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Energy Poverty and Democratic Values: A European Perspective

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Abstract: This paper explores the complex relationship between energy poverty and the maintenance of democratic values within the European Union (EU), suggesting that energy poverty not only impacts economic stability and health outcomes but also poses significant challenges to democratic engagement and equity. To measure energy poverty, a composite index is developed using the entropy method, which surpasses traditional measures focused solely on access to energy or its developmental implications. To assess the level of democratic governance in EU countries, the voice and accountability index (VEA), which is part of the World Governance Indicators compiled by the World Bank, is utilized. By analyzing EU data from 2006 to 2022, the findings suggest that a 1% improvement in VEA quality, represented by a coefficient of 0.122, is correlated with a notable improvement in the energy poverty index. This suggests that the EU should focus on enhancing transparency and public participation in energy decision-making, along with ensuring accountability in policy implementation. The research also differentiates between full and flawed democracies, noting that tailored approaches are needed. In full democracies, leveraging economic prosperity and trade is crucial due to their significant positive impacts on the energy poverty index. In contrast, in flawed democracies, enhancing governance and accountability is more impactful, as evidenced by a higher coefficient of 0.193. Strengthening legal and regulatory frameworks, improving regulatory quality, and ensuring public engagement in governance could substantially mitigate energy poverty in these contexts. In addition, this paper demonstrates that this relationship is influenced by factors such as income inequality, energy intensity, and trade openness.

Keywords: sustainable development; energy efficiency; energy price; democracy; energy poverty; European Union (EU)

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1. Introduction

The attainment of sustainable development goals (SDGs) necessitates a reduction in energy poverty, a condition that severely hampers economic and social development, particularly in underdeveloped regions. At the same time, it is crucial to analyze the complex relationship between energy poverty and democratic processes to ensure that sustainable development benefits are equitably distributed. This analysis is critical because democratic institutions sometimes fail to effectively address energy poverty, thereby exacerbating social inequalities and undermining the ideals of equity and inclusivity. Within the European Union (EU), the dynamics between energy poverty and democracy are shaped by the region's commitment to sustainable development and economic integration. The EU's energy policy framework, particularly the 'Clean Energy for All Europeans' package, aims to provide all citizens with affordable, reliable, and renewable energy while minimizing carbon emissions in alignment with SDG 13 (Climate Action) [1–6]. This policy initiative exemplifies how regulatory standards can promote the adoption of green technologies and sustainable practices. Moreover, the EU's European Green Deal aims to make Europe the first climate-neutral continent by 2050, closely aligning with SDG 7 (Affordable and

Clean Energy). The transition to renewable energy sources is integral to this goal and has significant implications for reducing energy poverty and combating climate change [7–11]. The success of these initiatives depends heavily on the democratic processes within member states, emphasizing the need for inclusive and participatory governance approaches.

Research on the marketing activities of electricity suppliers indicates that public perceptions shaped by marketing can significantly influence democratic engagement and policy support [12]. Additionally, studies on digital transformation and green branding show that technological advancements and sustainability initiatives can enhance a country's environmental, social, and governance performance, thereby reducing energy poverty and bolstering democratic values [13,14]. The implementation of blockchain in energy management suggests that decentralized and transparent energy transactions can democratize energy access and ensure equitable distribution [15–17]. These insights underscore the necessity of integrating technological innovation, public policy, and corporate responsibility to address energy poverty effectively and promote democratic engagement across Europe. Research [18–21] confirms that public governance, smart infrastructure, and stakeholder engagement are connected to energy efficiency and technology adoption. Studies [18,19] emphasize the role of innovative governance and smart infrastructure management in reducing energy poverty and enhancing democratic engagement through equitable energy solutions and socioeconomic improvements. Furthermore, work by Dacko-Pikiewicz [20], Szczepańska-Woszczyna, and Gatnar [21] underscores the importance of stakeholder-focused strategies and skilled project management in promoting sustainable practices and supporting democratic values by fostering transparency and inclusivity. The necessity of exploring the link between energy poverty and democracy underscores the importance of re-evaluating and possibly reforming democratic institutions to make them more responsive to the challenges of sustainable development. This requires innovative, inclusive, and deliberative democratic processes finely tuned to local vulnerabilities. By fostering a democratic environment that prioritizes participatory policy-making and ensures that no citizen is left behind, the EU could better address the multifaceted challenges of energy poverty and move toward a more sustainable and equitable future.

Energy poverty is a significant issue in the European Union (EU) due to its severe impact on public health, economic disparity, and energy inefficiency. Inadequate heating and cooling in homes can lead to increased mortality and exacerbate health issues, particularly affecting vulnerable groups such as elderly people and children, with cold homes linked to an increased risk of cardiovascular and respiratory diseases [22]. Economic disparities are further highlighted, as lower-income households spend a disproportionate amount of their income on energy costs, particularly in Eastern and Southern European regions where many homes remain energy inefficient. Policy fluctuations and market dynamics also impact energy affordability and availability, while climate change increases demand for energy, intensifying challenges for those already in precarious situations. Studies show that democratic governance can influence the management and mitigation of energy poverty, with policies that promote transparency, public participation, and accountability tending to align better with the needs of vulnerable populations [23]. The EU has recognized the importance of addressing energy poverty, incorporating measures to enhance energy efficiency, promote renewable energy, and support vulnerable populations as part of its broader goals for social equity and sustainable development. These efforts are part of the EU's commitment to ensuring that all citizens have access to affordable, reliable, and sustainable energy sources, demonstrating how democratic principles can directly influence policy effectiveness in this critical area.

This paper aims to analyze the relationship between energy poverty and the sustenance of democratic values within the European context. The contributions of this investigation are multifaceted and significantly enhance the current understanding of energy policies within various democratic contexts. First, it fills a notable gap in the literature by systematically differentiating between full and flawed democracies within the EU, tailoring energy policy recommendations to these distinct governance frameworks. This approach not only refines theoretical models but also provides targeted, practical strategies for energy poverty alleviation. Second, by integrating advanced econometric methods such as panel-corrected standard errors (PCSEs), feasible generalized least squares (FGLS), and two-stage instrumental variables (2SIV) for instrumental variable estimation, this study underscores the complex interdependencies between governance quality, technological advancements, and energy poverty outcomes, thereby illuminating the critical role of governance in facilitating energy efficiency and sustainability. Third, the investigation enriches the discourse on the interplay between democratic governance and technological deployment in energy policies, offering a comprehensive view of how these dynamics can be harmonized to achieve more effective energy poverty mitigation. Finally, it methodically explores both EU-wide initiatives and local projects, providing a dual perspective that bridges macrolevel policy frameworks with microlevel implementation insights.

This paper is organized into several sections aimed at exploring the intersection between energy poverty and democracy within the EU: Section 2—a literature review of the theoretical framework for energy assessments, linking between energy assessments and democracy values; Section 3—explanations of the materials and methods, data sources, and analytical tools used, providing a foundation for the empirical investigation; Section 4—the results of the empirical investigation on linking between energy assessments and democracy values; Section 5—a discussion on the implications of the findings in relation to democratic values, providing interpretative depth and context to the raw data and discussing the study's contributions to the literature, outlining the policy recommendations on how policymakers can address energy poverty through democratic processes effectively; Section 6—a summarization of the findings, and a discussion on the limitations and directions for future research.

2. Literature Review

2.1. Energy Poverty Assessment

Mohlakoana and Wolpe [24] explore energy poverty in South Africa, providing insights that highlight parallels with disparities in the Global North and South and offering a comparative understanding of these issues' universal and regional dimensions. Acheampong et al. [25] outline the dynamics of energy inclusiveness with a focus on rural energy poverty, questioning whether it can be attributed to political failures. Their analysis suggests that discrepancies in energy access are significantly influenced by institutional inefficiencies and a lack of robust governance structures. Improving political accountability and enhancing democratic engagement in rural areas are crucial for mitigating energy poverty and promoting equitable energy distribution. Arango et al. [26] explore various economic, regulatory, and public policy dimensions affecting energy management. They comprehensively review the regulatory landscape and public policies across different governance models, illustrating how democratic processes influence energy sector regulations and the broader implications for addressing energy poverty. This synthesis is instrumental in delineating how policy frameworks could be aligned with democratic ideals to enhance energy access and ensure equitable energy distribution. Aukes and Clancy [27] explore sociotechnical energy systems, emphasizing disparities in accessibility that reflect broader social inequalities due to technical biases. They underscore the need for inclusive policies. Barroco Fontes Cunha et al. [28] illustrate that community-led energy projects in Brazil and Italy not only mitigate carbon footprints but also enhance democratic engagement by fostering energy citizenship. Similarly, Campos and Marín-González [29] highlight the importance of grassroots movements and prosumerism in Europe, which empower communities and strengthen democratic values through active participation in energy policy shaping. Mohlakoana and Wolpe [24] outline the complexities of energy poverty in South Africa, emphasizing the interconnection between economic and social challenges and the need for integrated policy solutions. Ongo et al. [30] explore the paradox of natural resource richness versus widespread energy poverty in Sub-Saharan Africa, attributing these disparities to governance failures and systemic inefficiencies. Tadadjeu et al. [31] argue that enhancing women's political participation could significantly impact energy poverty mitigation, underlining the importance of democratic inclusivity. Wolpe and Reddy [32] analyze urban energy poverty in South Africa and the effectiveness of current policies, proposing innovative, context-specific responses.

2.2. Linking between Energy Poverty and Democracy Values

Jiglau [33] analyzes energy poverty in post-communist countries as a significant threat to democracy, urging policy interventions to stabilize democratic institutions and social structures. In contrast, Ongo et al. [30] highlight the paradox in Sub-Saharan Africa, where natural resource wealth coexists with rampant energy poverty due to governance failures, a scenario reminiscent of challenges in Eastern Europe. Rafey and Sovacool [34] provide a critical analysis of South Africa's Medupi coal-fired power plant, examining the sociopolitical and environmental implications of large-scale energy projects. Schiffer [35] advocates overcoming energy scarcity through 'collective capabilities' and power sharing, suggesting that collaborative energy management can enhance democratic engagement and reduce energy disparities. Osička et al. [36] critically analyze energy justice and energy democracy to determine whether these concepts are merely buzzwords or represent distinct, potentially conflicting frameworks. They emphasize the integration of democratic ideals in energy policies for fair and inclusive distribution. Tadadjeu et al. [31] examine how women's political participation in sub-Saharan Africa impacts energy poverty, suggesting that increased female political involvement can significantly improve energy poverty alleviation strategies through various effective channels. Nordholm and Sareen [37] delve into the concept of scalar containment in energy justice, exploring how solar power initiatives can alleviate energy poverty while also highlighting the democratic discontents that arise when energy justice is contained within certain administrative scales. This research points to the importance of scaling energy solutions to fit local contexts while maintaining broad democratic engagement. Wolpe and Reddy [32] focus on urban energy poverty in South Africa and discuss the effectiveness of the country's policy responses. Kanellou et al. [38] explore the enhancement of energy democracy and the alleviation of energy poverty through the promotion of renewable energy in Greece. Their study highlights the socioeconomic benefits and democratization of energy resources, providing a case study on the effective integration of renewable technologies to combat energy disparities.

Kumar et al. [39] address the dilemmas faced during energy transitions in the Global South, particularly by balancing the urgency of energy needs with the principles of justice. This analysis offers insights into the complexities of implementing equitable energy solutions that are both urgent and relevant to European nations grappling with similar transition challenges. Shyu [40] proposes a 'right to energy' framework, aimed at meeting the United Nations Sustainable Development Goal 7, which calls for universal access to affordable, reliable, and modern energy services. This framework underlines the necessity of eradicating energy poverty and enhancing energy justice, thereby reinforcing energy democracy through inclusive policy implications. Zhang et al. [41] investigate the relationships among energy access, democratic governance, and their collective impact on alleviating energy poverty within the context of sustainable development in South Asia. This research utilizes econometric analyses to explore how the expansion of renewable energy solutions and the practice of deliberative democracy can address energy poverty while also considering the roles of globalization and demographic changes. It concludes that enhancing democratic engagement and renewable energy infrastructure is crucial to effectively reducing energy poverty and achieving sustainable development goals in the region. Moskalenko et al. [42] investigate how economic, social, and governance dimensions interact to affect a country's investment attractiveness and, consequently, its energy sector, emphasizing the link between governance quality and sustainable energy initiatives. Similarly, the analysis of green finance's spillover effects on sustainable development demonstrates how green finance can promote sustainable energy solutions essential for reducing energy poverty and enhancing democratic engagement across regions. The scholar in [43,44] highlights the nonlinear impacts of digital technology on CO_2 emission reduction, illustrating the complex interplay between technological advancements and environmental outcomes that influence public policy and democratic processes. Lesniak et al. [45] discuss advancements in high-efficiency cogeneration units in Poland, enhancing energy efficiency and supporting sustainable economic development and social equity by improving the affordability and reliability of energy access. Tkachenko et al. [46] emphasize the importance of strategic planning in construction to incorporate energy-saving measures that can significantly mitigate energy poverty and promote democratic values by ensuring inclusivity and sustainability. Studies [47–51] show that a higher GDP per capita generally indicates a wealthier economy, with fewer individuals likely to face energy poverty as better infrastructure, including more reliable and affordable energy access, often correlates with greater economic output. However, GDP growth alone does not automatically alleviate energy poverty if wealth distribution remains skewed. Energy intensity, which measures energy consumption per unit of GDP, signifies that lower values often indicate a more energy-efficient economy, contributing to economic sustainability and resilience, crucial elements in the fight against energy poverty. Studies [52–59] show that trade openness mitigates energy poverty by lowering energy import costs and facilitating the adoption of advanced energy technologies, though the benefits hinge on fair trade practices and internal policy frameworks. Democratic governance structures promote policies that effectively combat energy poverty due to their transparency and accountability. Politically active citizens in democratic regimes are better positioned to influence energy policies toward equitable outcomes [60–62]. Furthermore, the Gini index, a measure of income inequality, often highlights the challenges of addressing energy poverty in environments where wealth is unevenly distributed. Democracy enhances policy targeting by mobilizing civil society and focusing government attention on vulnerable populations [63–66]. Thus, the synergistic effects of democracy, economic growth, and social equity lead to the mitigation of energy poverty. Scholars [67,68] note that nations with a high GDP but significant income disparities may find that these disparities undermine efforts to combat energy poverty unless targeted policies ensure energy affordability and accessibility for all societal segments. The relationship between trade openness and energy intensity underscores that without adequate energy efficiency measures, the potential benefits of increased trade might not substantially alleviate energy poverty. Previous studies [69–71] outline the links between public health efficiency, regional performance, economic stability, and broader societal conditions, including energy access. These studies highlight how robust health systems, equitable regional development, and adaptive economic strategies during crises such as pandemics are essential for mitigating energy poverty and reinforcing democratic values through improved social cohesion and participatory governance. Analyzing the impact of democracy on energy poverty allows us to reveal how institutional inefficiencies influence energy access, highlighting the need for improved political accountability and democratic engagement. Furthermore, understanding the interplay between democratic processes and energy sector regulations is essential for aligning policy frameworks with democratic ideals, ultimately enhancing energy access and ensuring equitable distribution.

3. Materials and Methods

3.1. Research Method

To investigate the impact of democratic values on energy poverty in the initial stage, pairwise correlations were utilized to examine primary associations between variables across EU countries. To assess multicollinearity, the variance inflation factor (VIF) was utilized [72], ensuring that the variables included in further analyses did not exhibit excessive multicollinearity, which could bias the regression estimates. Considering the panel structure of the dataset from 2006 to 2022, a series of panel unit root tests were implemented, including Levin–Lin–Chu, Breitung, Hadri LM, Im–Pesaran–Shin, Pesaran's CADF, and CIPS tests [73,74]. These tests were pivotal in determining whether the panel data required differencing to achieve stationarity, setting the stage for accurate analysis. To address potential heterogeneity across the countries in the dataset, the heterogeneity test proposed by Pesaran and Yamagata [75] was applied. This test assessed whether the slopes across different countries were homogeneous, significantly influencing the selection of econometric models for further analysis [75]. The long-term relationships between variables were examined using Pedroni, Kao, and Westerlund cointegration tests [76–78]. These tests were crucial for evaluating whether a statistically significant equilibrium relationship persisted across time among the dependent and independent variables. The analysis proceeded with the Granger noncausality test developed by Juodis, Karavias, and Sarafidis [79] to explore causal relationships between democratic governance and energy poverty. This test helped determine whether changes in one variable could predict changes in another, providing vital insights for policy implications. Finally, the presence of cross-sectional dependence in the panel data was assessed using Pesaran's [80,81] test for weak cross-sectional dependence. This test identified any unobserved common effects that might influence the variables across different units (countries), ensuring that such dependencies were appropriately accounted for in the analysis.

With the data prepared through the steps above, as a first step, the relationship between energy poverty and democratic government was analyzed using correlated panel-corrected standard errors (PCSEs) and cross-sectional time-series FGLS regression. The use of PCSEs is particularly advantageous in panel data, where there might be issues of heteroscedasticity and autocorrelation within panels. PCSEs adjust the standard errors of the estimates, making them more robust to such issues. This adjustment is crucial in cases where traditional OLS standard errors might be biased, potentially leading to incorrect inferences. Similarly, the feasible generalized least squares (FGLS) approach was employed to handle any heteroscedasticity or autocorrelation across the panel data. By efficiently estimating the model parameters, the FGLS approach improves the accuracy of the coefficients in the presence of such complexities. This method estimates a transformation of the data that decorrelates the errors, providing more efficient and reliable parameter estimates compared to standard least squares. Given the complex nature of panel data that spans multiple time periods and entities (countries), these methods effectively addressed the inherent data structure issues. To estimate panel regressions while considering unobserved common factors, instrumental variable estimation with common factors (2SIV) was applied. This method is adept at controlling for endogeneity that might arise from omitted variable bias (where important variables are not included in the model) or simultaneity (where causation between the independent and dependent variables is bidirectional).

3.2. Data

3.2.1. Energy Poverty Assessment

The investigation centers on energy poverty, examining it as the dependent variable influenced by the level of democracy within these nations. Energy poverty is a critical issue, with implications for public health, well-being, and socioeconomic status. It is quantified using three proxy measures selected for their significant impact on quality of life and health outcomes: the incapacity of households to maintain adequate warmth ($Inability$), the share of the population with arrears on utility bills ($Arrears$), and the general substandard conditions of housing ($HousingConditions$). The inability indicator reflects the thermal efficiency of a dwelling as well as the household's financial capacity to afford adequate heating, measured by Eurostat as the share of the population unable to keep their home adequately warm. An inability to maintain a warm living environment can lead to various health problems, including increased susceptibility to respiratory and cardiovascular diseases. Studies have shown that adequate warmth is crucial not only for physical health but also for mental well-being, affecting everything from mood to sleep quality [82]. The second indicator focuses on the financial aspects of energy poverty, highlighting households that struggle to meet their energy expenses. Arrears on utility bills are a clear sign of financial stress and often lead to energy disconnections, reduced energy consumption, and increased vulnerability to extreme temperatures. Additionally, the stress associated with financial instability can have psychological impacts, contributing to a cycle of poverty and poor health [83]. The housing conditions indicator encompasses insulation, outdated heating systems, and poor construction materials. It measures the share of the population living in a dwelling with a leaking roof, damp walls, floors, or foundations, or rot in window frames or floors. Poor housing conditions are a comprehensive indicator of energy poverty, highlighting issues that affect energy efficiency as well as the overall safety and livability of the dwelling. Living in poor housing conditions is linked to a myriad of health risks, a reduced quality of life, and lower educational and economic opportunities [84].

To synthesize these indicators into a singular measure, this study employed entropy methods to create an energy poverty index. Entropy methods are rooted in information theory and are primarily used to measure the uncertainty or the distribution of data across different variables [85]. In the context of constructing an index, the entropy method evaluates the variability and discriminative power of each indicator, ensuring that more variable indicators that provide unique information have a greater weight. The weights assigned to each indicator—0.240 for inability to maintain warmth, 0.402 for arrears in utility payments, and 0.358 for housing conditions—were calculated to reflect their relative importance within the index. These weights were derived through a process that began with the normalization of each indicator to ensure comparability. The normalized values were then used to calculate the proportion of each indicator relative to the total across all observations, which formed the basis for entropy calculations. The entropy of each indicator was computed as follows:

$$E_j = -\sum_{i=1}^{n} p_{ij} \log\left(p_{ij}\right) \quad (1)$$

where p_{ij} is the proportion of the i-th observation for the j-th indicator. The entropy value reflects the level of uncertainty or diversity within the indicator distribution; lower entropy suggests less diversity and hence less impact in differentiating between the states of energy poverty.

After calculating the entropy, the weight for each indicator was derived by subtracting this entropy from the total entropy of all indicators and then normalizing these values. This ensured that indicators with less uncertainty (i.e., those that are more consistent across observations) received greater weight, as they are more reliable measures of the conditions they aim to represent. The formula used to calculate the energy poverty index was as follows:

$$\mathrm{EP} = 0.240 \times Inability + 0.402 \times Arrears + 0.358 \times HousingConditions \quad (2)$$

where EP is the energy poverty index.

The higher weight assigned to an indicator in Formula (2) means it has a greater impact on the final energy poverty index. This signifies that changes in this indicator will more significantly affect the overall assessment of energy poverty. The weighting reflects the relative importance of each aspect of energy poverty, guiding focused interventions and resource allocation to effectively address the most influential factors. The EP index ranges from 0 to 1 according to the entropy methods, where a score closer to 0 indicates a higher level of energy poverty, and conversely, a score closer to 1 indicates a lower level of energy poverty. The results of the empirical assessment of the energy poverty index for each EU country are shown in Figure 1.

Figure 1. Energy poverty index for EU countries, 2006–2022.

3.2.2. Explanatory Variables

To assess the level of democratic governance in EU countries, the voice and accountability index (VEA), which is part of the World Governance Indicators (WGIs) compiled by the World Bank [86], was utilized. The VEA scores range from approximately −2.5 to 2.5. Higher scores indicate better governance outcomes in terms of voice and accountability. This index is based on fundamental elements that characterize an open and democratic society. Specifically, it measures the extent to which a country's citizens can participate in selecting their government, which includes not only voting in elections but also various forms of political participation that influence government decision-making. Additionally, it assesses the freedoms essential to democratic governance, such as freedom of expression, freedom of association, and independence of media [86]. These dimensions are critical because they directly relate to how citizens interact with their government and to what degree they can hold it accountable. The voice and accountability index thereby serves as a proxy for assessing whether citizens can freely discuss and critique government policies without fear of retaliation, whether they can form groups to press for changes, and whether the media can report on government actions without censorship. Such measures are central to the functioning of a democratic system, as they ensure that the government remains responsive to the needs of its constituents and that public officials can be held accountable for their actions [87]. Democratically governed nations, which typically score high on the voice and accountability index, are often more transparent, equitable, and effective in their policy implementations. This can lead to more inclusive energy policies that address the needs of vulnerable populations [88]. In addition to examining the role of governance, this paper added several economic indicators as explanatory variables. These indicators were chosen based on their theoretical relevance and empirical evidence supporting their impact on energy poverty among different countries [87–90].

The energy intensity of GDP (EI), defined as the amount of energy consumption per unit of GDP, reflects the efficiency with which an economy uses energy to produce economic output. A lower energy intensity indicates a higher efficiency level, which can be linked to advancements in technology and better energy policies [89]. Trade openness (TO) is measured by the sum of exports and imports divided by GDP. This indicator reflects the extent to which countries engage in international trade. Economies that are more open to trade are often more exposed to global market dynamics and may have better access to energy-efficient technologies and practices. Furthermore, trade openness can influence domestic energy prices and availability, impacting energy poverty levels [90]. The Gini index (GINI) measures income inequality within a country. A higher Gini coefficient indicates greater inequality. Studies have shown that higher income inequality can exacerbate energy poverty by widening the gap between those who can afford adequate energy services and those who cannot [91]. GDP per capita (GDP) is a common measure of a country's economic performance and an individual's economic well-being. A higher GDP per capita generally suggests a higher standard of living, including better access to essential services such as energy [92].

This study examines the impact of democratic governance on energy poverty across European Union member states from 2006 to 2022. The timeframe chosen reflects the period for which relevant data were readily available. Table 1 presents the sources and descriptive statistics of the selected variables.

Table 1. Summary statistics.

Variables	Source	N	Mean	SD	Min	Max
EP	Eurostat [93]	459	0.766	0.147	0.239	0.965
VEA	World Bank [94]	459	1.088	0.341	0.319	1.650
EI	Eurostat [93]	459	183.118	89.390	37.350	603.450
TO	World Bank [94]	459	126.650	67.849	45.419	393.141
GINI	World Bank [94]	459	31.280	3.702	23.200	41.505
GDP	Eurostat [93]	459	33,982.347	23,140.910	4523.147	133,711.790

4. Results

Kernel density estimation methods were used to analyze the distribution of the observed data and detect any outliers. The kernel density plots (Figure 2) revealed that the variables are not normally distributed. Based on this visual assessment, the next step in the analysis involved applying a logarithmic transformation to the variables to correct for the observed distributional irregularities.

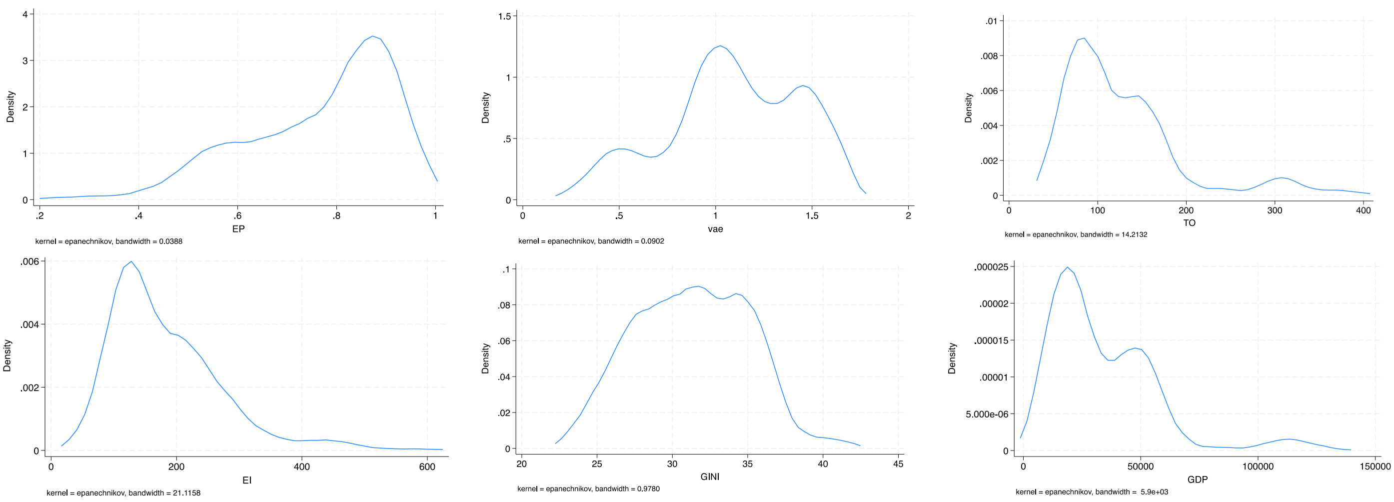

Figure 2. Kernel density estimate.

The Shapiro–Wilk W test (Table 2), a measure for assessing the normality of data distributions, strongly rejects the null hypothesis of a normal distribution for all variables.

This is evidenced by W statistics significantly less than 1 and *p* values effectively at zero, indicating a departure from normality for these variables.

Table 2. Shapiro–Wilk W test for normal data.

Variable	Obs	W	V	z	Prob > z
lnEP	459	0.856	44.764	9.103	0.000
lnVEA	459	0.892	33.709	8.423	0.000
lnEI	459	0.995	1.473	0.927	0.177
lnTO	459	0.969	9.808	5.467	0.000
lnGINI	459	0.984	4.974	3.841	0.000
lnGDP	459	0.985	4.667	3.689	0.000

Note: W—Shapiro–Wilk test statistic; V—more appealing index for departure from normality; z—*z* value.

The results of the Shapiro–Wilk test indicate that the distribution of the variables does not conform to normality, even with the application of a logarithmic transformation. This suggests that the data do not adhere to a standard Gaussian distribution.

The empirical results of pairwise correlations are presented in Table 3. The findings indicate that lnEP has a significant correlation with other variables, with *p* values not higher than 5%.

Table 3. The empirical results of pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	VIF
(1) lnEP	1.000						
(2) lnVEA	0.402 (0.000)	1.000					1.41
(3) lnEI	−0.388 (0.000)	−0.355 (0.000)	1.000				3.71
(4) lnTO	0.108 (0.020)	−0.165 (0.000)	0.075 (0.108)	1.000			1.42
(5) lnGini	−0.499 (0.000)	−0.119 (0.011)	0.078 (0.096)	−0.257 (0.000)	1.000		1.23
(6) lnGDP	0.625 (0.000)	0.451 (0.000)	−0.805 (0.000)	0.203 (0.000)	−0.310 (0.000)	1.000	4.74

There is a moderate positive correlation between lnEP and lnVEA, indicating that as values of lnVEA increase, so does the energy poverty index, suggesting a direct relationship between these two factors. Conversely, lnEP and lnEI are moderately negatively correlated, revealing that higher energy efficiency (or lower energy intensity) tends to coincide with a reduced energy poverty index. Trade openness (lnTO) shows only a weak positive relationship with lnEP, implying that the degree of a country's openness to trade has a slight, yet positive, influence on energy poverty levels. Intriguingly, lnEP is moderately negatively correlated with lnGini, indicating that regions with higher income inequality tend to experience more severe energy poverty. This highlights the socioeconomic dimensions of energy access and affordability. A strong positive correlation is observed between lnEP and lnGDP, underscoring the link that wealthier economies, on average, exhibit lower levels of energy poverty. This relationship points toward the economic underpinnings of energy access issues, where a higher GDP per capita is associated with better energy affordability and reliability. The analysis of the variance inflation factor (VIF) for all variables indicates moderate multicollinearity (Table 3), especially for lnGDP, which has the highest VIF value but is still below threshold 5, which is typically associated with significant multicollinearity concerns [72]. This suggests that while the variables are interrelated, they do not overly inflate the variance of the estimated coefficients in a regression model, maintaining the integrity of the statistical analyses.

The next phase of data analysis involved ensuring the stability of each variable through a stationary test. To achieve this, a range of panel stationary tests were employed, including the Levin–Lin–Chu, Breitung, Hadri LM, Im–Persaran–Shin, Pesaran's CADF, and CIPS tests (Table 4).

Table 4. The findings of the unit root test by Levin–Lin–Chu, Breitung, Hadri LM, Im–Pesaran–Shin, Pesaran's CADF, and CIPS.

Variables	Levin–Lin–Chu		Breitung		Hadri LM		Im–Pesaran–Shin		Pesaran's CADF		CIPS
	Statistic	p Value	Statistic	p Value	Statistic	p Value	Statistic	p Value	Statistic	p Value	Statistic
lnEP	−1.999	0.023	0.929	0.824	32.514	0.000	−0.104	0.459	−2.123	0.026	−2.552
d. lnEP	−7.642	0.000	−5.896	0.000	−0.398	0.655	−8.428	0.000	−2.775	0.000	−3.713
lnVEA	−3.167	0.001	−2.256	0.012	−0.092	0.537	0.625	0.734	−2.125	0.025	−2.046
d. lnVEA	−9.455	0.000	−10.003	0.000	33.245	0.000	−8.776	0.000	−2.520	0.000	−3.350
lnEI	4.883	1.000	8.803	1.000	44.132	0.000	7.824	1.000	−2.261	0.004	−2.583
d. lnEI	−8.124	0.000	−9.988	0.000	−0.829	0.797	−9.807	0.000	−2.929	0.000	−3.955
lnTO	0.708	0.760	2.219	0.987	34.079	0.000	3.101	0.999	−1.641	0.693	−1.184
d. lnTO	−8.795	0.000	−12.126	0.000	−1.528	0.937	−8.414	0.000	−2.820	0.000	−2.736
lnGINI	−2.000	0.023	−0.534	0.297	26.715	0.000	−1.899	0.029	−1.536	0.851	−2.133
d. lnGINI	−7.327	0.000	−8.347	0.000	−2.984	0.999	−10.969	0.000	2.947	0.000	−4.839
lnGDP	−0.620	0.268	1.540	0.938	31.014	0.000	−3.685	0.000	−0.856	1.000	−0.716
d. lnGDP	−21.612	0.000	−5.924	0.000	−2.408	0.992	−10.188	0.000	−2.596	0.000	−3.478

Among these, the Levin–Lin–Chu, Breitung, and Hadri LM tests have limitations in handling heterogeneity across panels and can be sensitive to cross-sectional dependencies that are common in complex economic data. In contrast, Pesaran's CADF and CIPS tests are performed in panel data contexts where heterogeneity and cross-sectional dependence are prevalent. These tests adapt the conventional unit root test better to handle variations in autoregressive coefficients across different panels, providing a more tailored and accurate assessment of stationarity. This capability makes them superior for datasets where cross-sectional interdependencies could significantly impact unit root testing results. The empirical results from the Levin–Lin–Chu, Breitung, Hadri LM, Im–Pesaran–Shin, Pesaran's CADF, and CIPS unit root tests reveal that certain estimated variables are stationary at levels I(0) but become stationary at level I(1) upon the first differencing of the estimated model. This indicates that the variables exhibit nonstationarity at their initial levels but achieve stationarity when first differences are applied, at significance levels of 1% and 5%. Furthermore, according to the CIPS unit root test results, it is inferred that at these levels, variables have root problems within the cross-section over the period 2006–2022, and the mean–variance of the estimated model changes over time. For the chosen sample sizes of N = 27 and T = 17, the critical values for the CIPS test at significance levels of 1%, 5%, and 10% are −2.11, −2.20, and −2.38, respectively. However, once the first difference is applied, the data show that all variables become free from root issues, thereby indicating that all observed variables are stationary at the first difference. lnEP exhibits a CIPS of −2.552 at this level, which does not meet the critical value for stationarity at any conventional significance level, indicating nonstationarity at I(0). However, its first difference shows a significant improvement in stationarity, with a CIPS of −3.713, which is the critical value at the 1% significance level. lnVEA and lnEI show similar patterns where their levels are not stationary, but their first differences are, with CIPS statistics of −3.350 and −3.955, respectively. For lnTO and lnGINI, the nonstationarity at these levels is pronounced, with CIPS statistics far above the critical value thresholds, but once again, their first differences suggest full stationarity. lnGDP is nonstationary at the level with a CIPS statistic of −0.716 and becomes stationary at the first difference with a CIPS statistic of −3.478. This consistency suggests that variables across EU countries share similar patterns of stationary order at I(1).

Table 5 reports the results of testing for slope heterogeneity in the dependent variable lnEP. The null hypothesis for these tests posits that the slope coefficients across different entities are homogeneous, meaning that they are the same across all units. Conversely, the alternative hypothesis suggests that there is heterogeneity in the slope coefficients, indicating differences across units.

Table 5. The results of testing for slope heterogeneity.

Depended Variable: lnEP	Delta	*p* Value
Δ tilde	7.039	0.000
Δ tilde adjusted	9.178	0.000

Both the Δ tilde and Δ tilde adjusted statistics show significant results, with *p* values less than 1% ($p = 0.000$ for both tests). This strongly rejects the null hypothesis of slope homogeneity, suggesting substantial heterogeneity in the slope coefficients among the units analyzed. The significant findings of heterogeneity indicate that the EU economies represented in this analysis exhibit varying levels of development and thus do not share homogeneous data characteristics. This heterogeneity can be attributed to several factors: EU countries vary widely in terms of economic size, level of industrialization, and energy consumption patterns. Countries with advanced economies may have different energy dynamics compared to those that are still developing; different national energy policies, regulations, and incentives can also lead to heterogeneity in how energy consumption and efficiency are approached, further contributing to the slope variations observed in the model; geographical and climatic differences across the EU can affect energy needs and consumption patterns, which in turn influence the slope coefficients in the model.

According to the results from the unit root tests and testing for slope heterogeneity, ordinary least squares (OLS) cannot be employed to verify the cointegration among these variables. This is because the presence of unit roots and slope heterogeneity suggests that the standard assumptions required for OLS estimation are violated, potentially leading to biased and inconsistent results. To address this issue, several cointegration techniques were employed, including tests developed by Kao [76], Pedroni [77], and Westerlund [78]. The outcomes of these tests are presented in Table 6.

Table 6. The cointegration results for the analyzed variables.

Test	Statistic	*p* Value
	Pedroni	
Modified Phillips–Perron t	5.142	0.000
Phillips–Perron t	−4.608	0.000
Augmented Dickey–Fuller t	−4.290	0.000
	Kao	
Modified Dickey–Fuller t	−1.272	0.102
Dickey–Fuller t	−2.640	0.004
Augmented Dickey–Fuller t	−1.458	0.072
Unadjusted Modified Dickey–Fuller t	−3.368	0.000
Unadjusted Dickey–Fuller t	−3.783	0.000
	Westerlund	
Variance ratio	−0.128	0.448

The Pedroni panel cointegration tests, which include both within-dimensional (Modified Phillips–Perron t, Phillips–Perron t, Augmented Dickey–Fuller t) and between-dimensional tests, show significant cointegration, as all associated *p* values are below the 0.001 threshold. These results strongly suggest that there is a stable long-term relationship among the variables under consideration. The Kao cointegration test, which assumes homogeneous cointegration across cross-sections, produced mixed results. The Modified Dickey–Fuller t, Augmented Dickey–Fuller t, and unadjusted Modified Dickey–Fuller t do not show significance at the usual 5% level (p values of 0.102 and 0.072, respectively), indicating a less robust indication of cointegration. However, the Dickey–Fuller t test and unadjusted Dickey–Fuller t test suggest significant cointegration (p values of 0.004 and 0.000, respectively). The Westerlund cointegration test, which is sensitive to the presence of cross-sectional dependence, does not indicate cointegration, as the variance ratio statistic is not significant (p value of 0.448).

The outputs of the Granger noncausality tests are presented in Table 7. Based on the calculated p values, Granger causality is confirmed in most cases.

Table 7. The results of the Granger noncausality test.

Variables	HPJ Wald Test	p Value	Coefficient L1	$p > \lvert z \rvert$
lnVEA	2.991	0.084	−0.051	0.084
lnEI	10.908	0.001	−0.213	0.001
lnTO	19.422	0.000	0.157	0.000
lnGINI	0.444	0.505	0.140	0.505
lnGDP	4.884	0.027	0.119	0.027

lnEI and lnTO show strong evidence of Granger causality, with p values of 0.001 and 0.000, respectively. This indicates that past values of these variables have predictive power over future values, suggesting a causal relationship in the context of the model used. lnGDP also shows evidence of Granger causality with a p value of 0.027, indicating a statistically significant causal effect at the 5% level. lnVEA exhibits a p value of 0.084. This suggests that there is evidence at the 10% level to conclude that past values of lnVEA have a predictive effect on future values within this model. However, lnGINI, with a p value of 0.505, clearly shows no Granger causality. This indicates that variations in lnGINI do not predict changes in the dependent variable in the context tested.

The findings from the test for weak cross-sectional dependence are shown in Table 8. All alpha estimates for the variables tested indicate strong evidence of cross-sectional dependence (CSD), with most values substantially exceeding the threshold of 0.5, suggesting robust interconnections among the units within the dataset.

Table 8. The findings of the test for weak cross-sectional dependence.

Variables	Alpha	Std. Err.	CD	p Value	CDw	p Value
lnEP	18.231	0.000	18.231	0.000	72.269	0.000
lnVEA	0.857	0.040	1.695	0.090	2.496	0.013
lnEI	67.431	0.000	67.431	0.000	77.231	0.000
lnTO	55.627	0.000	55.627	0.000	77.230	0.000
lnGINI	4.111	0.000	4.111	0.000	77.237	0.000
lnGDP	48.651	0.000	48.651	0.000	77.237	0.000

Note: CD—the estimation method following Bailey, Kapetanios, Pesaran [80] [2016]; CDw—the estimation method following Pesaran [81].

lnEP, lnEI, lnTO, lnGINI, and lnGDP show extremely high alpha values, with corresponding p values of 0.000 in both the standard CD and CDw tests, decisively rejecting the null hypothesis of weak cross-sectional dependence. These results imply a strong influence of shared or common factors affecting these variables across different cross-sections. While the lnVEA alpha estimate of 0.857 also indicates cross-sectional dependence, the CD test results in a p value of 0.090. However, the CDw test for lnVEA reports a p value of 0.013, indicating significant cross-sectional dependence. First, the relationships between the energy poverty index (EP) and various socioeconomic and economic variables were analyzed using two advanced econometric methods: correlated panel-corrected standard errors (PCSEs) and cross-sectional time-series FGLS regression. Table 9 presents the coefficients from these models.

Table 9. The empirical results of panel data analysis.

Variables	(1)	(2)
lnVEA	0.0704 *** (0.0186)	0.0690 *** (0.00541)
lnEI	−0.115 *** (0.0223)	−0.112 *** (0.00624)
lnTO	0.0532 *** (0.0129)	0.0516 *** (0.00386)
lnGINI	−0.591 *** (0.0463)	−0.581 *** (0.0127)
lnGDP	0.237 *** (0.0211)	0.235 *** (0.00547)
Constant	−1.020 *** (0.252)	−1.029 *** (0.0722)
Observations	459	459
Number of id	27	27
R-squared	0.532	
Wald chi2(5)	386.51	15,270.74
Prob > chi2	0.0000	0.0000

Note: (1) Correlated panels corrected standard errors (PCSEs); (2) cross-sectional time-series FGLS regression; standard errors in parentheses, *** $p < 0.01$.

Higher levels of voice and accountability are significantly associated with lower levels of energy poverty, suggesting that political factors play a critical role in addressing energy-related issues. For the PCSE technique, the lnVEA coefficient is 0.0704 with a standard error of 0.0186 and is significant at less than the 0.01 level ($p < 0.01$). Similarly, for the FGLS, the coefficient is 0.0690 with a standard error of 0.00541, which is also significant at the same level ($p < 0.01$). The negative coefficients for lnEI in both models (−0.115 and −0.112) indicate that higher energy intensity, reflecting less efficient energy use, is significantly correlated with greater energy poverty. This finding is consistent across both models and significant at the 1% level. Greater trade openness is associated with reductions in energy poverty, possibly due to increased economic activity and improved access to energy resources and technologies. The coefficients for trade openness are 0.0532 and 0.0516 in the PCSE and FGLS models, respectively, with corresponding standard errors of 0.0129 and 0.00386, respectively, and are significant at the 1% level ($p < 0.01$). The substantial negative coefficients for the Gini index (−0.591 and −0.581) highlight that higher inequality, as measured by the Gini index, is strongly associated with greater energy poverty. The strong statistical significance of these results underscores the adverse effects of inequality on energy access and consumption. Positive coefficients for GDP per capita (0.237 and 0.235) indicate that greater economic prosperity is associated with lower levels of energy poverty. The R-squared value of 0.532 in the PCSE model indicates that approximately 53.2% of the variability in energy poverty across panels is explained by the included variables. The Wald chi-square statistics (386.51 and 15,270.74) and their associated probabilities ($p < 0.0001$) confirm the overall significance of the models, suggesting the strong explanatory power and reliability of the estimates. These robust results provide a compelling argument for targeted policy interventions that address governance, economic disparities, and energy efficiency to effectively reduce energy poverty. Another approach to estimating panel regressions with unobserved common factors is instrumental variable estimation with common factors (2SIV). The outputs of this technique are presented in Table 10, where different models are applied to distinct groups of countries based on their democratic status: (1) includes all EU countries, (2) is focused on full democracies, and (3) covers flawed democracies.

Table 10. The empirical results for the 2SIV model.

Variables	(1)	(2)	(3)
	All Countries	**Full Democracies**	**Flawed Democracies**
L.lnEP	0.433 *** (0.0198)	0.861 *** (0.244)	0.588 *** (0.0361)
lnVEA	0.122 *** (0.0322)	0.0311 (0.0550)	0.193 *** (0.0591)
lnEI	−0.109 *** (0.0215)	−0.198 ** (0.0933)	−0.0764 * (0.0399)
lnTO	0.153 *** (0.0376)	0.189 *** (0.0634)	−0.0479 (0.0368)
lnGINI	−0.0986 *** (0.0233)	0.112 (0.286)	0.0452 (0.122)
lnGDP	0.236 *** (0.0267)	0.287 *** (0.0995)	0.331 *** (0.0206)
Constant	−3.509 *** (0.299)	−5.348 ** (2.241)	−3.722 *** (1.073)
sigma_f	0.040	0.012	0.051
sigma_e	0.039	0.016	0.020
rho	0.514	0.376	0.867
Observations	378	140	221
Number of id	27	10	17

Note: Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The results from Model 1 of the 2SIV panel regression for all EU countries indicate that previous levels of energy poverty strongly predict current levels, with a significant lagged coefficient of 0.433 ($p < 0.01$). This finding underscores the persistence of energy poverty across time, emphasizing the importance of sustained policy efforts. Voice and accountability positively impact energy poverty, suggesting that higher governance quality leads to more effective energy management, with a coefficient of 0.122 ($p < 0.01$). Conversely, a negative coefficient for energy intensity (−0.109, $p < 0.01$) reveals that increased energy efficiency is crucial for reducing energy poverty. Similarly, trade openness and GDP per capita are positively associated with better energy poverty outcomes, with coefficients of 0.153 and 0.236, respectively, both of which are significant at $p < 0.01$, indicating that economic openness and prosperity play key roles in mitigating energy poverty. However, higher income inequality, as reflected by the negative coefficient of the Gini index (−0.0986, $p < 0.01$), tends to exacerbate energy poverty, highlighting the need for equitable growth. The model's robustness is confirmed by an R-squared value of 0.532 and a significant Wald chi-square statistic, suggesting that these factors collectively explain more than half the variability in energy poverty across the EU.

Model 2, representing full democracies, shows a very strong persistence of energy poverty levels, as indicated by the lagged energy poverty index, with a coefficient of 0.861 ($p < 0.01$). However, lnVEA does not significantly impact energy poverty in these nations, suggesting that incremental improvements in already well-functioning democracies yield minimal returns. Conversely, economic factors such as trade openness and GDP per capita have positive and significant impacts, reinforcing the idea that economic integration and prosperity are crucial for mitigating energy poverty in full democracies. In Model 3, which encompasses flawed democracies, the persistence of energy poverty is also significant but less intense than that in full democracies, with a coefficient of 0.588 ($p < 0.01$). Here, improvements in governance have a more substantial and significant effect on reducing energy poverty, as indicated by a significant coefficient for lnVEA (0.193, $p < 0.01$). This suggests that in environments with less robust democratic structures, enhancing governance can have a pronounced beneficial impact on energy poverty. However, unlike in full democracies, trade openness does not alleviate energy poverty in flawed democracies, indicating differing economic dynamics. While economic prosperity consistently aids in reducing energy poverty across all models, the role of governance and trade varies markedly between full and flawed democracies. Such insights highlight the importance of tailoring policy interventions to the specific political and economic landscapes of countries to effectively combat energy poverty. This approach ensures that strategies are contextually relevant and capable of addressing the unique challenges faced by different governance systems.

5. Discussion

Investigating the impact of democracy on energy poverty significantly advances the understanding of energy poverty by integrating complex econometric analyses of how democratic governance affects energy access. The findings resonate with previous studies that suggest that a higher GDP per capita, a common trait in more democratic nations, is typically associated with lower levels of energy poverty [25,47]. This correlation supports the notion that economic prosperity, facilitated by stable democratic institutions, can provide a buffer against energy poverty. The analysis further reveals that higher energy intensity correlates with increased energy poverty, aligning with research by Jones and Warner [95], which highlighted the critical role of energy efficiency in mitigating poverty. The persistent nonnormality in the data prompted the use of logarithmic transformations and first differencing to achieve stationarity, a methodological sophistication that echoes the approaches found in Lee and Strazicich [96], where addressing nonstationarity was crucial for avoiding spurious results in time-series analyses. Moreover, the moderate multicollinearity observed among our economic variables is consistent with findings from Apergis and Payne [97], who also reported interdependencies among energy-related economic indicators but confirmed that these did not detract from the robustness of their econometric models. The heterogeneity in slope coefficients across EU countries, suggesting varying impacts of democratic governance on energy poverty, adds a novel dimension to the literature, which often treats European countries as homogenous blocks [98]. This finding underlines the importance of considering local contexts and specific national policies when analyzing the effects of democracy on energy access, an approach supported by the work of Sovacool and Dworkin [99], who conducted country-specific analyses in energy studies.

The positive association between the voice and accountability index and a reduction in energy poverty suggests that better governance practices, characterized by higher levels of citizen participation and government accountability, contribute significantly to alleviating energy poverty. This is consistent with the view of the authors of [100], who argue that democratic governance can lead to better public goods provisions due to greater accountability and responsiveness to citizens' needs. This relationship can be attributed to several mechanisms. First, democratic governance fosters transparency and accountability, reducing the likelihood of corruption and mismanagement of resources [86]. This can lead to a more efficient and equitable allocation of resources, ensuring that public investments in energy infrastructure and subsidies reach the intended beneficiaries. Second, democratic institutions often encourage greater public participation in policy-making processes, allowing for a more inclusive approach that considers the needs of marginalized and vulnerable populations [101]. This inclusiveness can result in policies that are better tailored to addressing the root causes of energy poverty, such as inadequate infrastructure and high energy costs. Additionally, democratic governance typically promotes free and independent media, which can play a crucial role in highlighting issues of energy poverty and holding governments accountable for their actions [102]. Media coverage can raise public awareness and generate political pressure for reforms aimed at improving energy access and reducing poverty. Furthermore, civil society organizations and advocacy groups, which are more likely to thrive in democratic settings, can mobilize communities, advocate for policy changes, and provide essential services and support to those affected by energy poverty [103]. The results do not fit with the theory that economic factors alone are sufficient to address energy poverty. Instead, the findings underscore the importance of political and institutional factors, demonstrating that governance quality is a critical component in the fight against energy poverty [104].

Based on the research results, the following policy implications for decreasing energy poverty are outlined:

1. It is necessary to strengthen democratic institutions, particularly in flawed democracies, where enhancements in governance could significantly mitigate energy poverty. Policies that improve transparency, such as the public disclosure of energy usage data and government spending on energy subsidies, help build trust and accountability in energy provision [99]. The push for increased transparency and accountability in energy sectors, as seen in various policy frameworks, exemplifies how such measures can lead to more equitable energy distributions [56]. Furthermore, enhancing accountability through regular audits and independent regulatory bodies can ensure that energy policies are implemented effectively and are free from corruption [88]. The rigorous monitoring mechanisms included in major green initiatives, which track progress and ensure policy compliance, serve as models that can be adapted by individual nations within the EU to address specific local challenges related to energy poverty [68]. Additionally, increasing public participation in energy decision-making processes can empower consumers and local communities, thereby fostering more inclusive policy development. Public consultations, participatory budgeting in energy projects, and community-based energy planning sessions can make energy systems more responsive to the needs of vulnerable populations [95]. For example, Sweden and Denmark have successfully involved local communities in planning and executing local wind power projects, which has not only helped in reducing energy poverty but also supported community cohesion and local economic development [39]. These practices highlight the critical role of democratic engagement in energy policy formulation and underscore the potential for community-driven initiatives to alleviate energy poverty while promoting social and economic benefits.
2. Reducing energy intensity through enhanced efficiency across all economic sectors is critical to addressing the broader challenges of energy sustainability and affordability. Successful initiatives, such as Poland's electromobility and high-efficiency cogeneration projects, clearly demonstrate the potential impacts of such policies on reducing energy intensity, making significant strides toward cleaner, more efficient energy use [6,45]. These projects not only improve the energy efficiency of power systems but also contribute to substantial reductions in greenhouse gas emissions, aligning with global climate goals. Furthermore, encouraging green investments, such as those in renewable energy sources and energy-efficient technologies, can bolster economic resilience and sustainability [2]. These investments are instrumental in driving down energy costs, improving energy security, and facilitating the transition toward low-carbon economies. For instance, Germany's extensive investments in solar and wind energy have not only reduced its carbon footprint but also created numerous jobs, proving that environmental sustainability can go hand in hand with economic prosperity [8].
3. Increasing trade openness to encompass energy-efficient technologies and renewable resources can help alleviate energy poverty. This approach not only improves access to advanced energy solutions but also reduces costs through increased competition and innovation, supporting broader economic development goals. Facilitating international trade in green technologies, such as solar panels and wind turbines, allows countries to leapfrog to cleaner energy solutions, thereby reducing dependency on fossil fuels and enhancing energy security [90]. For instance, Denmark's aggressive pursuit of wind energy exports has not only solidified its own energy security but also positioned it as a global leader in renewable technology, demonstrating the dual benefits of this strategy.

4. Addressing income inequality is crucial for mitigating energy poverty. Implementing progressive taxation, equitable fiscal policies, and targeted energy subsidies for low-income households can effectively address the issues highlighted by the Gini index. These strategies ensure that economic growth benefits all societal segments, thus enhancing overall energy access. For example, Sweden's use of high marginal tax rates and extensive welfare benefits has been effective in both reducing inequality and ensuring that lower-income households have access to necessary services, including energy [50]. Additionally, targeted subsidies can help buffer vulnerable populations from the volatility of energy prices, ensuring that energy remains affordable for all people.
5. Customizing policies based on the type of democracy is essential for effectively addressing energy poverty. In full democracies, prioritizing economic and technological advancements may yield more significant results, as these societies typically have robust institutional frameworks that can rapidly implement and capitalize on high-tech solutions. For instance, the advancement of smart grids and renewable integration in Germany demonstrates how technological innovation can enhance energy efficiency and sustainability within established democratic structures [5]. Conversely, in flawed democracies, where institutional weaknesses might hinder rapid technological adoption, focusing on governance improvements could lead to substantial reductions in energy poverty. Enhancing regulatory frameworks, increasing governmental transparency, and fostering citizen participation in energy decisions can create a more stable environment that supports sustainable energy policies [68]. The success of governance reforms in Bulgaria and Romania post-EU accession highlights how strengthening institutional capacities can facilitate energy sector reforms and reduce energy inefficiencies [16,71]. This tailored approach ensures that interventions are optimally aligned with the specific political and economic contexts of different EU countries. By acknowledging the unique characteristics of each democracy type, policies could be designed to exploit the strengths and address the weaknesses specific to each context. For example, integrating EU-wide policies such as the European Green Deal with local initiatives provides the necessary flexibility and support to ensure that all member states effectively reduce energy poverty, regardless of their democratic status. Furthermore, leveraging international cooperation through agreements and partnerships can enhance resource sharing and innovation transfers between full and flawed democracies, promoting a more cohesive approach to energy poverty across the EU. Such collaborations allow for the diffusion of best practices and advanced technologies from more developed democracies to those still strengthening their institutions, amplifying the impact of individual efforts through collective action [99].

6. Conclusions

For all EU countries, enhancing voice and accountability has been shown to significantly improve the energy poverty index. A 1% increase in VEA, indicated by a coefficient of 0.122 in the model with all EU countries, suggests a corresponding improvement in the energy poverty index. To capitalize on this, the EU should promote transparency, public participation in energy decision-making, and accountability in energy policy implementation. This could include public forums, stakeholder consultations, and ensuring transparency in energy pricing and policy impacts. The negative coefficient of energy intensity (−0.109) indicates that increased energy efficiency leads to a reduction in energy poverty. Policies should thus focus on promoting energy-efficient technologies, upgrading infrastructure, and encouraging energy-efficient practices among consumers and industries. The EU could enhance incentives for businesses and households to adopt energy-saving technologies and implement stricter energy consumption standards. Economic variables such as GDP per capita and trade openness also play critical roles. For instance, a 1% increase in GDP per capita (coefficient of 0.236) and trade openness (coefficient of 0.153) significantly improves the energy poverty index. Policies that stimulate economic growth, support innovation in green technologies, and reduce trade barriers for energy-efficient and renewable energy products are essential. The EU should integrate energy efficiency into trade agreements and support cross-border energy trade initiatives. The impact of the Gini index suggests that addressing income inequality can also influence energy poverty. A 1% reduction in the Gini coefficient could improve the energy poverty index by 0.0986%, indicating the need for progressive taxation, enhanced social welfare programs, and targeted support for lower-income households in energy matters. Different models underscore the need for tailored approaches in full and flawed democracies. In full democracies, leveraging economic prosperity and trade is crucial, given the significant coefficients of the energy poverty index. In flawed democracies, enhancing governance and accountability appears more impactful, as indicated by a more substantial coefficient (0.193). Strengthening the legal and regulatory frameworks for energy policies, improving regulatory quality, and ensuring public engagement in governance could substantially mitigate energy poverty in these contexts.

There are a few limitations to the study. The scope of the variables is limited, excluding specific factors such as energy policies, renewable energy adoption rates, and direct measures of economic activities. The research is also geographically confined to EU countries, without incorporating comparative analyses with non-EU regions. Additionally, the analysis primarily relies on quantitative data, potentially overlooking nuanced insights that qualitative research could offer. Last, the study does not consider the impacts of technological advancements and climate change on energy resources, which are critical factors in the current global shift toward sustainable energy solutions. Therefore, further research directions should include expanding the scope of variables to encompass specific energy policies, renewable energy adoption rates, and direct measures of economic activities to provide deeper insights. Comparative studies with non-EU regions and qualitative analyses could complement quantitative data, offering a richer context to the numerical findings. Moreover, exploring the role of technological advancements and the impacts of climate change on energy resources is crucial.

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