel mix.	2003–2020	U.S. Energy Information Administration
Electricity Price	Cost of household electrcity per MWh.	2003–2020	Eurostat
Market_Share Largest Generator	Refers to percentage market concentration of the largest electrcity producing company.	2003–2020	Eurostat
Total Electricity Retailers	Refers to the total number of retail companies providing household electrcity.	2003–2020	Eurostat
Energy Taxes	Refers to the percentage share of total national tax revenues concerning exclusively energy production.	2003–2020	Eurostat

With respect to the selected variable representing RES's impact, the study followed the recommendation of [49] due to the fact that energy policymaking involves specific targets for RES participation in the generation scheme, while climate change preventive initiatives set certain goals for the increase of RES usage at the expense of carbon intensive technologies. Moreover, the energy tax variable is comprised of all taxes imposed on energy production. These include taxes on all types of fossil fuels used for electricity generation, taxes on energy product stocks, carbon emission taxes, as well as any other tax referring to greenhouse emissions.

In Tables 2 and 3, a detailed analysis of the entire panel and individual country descriptive statistics has been provided. Table 2 generates a broad but representative view of the energy markets in the examined EU member states and the energy sector in the European region as a whole. The statistical values for renewables' share reveal persistent high reliance on fossil fuels. A roughly 30% RES participation is reported on average, which is well under the EC's anticipated usage rate during the investigated period and way poorer than the necessary level of RES deployment set by IEA to successfully carry out the recently established RePowerEU plan. What is more, the minimum and maximum values for percentage RES contribution in national electricity production show that within the same dataset countries co-exist with recorded values from nearly 0% up to 99.47%. On the other hand, the nearly equal mean and median values regarding electricity prices indicate a strong sign of coherence among national energy strategies and compliance with the EC's proposed initiatives, targeting European power market integration. Nonetheless, the almost double than average maximum electricity price of 197.6 EUR/MWh is indicative of the relative instability that was present even prior to the recent energy crisis, possibly because of the EU's lack of natural resource autonomy and the insufficient development of RES. Focusing on electricity generation deregulation, it is evident that in a high number of the sample's countries there is absence of market competition. In most cases, one main utility company holds a market share exceeding 40%, indicating oligopolistic conditions. Conversely, the retail electricity market reflects a high degree of liberalization and economic antagonism; as a result, European consumers are benefited by the existence of several electricity providers. Exploring the taxation of energy production, there is an obvious policy convergence between EU country members with a common tax rate that accounts for approximately 5% of overall government tax revenues. Lastly, results for skewness, kurtosis, and the Jarque–Bera normality test in Table 2 reject the normality hypothesis for the dependent variables, as well as all explanatory variables.

Table 2. Descriptive statistics of total panel (Years: 2003–2020).

	Renewables (% Total Fuel Mix)	Electricity Price (EUR/MWh)	Market_Share Largest Generator (% Total)	Total Electricity Retailers	Energy Taxes (% Total Taxes)
Mean	34.09	112.09	49.09	190.48	5.36
Median	27.60	109.3	41.85	100	5.04
Std. dev.	25.96	26.98	24.94	282.37	1.52
Minimum	0.98	53.5	10.27	1	2.77
Maximum	99.47	197.6	100	1485	9.93
Skewness	0.90	0.74	0.44	2.63	0.69
Kurtosis	3.09	3.58	1.82	10.17	2.94
Jarque–Bera	41.9 ***	32.08 ***	27.56 ***	1009 ***	24.46 ***

*** Denotes significance at 1%.

Table 3 shows the main statistical values for each of the 17 nations, unveiling a broad profile of their domestic power market. Interestingly, Scandinavian countries appear to be the protagonists in green electricity generation, with all four of them being in the leading places of that particular category. Specifically, Norway achieved an average 98.22% annual electricity production through RES between 2003 and 2020. This strategic energy planning resulted in less volatile and relatively lower electricity prices. Among with the highest electricity prices lie heavily industrialized economies, including Germany, Italy, Spain and Belgium, showing a tendency for both high prices and increased instability. Scandinavian countries, together with Poland, Germany, and Spain, have the lowest generation concentration, while the most pluralistic retail electricity markets appear to be present within the largest European economies. Finally, all of the dataset's countries seem to have an aligned policy relative to energy taxes.

Table 3. Descriptive statistics of total panel (Years: 2003–2020).

	Renewables (% Total Fuel Mix)				**Electricity Price (EUR/MWh)**				**Market_Share Largest Generator (% Total)**				**Total Electricity Retailers**				**Energy Taxes (% Total Taxes)**			
	Mean	**Std.dev.**	**Min**	**Max**	**Mean**	**Std.dev.**	**Min**	**Max**	**Mean**	**Std.dev.**	**Min**	**Max**	**Mean**	**Std.dev.**	**Min**	**Max**	**Mean**	**Std.dev.**	**Min**	**Max**
Belgium	12.86	9.50	1.43	27.90	155.35	30.04	110.1	197.6	64.64	19.79	38.36	92	43.56	12.15	23	60	3.71	0.38	3.22	4.31
Croatia	58.44	11.28	37.81	74.61	94.81	11.66	72.5	110	84.47	2.93	80.01	92	5	3.24	1	9	6.16	0.81	4.81	7.21
Czech Republic	8.29	3.97	2.27	13.51	113.52	21.80	67.80	137.7	67.25	6.32	54.34	74.19	347.11	56.32	238	419	5.90	0.53	5	6.59
Denmark	46.36	22.45	17.49	82.76	101.72	10.88	86.90	126.2	39.40	7.50	31.87	56	50.89	20.07	33	113	4.91	0.67	3.53	6.16
Finland	40.89	6.35	29.61	52.94	99.96	13.83	77.60	120.5	21.79	4.36	15.77	27	98.33	4.01	86	100	4.42	0.26	3.82	4.79
France	15.37	4.35	9.86	25.10	104.27	13.16	89	129.2	80.31	9.32	63.87	90.20	172.33	7.62	160	185	3.76	0.31	3.33	4.28
Germany	23.41	12.20	7.55	46.52	137.43	6.37	125.4	148.9	27.84	2.78	22	32	1144.8	203.18	940	1485	4.61	0.73	3.53	5.97
Greece	20.13	10.22	7.33	41.86	102.36	17.98	72.20	127.8	76.36	19.59	50.02	100	10.5	8.15	2	26	6.21	1.85	3.91	8.34
Hungary	8.72	4.48	0.98	17.88	98.95	18.86	72.80	132	36.96	7.09	23.66	47.10	33	13.56	12	52	5.05	0.38	4.59	5.83
Italy	29.85	11.07	15.48	43.58	144.63	7.86	132.6	162.6	30.35	6.70	23	46.30	490	153.72	268	775	5.98	0.59	4.80	6.85
Latvia	59.32	6.92	50.17	72.50	92.94	16.40	58.40	114.4	88.16	2.74	85.47	95	10.72	8.57	1	26	8.27	1.24	6.05	9.93
Lithuania	33.37	31.77	1.76	89.65	81.22	15.09	53.5	104.8	49.36	20.46	24.9	79.70	16.5	7.75	7	27	5.84	0.42	4.98	6.88
Norway	98.22	1.11	95.73	99.47	117.11	13.96	92.70	138.8	30.78	1.46	27.4	33.60	194.67	16.47	163	226	3.33	0.27	2.77	4.08
Poland	9.06	5.69	1.50	19.44	97.41	13.09	73.70	119.5	14.90	3.49	10.27	19.20	162.44	36.52	118	265	6.80	0.27	6.26	7.30
Slovenia	28.56	4.48	22.28	38.52	104.91	12.61	85.20	119.2	55.40	6.96	50.10	82	15.67	4.69	7	23	7.46	1.07	5.98	8.81
Spain	30.78	9.47	15.2	44.62	144.52	37.05	87.20	194.7	26.62	5.92	17.92	39.10	300.39	94.63	121	459	4.31	0.33	3.72	4.79
Sweden	55.98	6.46	43.38	69.81	114.38	18.55	80.60	134.5	39.98	5.68	30.1	47	142.28	31.29	75	193	4.44	0.58	3.55	5.16

3.2. Causality Analysis

3.2.1. Pearson Correlation Test

The Pearson's correlation coefficients illustrated in Table 4 signify the considerably low correlation between the five investigated variables. In detail, the most commentworthy relationships include that of the electricity prices with generation concentration and total electricity retailers, which appear to be statistically significant at 1% with positive correlation coefficients (0.3118 and 0.3886, respectively). These relationships basically reflect the propensity of electricity prices to rise alongside the market share of the largest stakeholders in electricity production, while higher prices is reasonable to attract more electricity providers that are willing to enter the retail market. Likewise, a higher number of electricity retail companies seem to be negatively correlated with generation concentration. This strongly statistically significant connection suggests that a competitive electricity retail market influences a more liberalized power sector.

Table 4. Pearson's correlation coefficients.

Variable	Renewables	Electricity Price	Market_Share Largest Generator	Total Electricity Retailers	Energy Taxes
Renewables	1.0000				
Electricity Price	−0.0079 (0.8900)	1.0000			
Market_Share Largest Generator	−0.1110 * (0.0524)	0.3118 *** (0.0000)	1.0000		
Total Electricity Retailers	−0.1024 * (0.0737)	0.3886 *** (0.0000)	−0.3571 *** (0.0000)	1.0000	
Energy Taxes	−0.0857 ** (0.1349)	−0.2335 *** (0.0000)	0.2143 *** (0.0002)	−0.2021 *** (0.0004)	1.0000

*** Denotes significance at 1%, ** at 5%, and * at 10% level, respectively. Numbers in parentheses show the test corresponding *p*-values.

3.2.2. Dumitrescu–Hurlin (2012) Causality Test

Conducting a causality analysis among the dependent and explanatory variables is a vital prerequisite for avoiding the econometric process of a misspecified model and the misinterpretation of the potential effects between the investigated parameters of interest. The present paper employs the Dumitrescu–Hurlin (2012) [56] causality test, which is widely accepted in the academic community as a fairly reliable test that is commonly applied in the research field of economics and energy. Table 5 exclusively portrays the statistically significant causal connections concerning the five parameters included in the data sample with the implementation of a 2-period lag. The outcomes in Table 5 reveal two bidirectional relationships, one among RES and generation concentration and another among generation concentration and energy taxes. These findings suggest that investments in renewable electricity and energy taxes can affect the competition level of power production. Furthermore, there is a unidirectional causal effect running from electricity price towards RES and total retailers, meaning that electricity prices can trigger RES deployment as well as the entry of extra electricity sellers. Finally, from the one-way effect of RES to energy taxes and from generation concentration to total retailers it can be comprehended that state policies—up to an extent—involve the taxation of green electricity production, while electricity generators can intervene in the retail market.

Table 5. Dumitrescu–Hurlin (2012) causality testing, Lag Order: 2.

Null Hypothesis (H_0)	Obs	Test-Statistic	*p*-Value
Electricity Price does not Granger cause **Renewables**	302	**2.9575**	**0.0031**
Renewables does not Granger Cause **Market_Share**	302	**2.7704**	**0.0056**
Market_Share does not Granger Cause **Renewables**	302	**3.2157**	**0.0013**

Table 5. *Cont.*

Null Hypothesis (H_0)	Obs	Test-Statistic	*p*-Value
Renewables does not Granger Cause **Energy Taxes**	302	**5.7545**	**0.0000**
Electricity Price does not Granger Cause **Total Retailers**	302	**3.4564**	**0.0005**
Market_Share does not Granger Cause **Total Retailers**	302	**2.0952**	**0.0362**
Market_Share does not Granger Cause **Energy Taxes**	302	**3.7058**	**0.0002**
Energy Taxes does not Granger Cause **Market_Share**	302	**2.1929**	**0.0283**

Note: For the estimation of Dumitrescu–Hurlin (2012) [56] causality test, the analysis used the *xtgcause* command with 2 lags of "STATA" software (version 15.0).

3.3. Model Specification and Diagnostic Tests

The Dumitrescu–Hurlin (2012) [56] test validated a variety of interconnections among the dataset's examined variables. As a result, the econometric model that will be utilized to assess the impact of electricity sector liberalization, household retail prices, and energy tax policy on RES deployment in the 17 European states is formed as follows:

Main model econometric representation:

$$\begin{aligned} Renewables = \; & \beta_0 + \beta_1 Electricity\ Price_{i,t} + \beta_2 Market\_Share\_Largest\_Generator_{i,t} \\ & + \beta_3 Total\_Retailers_{i,t} + \beta_4 Energy\ Tax_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

The existence of a strong statistical connection between the component variables is an important first step for correct model specification. Nevertheless, to ensure the robustness and reliability of the model's econometric analysis through the selected panel methodological procedures, it necessitates a series of statistical diagnostic checks. The confirmation of cross-sectional dependence in the error term ($\varepsilon_{i,t}$) might be responsible for poor estimation of both the variables' coefficients and standard errors, which may in turn result in misleading final outcomes and unsound generalizations, in case the proper regression estimator is not applied. Tables 6 and 7 report the findings for time-series and panel cross-sectional dependence, respectively. Apparently, the null hypotheses (H_0) for both time-series and panel cross-sectional independence are emphatically rejected by all implemented tests, suggesting that the examined countries act under a central, longstanding EU energy strategy and that any shocks related to the deregulation of the electricity market, retail prices, and tax policy are spread from one or more countries to all the rest. The size and persistence of this effect may differ from one country to another and might be subject to regional and local characteristics.

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

Variable	Pesaran (2004) CD_{test}	Correlation	Absolute Correlation	Pesaran (2015) Weak CD_{test}
Renewables	30.39 *** (0.0000)	0.614	0.714	46.638 *** (0.0000)
Electricity Price	24.72 *** (0.0000)	0.500	0.541	48.930 *** (0.0000)
Market_Share Largest Generator	21.25 *** (0.0000)	0.429	0.493	48.452 *** (0.0000)
Total Electricity Retailers	9.96 *** (0.0000)	0.201	0.454	45.098 *** (0.0000)
Energy Taxes	5.65 *** (0.0000)	0.114	0.448	48.801 *** (0.0000)

Note: *** Denotes significance at 1%. Numbers in parentheses show the test corresponding *p*-values. The null hypothesis (H_0) of Pesaran (2004) [57] CD test assumes strict cross-sectional independence. The null hypothesis (H_0) of Pesaran (2015) [58] CD test assumes weak cross-sectional independence. For the Pesaran (2004) CD [57] and Pesaran (2015) [56] CD tests, the *xtcd* and the *xtcd2* commands of "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.

Table 7. Cross-section dependence among groups.

Pesaran's test of cross-sectional independence	1.848 *	
	(0.064)	
Friedman's test of cross-sectional independence	26.684 **	
	(0.045)	
Frees' test of cross sectional independence	3.201	
Critical values from Frees' Q distribution:	**Alpha** = 0.10	0.1438
	Alpha = 0.05	0.1888
	Alpha = 0.01	0.2763

** Denotes significance at 5% and * at 10% level, respectively. Numbers in parentheses show the test corresponding *p*-values. For the Pesaran, Friedman [59], and Frees [60,61], group cross-sectional dependence tests, the *xtcsd pesaran abs*, *friedman xtcsd*, and *frees xtcsd* post commands after *xtreg* POLS regression in "STATA" software were utilized.

The appropriate implementation of panel FMOLS approach presupposes co-integrated variables, as well as the elimination of the possibility of potential existence of unit roots in the processed data sample. With respect to the dataset's stationarity, the analysis makes use of the traditional LLC test [62], which manages to generate fairly consistent results when applied to panel data with a long time-series, along with the ADF–Fisher test [63–67] with relaxed conditions relative to the allowed lag length across units. In addition, the analysis further utilizes the CIPS stationarity test developed by Pesaran (2007) [68], a second generation panel unit-root test able to avoid the restriction of the first two tests by relying on a standard type of distribution to produce the corresponding P-values, which is proved in the literature to outperform all other unit-root tests in the presence of cross-sectional dependence. Similarly, the validation of co-integration hypothesis is examined by Pedroni (1999) [65] and Pedroni (2004) [66] tests, as well as the second generation Westerlund (2005) [67] co-integration test. The latter is based on an error-correction pattern, allowing it to remain robust regardless of the potential existence of cross-sectional dependence. Table 8, Table 9 andTable 10 summarize the outcomes of the statistical tests by examining the previously discussed econometric parameters. In Table 8, it is shown that the unit root null hypothesis (Ho) is rejected at first difference by all three tests at 1% statistical significance, including both intercept and trend options. This outcome signifies that the dataset's components are integrated and are stationary at order one I(1). Tables 9 and 10 highlight the rejection of non-co-integration null hypothesis (H_0) by all three tests at 1% and 5% significance levels respectively.

Finalizing the necessary statistical diagnostic procedure, which aims to select appropriate and more robust panel econometric techniques and estimators, includes checking the investigated dataset for the presence of heteroskedasticity and serial correlation. Table 11 portrays the results of a variety of widely acceptable heteroskedasticity tests, together with the Breusch–Godfrey/Wooldridge (2010) [68] test for serial correlation. From the table, it is made clear that within the processed data sample both statistical phenomena are present, while Table A1 verifies the absence of multicollinearity in the data.

Table 8. Unit root tests.

	Level						First-Difference					
	Intercept			Intercept and Trend			Intercept			Intercept and Trend		
Variable	**ADF–Fisher**	**LLC**	**CIPS**	**ADF–Fisher**	**LLC**	**CIPS**	**ADF–Fisher**	**LLC**	**CIPS**	**ADF–Fisher**	**LLC**	**CIPS**
Renewables	13.183 (0.999)	−4.597 (1.000)	−2.772 ***	31.464 (0.592)	0.324 (0.627)	−3.082 ***	130.289 *** (0.000)	−6.487 *** (0.000)	−4.020 ***	113.655 *** (0.000)	−3.716 *** (0.000)	−4.065 ***
Electricity Price	39.598 (0.234)	−5.985 *** (0.000)	−2.518 ***	27.450 (0.779)	−0.941 (0.173)	−2.451	65.527 *** (0.000)	−5.624 *** (0.000)	−3.816 ***	64.129 *** (0.001)	−3.194 *** (0.000)	−3.922 ***
Market_Share Largest Generator	36.508 (0.352)	−0.960 (0.168)	2.886 ***	44.473 (0.107)	−4.413 *** (0.000)	−3.034 ***	166.756 *** (0.000)	−9.122 *** (0.000)	−4.339 ***	122.529 *** (0.000)	−6.802 *** (0.000)	−4.341 ***
Total Electricity Retailers	35.046 (0.177)	−0.141 (0.443)	−2.200 *	28.311 (0.742)	0.286 (0.612)	−3.104 ***	99.104 *** (0.000)	−14.269 *** (0.000)	−4.344 ***	33.107 *** (0.511)	−5.165 *** (0.000)	−4.459 ***
Energy Taxes	32.620 (0.535)	1.948 (0.974)	−2.074	30.402 (0.992)	1.07 0 (0.857)	−2.629 *	109.784 *** (0.000)	−5.924 *** (0.000)	−3.751 ***	66.435 *** (0.000)	−5.949 *** (0.000)	−3.838 ***

Note: *** Denotes significance at 1% and * at 10% level. Numbers in parentheses show the test's corresponding P-values. The null hypotheses (H_0) of the tests assume non-stationary variables. For the ADF–Fisher, LLC, and CIPS Refs. [62–64] unit root tests, the *xtunitroot* and *xtcips* commands of "STATA" software were utilized. Critical values for the CIPS test of Pesaran (2007) [68] are −2.1 (10%), −2.21 (5%), and −2.4 (1%) for constant, and −2.63 (10%), −2.73 (5%), and −2.92 (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.

Table 9. Pedroni's (1999, 2004) panel co-integration tests.

Pedroni (2001)	**Panel v-Statistic**	**Panel ho-Statistic**	**Panel t-Statistic**	**Panel ADF-Statistic**	**Group rho-Statistic**	**Group t-Statistic**	**Group ADF-Statistic**
Test-Statistics	−1.33	1.803	−8.002	2.603	3.39	−8.525	3.823
Pedroni (2004)						**Statistic**	***p*-value**
Modified Phillips-Perron-t						3.7523	0.0001
Phillips-Perron-t						−8.9462	0.0000
Augmented Dickey-Fuller-t						−21.2287	0.0000

Note: For the Pedroni (1999, 2001) [65,66] panel co-integreation test, the *xtpedroni* command of "STATA" software was utilized with *trend* option. 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. The null hypothesis (H_0) of the test assumes no co-integration in the examined models while the alternative hypothesis (Ha) assumes that all panels are co-integrated. All test statistics are distributed N(0,1) and diverge to negative infinity except for panel v, in which the test statistic diverges to positive infinity. The null hypothesis (H_0) assumes no co-integration of the models' variables. The probability upon which it is decided whether to reject or accept the H_0 is estimated based on the z-score of the values of the test stastistics. Additionally, for the Pedroni (1999, 2004) Refs. [63,64] panel co-integreation 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), and all other bandwidth orders are set according to the rule $4(T/100)2/9 \approx 3$. The null hypothesis (Ho) of the test assumes no co-integration in the examined models while the alternative hypothesis (Ha) assumes that all panels are co-integrated. The null hypothesis (H_0) of the test assumes no co-integration in the examined models while the alternative hypothesis (Ha) assumes that all panels are co-integrated. *Demean option: Stata computes the mean of the series across panels and subtracts this mean from the series. Ref. [62] suggests this procedure to mitigate the impact of cross-sectional dependence.

Table 10. Westerlund panel co-integration test.

	Statistic	***p*-Value**
Variance ratio	−1.9407	0.0262

Note: The null hypothesis (H_0) of the Westerlund (2005) [65] panel co-integration test assumes no co-integration, while the alternative hypothesis (H_1) assumes co-integration in all panels. The Westerlund (2005) [67] tests were estimated by using the xtcointtest westerlund command of "STATA" software, including the *trend* and *demean** options. *Demean option: Stata computes the mean of the series across panels and subtracts this mean from the series. Ref. [62] suggests this procedure to mitigate the impact of cross-sectional dependence.

Table 11. Heteroskedasticity and serial correlation tests.

	Statistic	***p*-Value**
Breusch–Pagan Heteroskedasticity test	45.94	0.0000
Glejser Heteroskedasticity test	28.04	0.0000
Harvey Heteroskedasticity test	10.07	0.0000
White Heteroskedasticity test	12.06	0.0000
Breusch–Godfrey/Wooldridge Serial Correlation test	113.98	0.0000

Note: The null hypothesis (H_0) of the Breusch–Pagan (1979) [69], Glejser (1969) [70], Harvey (1976) [71] and White (1980) [72] tests assume no heteroskedasticity in the models. Similarly, the null hypothesis (H_0) of the Breusch–Godfrey/Wooldridge (2010) [68] test assumes no serial correlation, (pbgtest {plm} from "R" software, version 4.3.1).

4. Empirical Analysis and Results

The recent studies from Refs. [27–30] unveiled the different rhythm that European nations seem to adopt in promoting RES deployment strategies due to structural differences in energy taxation and in the deregulation process of power generation and retail markets. In harmony with the findings and recommendations of the aforementioned papers, the present research attempts to shine a spotlight on individual electricity markets and country-specific characteristics that may affect the transition of certain EU countries to renewable electricity. For this purpose, the analysis incorporates the FMOLS econometric methodology, which enables the generation of endogeneity and serial-correlation robust error-terms (even though no instrumental or synthetic variable has been utilized), as well as separate regression coefficients for each panel of the 17 examined countries. These essential merits have been praised by a series of academic papers. The FMOLS model is recommended by Refs. [73–75] as a fairly suitable and appropriate model for processing extended economic, energy, and RES panel datasets. The FMOLS approach was preferred from other panel methodologies, such as difference and system GMM, since the relative econometric literature, among which Refs. [76,77], proposes that when the number of time-series (T) in the panel is larger than the number of total panels (N) (i.e., T > N), then FMOLS and PDOLS methodologies provide more accurate and consistent estimates. The FMOLS estimator was initially developed by [78] with the goal of overcoming the inconsistencies stemming from the long-run correlation between the co-integrating equation and the stochastic regressor innovations. The typical FMOLS estimator, which was originally intended for time-series econometric processing, was further modified into the widely applied pooled FMOLS by Refs. [79,80].

Table 12 contains the final outcomes of the panel regression analysis that was conducted with the use of the FMOLS model and was suitably adjusted for the aims and scope of this study. Interestingly, the findings for the individual country panels fully verify the conclusions of all previous studies referring to the exhibited disparities concerning the sustainable development of the energy sector, even between countries belonging to the same region and actively participate in international country coalitions, such as the EU. Household electricity prices proved to be a highly statistically significant parameter of RES contribution in the production scheme for 14 out of the 17 countries, with the vast majority of the panels revealing a slightly negative effect of the variable—except for the cases of Greece, France, and Hungary. In all other countries, for every 1% increase in retail prices, there has been a recorded negative impact on renewable electricity production, varying from −0.02% in Italy and Spain to −0.53% in Croatia and −1.1% in Lithuania ceteris paribus. Similarly, lack of competition and monopolistic or oligopolistic conditions in power generation constitutes a detrimental factor for the transition to eco-friendly electricity in 13 countries. A potential increase in the percentage market share of the largest power company by 1% can approximately negatively affect RES contribution by −0.59% in Spain, −0.82% in Germany, and -0.94% in Latvia—when holding constant all other explanatory parameters. Surprisingly, such an increase in Norway, Sweden, Italy, and Croatia seems to benefit renewable electricity production, implying that the stakeholder's power production activity in these countries is mainly supported by zero-carbon emitting technologies. In contrast with generation concentration, an increase in the number of total electricity retail sellers triggers a rather complicated effect to the overall contribution of RES into the various energy systems' fuel mixes. Specifically, for 9 of the countries, the entry of 1% additional electricity providers boosts RES development, with that influence varying from nearly 0.05% for Czech Republic and France up to 2.17% for Croatia. For 5 of the countries, increasing the number of total electricity retail companies causes the exact opposite effect; particularly in Slovenia an increase of 1% reduces the proportion of renewable electricity by 0.66%. For Norway, Sweden, and Poland, this parameter is found to be statistically insignificant. Finally, in 9 countries the intensification of the imposed energy taxes led to the development of an upward trend in RES installation projects. It is noteworthy that for 6 of these countries, a 1% growth of domestic energy taxation increases RES share in total electricity generation multiple times. Indicatively, this increase reaches roughly 4.72% in Croatia, 6.78% in Spain, and 7.39% in Sweden. The opposite, however, seems to apply for France, Germany, and Greece, while for Belgium, Poland, and Latvia, where energy taxes compose a statically insignificant factor.

Table 12. Panel FMOLS coefficients for the 17 European markets for the period of 2003–2020.

	Panel FMOLS			
Country	**Electricity Price**	**Market_Share Largest Generator**	**Total Electricity Retailers**	**Energy Taxes**
Belgium	0.000 (0.05)	−0.210 *** (−14.65)	0.080 *** (9.09)	−0.370 (−0.71)
Croatia	−0.53 *** (−21.71)	1.77 *** (49.25)	2.170 *** (26.75)	4.720 *** (21.53)
Czech Republic	−0.000 (−0.67)	−0.080 *** (−2.36)	0.040 *** (11.64)	0.51 * (1.90)
Denmark	−0.120 *** (−4.19)	−0.380 *** (−8.40)	0.150 *** (5.36)	3.12 *** (3.75)
Finland	−0.060 *** (−9.88)	−0.10 *** (−6.05)	−0.160 *** (−21.70)	2.70 *** (24.44)
France	0.070 ** (2.55)	−0.48 *** (−8.27)	0.050 *** (2.97)	−1.21 *** (−2.59)
Germany	−0.080 *** (−5.96)	−0.820 *** (−19.34)	0.010 *** (6.89)	−3.69 *** (−6.99)
Greece	0.110 ** (2.38)	−0.280 *** (−6.40)	0.300 *** (4.15)	−0.930 *** (−3.56)
Hungary	0.010 * (2.47)	−0.010 (−1.45)	−0.060 *** (−10.14)	0.900 *** (7.16)
Italy	−0.02 *** (−3.57)	1.120 *** (73.19)	−0.030 *** (−67.15)	3.400 *** (50.96)
Latvia	−0.39 *** (−5.29)	−0.94 ** (−2.56)	0.270 * (1.92)	−0.120 (−0.20)
Lithuania	−1.100 *** (−25.01)	−0.620 *** (−13.17)	0.410 *** (4.01)	2.370 ** (2.34)
Norway	−0.040 *** (−10.76)	0.440 *** (16.81)	−0.000 (−1.25)	0.760 *** (3.32)
Poland	0.010 (1.37)	−0.110 ** (−2.26)	−0.000 (−0.21)	−0.510 (−1.40)
Slovenia	−0.080 *** (−4.43)	−0.060 *** (−5.74)	−0.660 *** (−16.54)	0.980 *** (8.38)
Spain	−0.020 *** (−9.46)	−0.590 *** (−35.59)	−0.020 *** (−31.71)	6.780 *** (38.42)
Sweden	−0.140 *** (−10.71)	0.59 *** (4.87)	−0.020 (−1.37)	7.390 *** (7.18)

Note: ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively. For the estimation of panel FMOLS, the *xtcointreg* command of "STATA" software was utilized along with suitable options for *kernel*, *bmeth*, *eqtrend*, *xtrend*, and *stage*.

5. Discussion and Policy Implications

By applying a sophisticated panel econometric approach, the research revealed the complex interactions and underlying causality relationships between RES deployment and electricity retail market, power generation, and energy taxation in Europe. The econometric analysis highlighted the unique characteristics of each country's energy sector as well as the individual effects of the four explanatory variables on RES share electricity production. Focusing on the impact of retail electricity charges, in 11 out of 17 countries price increases constituted a detrimental driver of new RES investment plans. Investors are expecting household consumers to negatively react in potential rises of electricity bills by reducing their annual consumption in the near future, leading to lower marginal revenues and profits for electricity generation companies. As a result, it would be wise for public administrators in these countries to incorporate into their national energy strategy a flexible feed-in tariff policy supporting RES producers whenever electricity consumption falls below a certain level. A similar feed-in tariff policy is also suggested for Greece, France, and Hungary, with a price subsidy clause being activated whenever electricity prices drop and cross the point which green electricity production units are profitable and viable long term investment.

Furthermore, the degree of liberalization in power production reflected by generation concentration proved to be a considerably adverse determinant of RES development for 14 of the countries, indicating that the lack of competition between generators makes them more reluctant to replace conventional fossil fuel plants with RES electricity production units. Hence, regulators in these countries should build an energy strategy based on two main pillars. The first pillar, in collaboration with the EC, is advisable to involve subsidies that target the amortization of RES installation costs concerning the initial investment. In this way, according to [24], potential private investors will enjoy higher total revenues, incentivizing them to prioritize RES investment plans in their portfolios. Such subsidy policies are capable according to [81] of guaranteeing an extensive generation contribution by clean electricity technologies, regardless the degree of market deregulation. In addition to the possible financial aid in the form of European and state subsidies, central governments are advised to further enable the funding of RES projects by relaxing the credit conditions set by banks and other financial institutions in order for private investors to gain access to affordable loans. Nevertheless, Ref. [82] alleges that such funding policies necessitate the complete reform of the current financial sector so that credit availability regarding carbon-free generation units is hierarchized at the top of loan request lists. Clean energy funds are reported by [54] to have increased market penetration for all types of alternative energy production. On the other hand, the second pillar is proposed to include the reduction of market concentration of publicly owned generation companies through gradual privatizations. With regard to the countries where generation concentration composes an encouraging driving force of RES deployment, the dominant power generation stakeholder, which is most probably a public utility company, seems to have already invested vast amounts of capital in RES in the previous years. Among others, an essential benefit of RES, based on Refs. [83,84], lies in their ability to enhance a country's energy self-sufficiency. Hence, these generation companies most likely follow the central government's inducements for a more eco-friendly strategic energy planning, so that it complies with the EC's initiatives about certain climate change goals and future prospects for accomplishing energy autonomy.

With respect to the influence of the number of electricity retailers, the mixed econometric outcomes dictate governmental authorities in countries where a higher number of providers enhance RES deployment to proceed on the establishment of a liberalized legal framework which will effectively remove any entry barriers to the retail market. Conversely, for a group of countries including Italy, Spain, Finland, Hungary, and Slovenia, in which constantly increasing the total number of electricity sellers triggers an unfavorable effect on clean electricity production, certain control measures of the retail market should be implemented.

Lastly, the outcomes for energy taxes show a controversial impact of this factor on the development of an eco-friendly energy system, which depends on the different countries' power sector characteristics. Energy taxes appear to considerably increase RES electricity production in 7 out of the 17 countries, particularly Spain, Sweden, Italy, and Croatia, while it shows an analogous but more moderate effect in another 3 countries. Apparently, the imposed energy taxes in these countries either solely concern fossil fuel energy conversion or the ratio between them and RES taxes is comparatively well uneven. Therefore, central governments are recommended to follow a dual strategy involving the continuation of the current tax policy narrowing fossil fuel electricity, while further increase energy tax rates to narrow fossil fuel electricity production and accumulate essential capital for financing new RES projects. Conversely, it would be wise for Germany, France, and Greece to relax energy taxation and proceed to incorporate tax reductions of RES electricity production as soon as the figures in their national budgets allows for it.

6. Conclusions

Replacing conventional CO_2 intensive electricity generation with green energy from RES constitutes an essential prerequisite of sustainable development. In order to cope with the challenges of the EU's newly established REPowerEU plan, as well as to fulfill the provisional commitments relative to the UN's SDG 7 and 13referring to clean low-cost energy production and tackling climate change, European governments need to shed light on the fundamental determinants driving RES deployment. The present research, utilizing a panel FMOLS econometric methodology, provides a detailed analysis of the impact of electricity prices, energy taxes, and the competition level in both power generation and the retail market respectively, in each of the 17 European countries included in the processed data sample. The different outcomes from country to country signify the complexity of effectively implementing a common European energy strategy that is obligatory for all EU member states. The main problem behind this compound task lies in the multiple conflicts of interest due to the different socioeconomic characteristics of each country, hence a series of groupwise policy implications are proposed with respect to the four explanatory variables. Considering the causal interactions between RES and generation concentration, as well as the outcomes of the FMOLS model, policymakers are advised to rapidly respond to the dynamic effect of the examined parameters. Green electricity production might have a broader impact that can spread to other activity sectors such as transport, considering the explosive growth in electric vehicles which constantly gain higher market shares. In addition, both individual states and the EU are recommended to fund acts and an extensive pro-environmental campaign that will mobilize European public opinion to actively participate in the promotion of clean electricity consumption, even when this requires putting aside personal interest and supporting RES producers at the expense of a price premium. In economically developed and sophisticated societies [85,86] observed that consumers show a condensed willingness to pay for even slightly more expensive RES-generated electricity. Reversing this quite worrying phenomenon requires a modern education policy emphasizing on environmental awareness and ecological training of its citizens, such that to embrace post-materialistic values and choose the wellbeing and the innumerable benefits of a healthy natural environment over personal wealth. Finally, dealing with the main limitation of the study, at a future time it would be wise for the dynamic aspect of the dataset to be taken into account by additionally employing the PDOLS methodology and examine whether the latter confirms the current study's results. Likewise, as a further extension of the current paper and prospect for future research, it would be rather interesting to scrutinize if splitting the same dataset into groups based on each country's energy import dependency, as advocated by Refs. [28,30], would cause alterations in the identified relationships as well as their size effect.

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Abbreviations

RES	Renewable Energy Sources
EU	European Union
EC	European Commission
GDP	Gross Domestic Products
MWh	Mega Watt hour
UN	United Nations
SDG	Sustainable Development Goal

Appendix A

Table A1. Variance Inflation Factor Test.

Variable	VIF	1/VIF
Electricity Price	1.25	0.7974
Market_Share Largest Generator	1.21	0.8240
Total Electricity Retailers	1.28	0.7812
Energy Taxes	1.09	0.9162

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

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