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Electricity Consumption and Financial Development: Evidence from Selected EMEs—A Panel Autoregressive Distributed Lag–Pooled Mean Group Approach

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Abstract

This study explores the relationship between electricity consumption and financial development in 20 emerging market economies (EMEs) from 2000 to 2020. Employing the panel ARDL–PMG estimator and a two-step system GMM to address endogeneity, we identify a significant positive long-run cointegrating relationship, where electricity consumption fosters financial development. The estimated error correction term suggests a stable equilibrium, with deviations corrected at a 29% annual rate, in the short-run adjustment. These results underscore the significance of targeted energy investments in driving financial market growth. Policies promoting grid action, renewable integration, and innovative financing tools, such as green bonds, can align electricity expansion with financial stability objectives. By incorporating recent global disruptions and applying advanced econometric methods, this study provides updated empirical evidence and actionable policy insights on the electricity–finance nexus in EMEs.

Keywords: electricity consumption; financial development; emerging market economies (EMEs); panel ARDL–PMG; two-step system GMM; long-run cointegration; resource diversion effect; energy–finance nexus; grid modernization; renewable energy integration



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1. Introduction

Financial development enables efficient allocation of resources and economic growth in emerging market economies (EMEs) [1–3]. In addition, developed financial systems enhance resilience to macroeconomic shocks and attract capital flows [1,4,5].

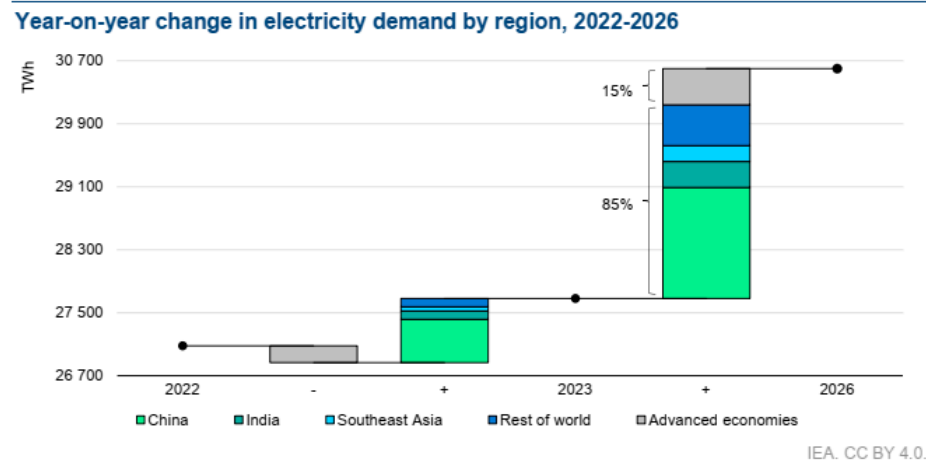
Financial markets in EMEs have grown significantly since 1997; however, structural weaknesses exist and have limited capacity in funding capital-intensive energy projects [2]. These vulnerabilities have increased due to recent global shocks. The COVID-19 outbreak, the Russia–Ukraine conflict, and other international disputes triggered capital flight from EMEs to advanced economies [6]. This was further exacerbated by supply chain volatilities and inflationary pressures [7,8].

The post-pandemic economic recovery has driven a surge in electricity demand in EMEs, with a projected annual growth rate of 3.4% from 2024 to 2026 [9]. This raises the risks of energy crises, exacerbated by ongoing inflation and debt challenges in these economies [9].

South Africa’s electrification of 7.4 million households from 1994 to 2018 significantly increased electricity demand, outpacing supply and eroding the electricity margin [10].

Broadly, EMEs lag behind advanced economies in terms of energy investment, efficiency, and the energy transition. Overall, electricity consumption in EMEs is expected to increase by 85%, primarily driven by the industrial, residential, and transportation sectors, and is projected to rise from its current share of 18% in 2015 to 20% by 2024 [9].

Figure 1 highlights the dominant role of EMEs in driving global energy demand (Source: [9]).



Note: Advanced economies grouping in this chart excludes Mexico and Türkiye.

Figure 1. Year-on-year change in electricity demand by region, 2022–2026.

There are relatively few studies that focus on EMEs, despite a growing literature on the nexus between financial development and electricity consumption [11]. Understanding this nexus is crucial as economies transition from primarily agricultural to more industrialized economies, resulting in fundamental changes in both the energy and financial markets. EMEs interact uniquely with financial development and energy consumption as economies undergo a transformation process [11]. The study investigates the relationship between financial development and electricity consumption in the EMEs using cointegration and causality tests for the period 2000–2020. The research provides key insights into energy policy and development in the context of EMEs.

This study contributes to the literature by addressing post-2020 dynamics (e.g., COVID-19, the Russia–Ukraine conflict), using panel ARDL-PMG and two-step GMM methods, and analyzing a diverse panel of 20 EMEs from 2000 to 2020 [11,12]. Second, the study employed the panel ARDL-PMG approach, in contrast to previous studies that primarily relied on the GMM system or static panel methods. Additionally, the study used a two-step GMM to address potential endogeneity. Third, the study provides updated and policy-relevant information on the coexistence of energy and financial systems in a diverse panel of 20 EMEs from 2000 to 2020.

The rest of the paper is organized as follows: Section 2 constitutes a discussion of the theoretical and empirical literature as applied in this article. Section 3 describes the estimation method, and empirical results are given in Section 4. Section 5 presents the conclusions and recommendations.

2. Review of the Literature

Financial development has three dimensions: depth, access, and efficiency. Deeper markets are more liquid and resilient and attract institutional capital, providing steady project financing and enabling macroeconomic risk diversification [13–17]. It also mobilizes savings and channels them into productive investments, supporting economic growth and

serving as a reliable predictor of future growth [18,19]. However, lack of innovation limits growth in developing countries; see, for example, [10].

Financial development encompasses two categories: quantitative measures (financial prices, product range, and transaction costs) and market-based indicators (depth, access, and efficiency) [20,21]. The study employs the multidimensional financial development index, as developed by [21].

2.1. Theoretical Literature Review

Despite extensive research on the electricity–finance nexus, there is no consensus in the literature. Four hypotheses are proposed regarding the nexus [10,22]:

2.1.1. Financial Development Led Energy Demand Hypothesis

Financial development is a key driver of electricity consumption through facilitating the financing of energy-intensive products at both the corporate and household level [12,23,24]. This view aligns with the supply-leading hypothesis, which posits that financial development stimulates economic activity, leading to increased energy demand [19].

2.1.2. The Energy-Led Financial Development Hypothesis

Higher electricity consumption boosts financial development by increasing financial transactions and demand for services, deepening financial markets [10,25,26].

2.1.3. The Bidirectional Causality Hypothesis

There is a feedback loop, where financial development facilitates efficient allocation of capital into energy markets, which in turn supports economic growth and further financial development [23,27]. This mutual causality aligns with the endogenous growth theory, which posits that financial and energy sectors jointly contribute to sustained long-term economic growth [28].

2.1.4. The Neutrality Hypothesis

No relationship between electricity consumption and financial development in economies with underdeveloped financial markets or constrained energy markets, which thereby hinder industrial activity [29,30].

Significantly, structural factors such as energy efficiency and the sectoral composition of consumption (industrial, residential, or commercial) vary substantially across countries, influencing the interaction between energy use and financial development [31,32].

2.2. Empirical Literature Review

There are mixed findings on the relationship between electricity and finance from empirical studies. Refs. [27,33] found that financial development results in the channelling of funds into energy-intensive industries and infrastructure, increasing electricity demand. Furthermore, the studies by [23,34] emphasize that easy access to credit enables consumers to afford electricity-consuming products, thereby increasing energy consumption. The premise of these findings is that developed financial markets drive electricity consumption by facilitating credit availability and investment.

This is in contrast to other studies, which have found evidence that electricity consumption stimulates financial development through the energy-led financial development hypothesis. According to [26], increased electricity demand stimulates business activity and demand for financial services. Ref [10] further argues that increased electricity demand leads to economic growth, thereby increasing credit demand and investment opportunities.

The findings of [23,27,35] support the bidirectional relationship between financial development and electricity consumption. These studies used the panel cointegration

techniques and Granger causality tests. This bidirectional causality suggests that policies promoting financial sector deepening should consider improvements in the energy sector, and vice versa, to ensure sustainable growth.

In contrast, some studies reject the existence of an electricity–finance nexus, consistent with the neutrality hypothesis, for example [36]. These studies’ findings reinforce the structural differences in economic composition and regulatory frameworks, indicating that the energy and financial markets operate independently. These findings reinforce the fact that financial markets can develop without resulting in increased electricity consumption. In many EMEs, low industrialization levels are among the factors limiting such interactions.

Table 1 below presents a summary of the empirical findings from previous studies.

Table 1. Summary of the financial development-electricity consumption nexus empirical findings.

Authors	Time	Countries	Methodology	Results
[37]	1990–2011	27 EU Countries	Sys-GMM	No effect in the 27 EU countries.
[12]	1990–2006	22 EMEs	Sys-GMM	There is a positive effect when the banking variable is used.
[38]	1960–2000	OECD Countries	VECM	Strong unidirectional causality running from GDP to energy usage
[39]	1965–2009	PIGST Countries	ARDL test	Bidirectional causality between energy and growth, in both the long run and the short run, supports the feedback hypothesis.
[40]	1980–2007	40 SSA countries	Pedroni cointegration test, Granger Causality test	There is a direct relationship between economic growth and energy demand.

Source: Author, 2025.

3. Data and Methodology

3.1. Data and Variables

The study employs annual data for a balanced panel of 20 EMEs. From 2000 to 2020, based on the International Monetary Fund classification and data availability. The primary data sources were the World Development Indicators, the World Bank’s Global Financial Development Database, and the Energy Information Administration. The panel is geographically diverse, capturing different levels of industrialization, electricity access, and financial market maturity. The sample is well-diversified and increases the external validity of the findings while accounting for potential regional heterogeneity. The sample includes the following EMEs: Africa: Egypt, Kenya, Nigeria, and South Africa; Asia and the Middle East: China, India, Indonesia, Iran, Malaysia, the Philippines, Thailand, the United Arab Emirates, and Saudi Arabia; Europe and Eastern Europe: Hungary, Russia, and Turkey; Latin America: Argentina, Brazil, Chile, and Colombia; and North America: Mexico. Table 2 below outlines the variables used in this study.

Table 2. Definition of variables and data sources.

Variable	Definition of Variables	Data Source	Expected Sign
Dependent Variable			
FinDev	The financial development index measures the breadth and depth of financial markets.	World Bank's Global Financial Development Database (2023)	N/A
Independent Variables			
EC	Electricity consumption (billion kWh)	International Energy Agency	+ / −
EG	Real GDP per capita	World Development Indicators	+ / −
FDI	Foreign direct investment	World Development Indicators	+

Source: Author's compilation, 2025.

3.1.1. Panel Unit Root Test

The study employed four main panel unit root tests performed in Stata version 18 (LLC, IPS, ADF-Fisher chi-square, and PP-Fisher chi-square), which were derived from the time series unit root testing and are presented in Table 3. The unit root tests for the panel data are conducted as diagnostic tests to establish the stationarity of the series. Individual unit root tests have low power in panel data sets, and this is further exacerbated by small samples [41,42]; hence, the standard unit root tests are not suitable for this study.

Table 3. (1) Panel unit root test using LLC. (2) Panel unit root tests using IPS. (3) Panel unit root testing using ADF—Fisher Chi-square. (4) Panel unit root testing using PP—Fisher Chi-square.

Variable	No Trend	Intercept and Trend	Individual Effects	Decision
(1)				
EG	−9.00243 ***	−14.1579 ***	−14.8932 ***	I (1)
EC	−5.19401 ***	−3.51018 ***	−3.39410 ***	I (1)
FDI	−3.73481 ***	−3.84931 ***	−3.59057 ***	I (1)
FINDEV	−12.5368 ***	−5.76010 ***	−7.01951 ***	I (1)
(2)				
EG	-	−7.32238 ***	−8.86368 ***	I (1)
EC	-	−4.90339	−6.80038 ***	I (1)
FDI	-	−3.15388 ***	−4.64037 ***	I (1)
FINDEV	-	−6.80194 ***	−8.89608 ***	I (1)
(3)				
EG	162.126 ***	119.625 ***	165.202 ***	I (1)
EC	97.4080 ***	97.5214 **	121.693 ***	I (1)
FDI	58.5960 ***	69.1745 ***	95.5074 ***	I (1)
FINDEV	205.413 **	121.031 ***	155.718 ***	I (1)
(4)				
EG	288.937 ***	183.140 ***	211.156 ***	I (1)

Table 3. Cont.

Variable	No Trend	Intercept and Trend	Individual Effects	Decision
EC	196.560 ***	227.986 ***	279.949 ***	I (1)
FDI	62.4167 ***	99.6138 ***	125.058 ***	I (1)
FINDEV	342.526 ***	282.882 ***	338.690 ***	I (1)

***, and **, indicate that the null hypothesis of unit root tests is rejected at 1%, 5%, and 10%, respectively. All tests are based on first differences (except where indicated otherwise). Probabilities for all the tests assume asymptotic normality except for Fisher tests, which are computed using the asymptotic chi-square distribution. *EC* is the electricity consumption, *FinDev* is the financial development index, *EG* is the gross domestic product per capita, and *FDI* is the foreign direct investment. Source: Author's compilation using Stata, 2025.

The variables are integrated of order one, *I* (1), in all four testing methodologies. This indicates that the variables exhibit non-stationarity in levels but become stationary after first differencing, thereby justifying the need for panel cointegration analysis to determine long-run equilibrium relationships [43]. The findings support further econometric modelling, such as panel VECM or ARDL, to assess dynamic interactions between financial development and electricity consumption in emerging markets [20].

3.1.2. Descriptive Statistics

The financial development index (*FinDev*) ranged from 0.09 to 0.74, with a mean of 0.42 and a standard deviation of 0.14, explaining the disparities in financial development maturity across EMEs. Electricity consumption (*EC*) varied widely, ranging from 3.38 billion kWh to 7115.08 billion kWh per capita. The mean electricity consumption was 385.61 billion kWh, with a high standard deviation of 934.45 billion kWh, indicating wide cross-country disparities. Table 4 below presents the descriptive statistics of the study.

Table 4. Descriptive statistics for 2000–2020 sample.

	Mean	Median	Minimum	Maximum	Std. Dev	Skewness	Kurtosis	Jarque-Bera	Observ
FD	0.42	0.42	0.09	0.74	0.14	0.08	2.39	6.90	419
EC	385.61	123.61	3.38	7115.08	934.45	4.89	28.72	13,216.14	419
EG	8264.37	6141.83	755.48	59,986.44	9618.28	3.51	13.50	4062.22	419
FDI	3.08	219	−40.09	106.60	7.81	7.76	93.34	146,682.60	419

Source: Author's analysis. Descriptive statistics are calculated on all available annual data for the 2000–2020 period. Notes: std. Dev. = standard deviation, Obs = number of observations, *FinDev* = financial development index, *EC* = electricity consumption (billion kWh), *EG* = GDP per capita (Constant 2015 USD), *FDI* = foreign direct investment (net inflows as a % of GDP).

GDP per capita (in constant 2015 US dollars), with a mean of USD 8264.37 and a standard deviation of USD 9618.28. The findings indicate economic heterogeneity within the sample. There was significant volatility in foreign direct investment (*FDI*) inflows among the emerging market economies (EMEs). The mean of 3.08% of GDP, combined with a significant standard deviation of 7.81, clearly indicates this.

3.1.3. Cross-Correlation Analysis

Table 5 reports the correlation coefficients, which measure the strength of the relationships between the variables.

Table 5. Correlation analysis.

Variables	FINDEV	EC	EG	FDI
FINDEV	1			
EC	0.2947 ***	1		
EG	−0.2951 ***	−0.0408	1	
FDI	0.0977 **	−0.0323	−0.0788	1

Source: Author, 2025. Notes: *** and ** indicate statistical significance at the 1% and 5% levels, respectively.

There is a statistically significant but moderate positive correlation ($r = 0.2947$ **) between financial development (*FinDev*) and electricity consumption (*EC*) at the 1% significance level. Among the control variables, a weak negative relationship (-0.2951 ***) exists between financial development (*FinDev*) and economic growth (*EG*). The weak positive correlation between FDI and financial development (0.0977 **) suggests that deeper financial markets may facilitate limited capital inflows.

3.2. Methodology

3.2.1. Empirical Analysis

The study employs the Pooled Mean Group (PMG) estimator within a panel autoregressive distributed lag (ARDL) framework [44–46] to investigate the long-run and short-run dynamics among financial development, electricity consumption, and economic growth in EMEs. The PMG is a suitable estimator, as it allows for heterogeneity in short-run coefficients and error variances while constraining long-run coefficients to be homogeneous across countries. The ARDL-PMG approach offers the following advantages: first, it accommodates variables integrated of different orders ($I(0)$ and $I(1)$), provided none are $I(2)$. Second, it simultaneously estimates short- and long-run relationships. Third, it incorporates immediate impacts and equilibrium adjustment dynamics.

The Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (SBIC) were used to select lag lengths. The Hausman test for the homogeneity of long-run coefficients guided the choice of PMG over the Mean Group (MG) and Dynamic Fixed Effects (DFE) estimators.

3.2.2. Model Specification

The study employs the ARDL and error correction model (ECM) to capture the speed of adjustment in the presence of disequilibrium [44]. This approach enables the capture of both the cointegrating and short-run effects of the variables under study [47]. The following error correction model (ECM) for financial development was tested empirically:

$$\Delta FinDev_{it} = \varnothing_i (FinDev_{i,t-1} - \gamma_{1i} EC_{i,t} - \gamma_{2i} EG_{i,t}) + \sum_{j=1}^{p-1} \delta_{ij} \Delta FinDev_{i,t-j} + \sum_{j=0}^{q-1} \beta_{1i} \Delta EC_{i,t} + \sum_{j=0}^{q-1} \beta_{2i} \Delta EG_{i,t} + \mu_i + \varepsilon_{i,t} \quad (1)$$

where the variables are defined as follows:

- $\Delta FinDev_{it}$ = The change in financial development for country i at time t .
- $\varnothing_i (FinDev_{i,t-1} - \gamma_{1i} EC_{i,t} - \gamma_{2i} EG_{i,t})$ = The error correction term, which captures the long-run equilibrium relationship between financial development (*FinDev*), energy development (*EC*), and economic growth (*EG*). The term $\varnothing_i$ represents the speed of adjustment back to equilibrium.
- $\Delta FinDev_{i,t-j}$ = The lagged changes in financial development, accounting for short-term dynamics.

- $\Delta EC_{i,t}$, $\Delta EG_{i,t}$ = The short-run effects of changes in energy development and economic growth, respectively.
- μ_i = The country-specific fixed effect.
- $\varepsilon_{i,t}$ = The error term or disturbance.

3.2.3. Robustness Check: Two-Step System GMM

The study employed a two-step system Generalized Method of Moments (GMM) estimator for a robustness check to address potential endogeneity from the bidirectional relationship between financial development (*FinDev*) and economic growth (*EG*) as evidenced in the literature [18,19] and our analysis in Table 5, in which economic growth is treated as a dependent variable. This simultaneity violates the exogeneity assumption of the ARDL-PMG model, leading to biased estimates. The system GMM addresses simultaneity by using lagged levels and differences of *FinDev* and *EG* as instruments, following the methodologies established by [48]. The GMM model is specified as follows:

$$\Delta FinDev_{it} = (\alpha - 1)\Delta FinDev_{i,t-1} + \beta_1 \sum_{i=1}^n \Delta EC_{it} + \beta_2 \sum_{i=1}^n \Delta EG_{it} + \beta_{3it} \sum_{i=1}^n \Delta X_{it} + \beta_4 \sum_{i=1}^n DummyCovid_{it} + \beta_5 \sum_{i=1}^n DummyGFC_{it} + \Delta \varepsilon_{i,t} \quad (2)$$

where L. *FINDev*_{it} and L.*EG* are lagged values of financial development and economic growth, respectively. The Hansen test for instrument validity and the Arellano-Bond test for autocorrelation were conducted to ensure the robustness of the GMM estimates. Results from the GMM model are reported in Table 5 alongside the ARDL-PMG estimates to confirm the reliability of the causal inferences.

3.2.4. Diagnostic Tests and Their Implications

The diagnostic tests confirmed the validity of the estimated models. The Pooled Mean Group (PMG) estimator was supported by the Hausman test, which favored it over the Mean Group (MG) or Dynamic Fixed Effects (DFE) estimators under the null hypothesis of consistency for both, producing *p*-values below 0.05 in all cases and confirming the homogeneity of long-run coefficients. There is no evidence of residual correlation across countries, as indicated by a non-significant cross-sectional dependence test. Second-order serial correlation was ruled out through the Arellano-Bond tests, which showed significant AR (1) autocorrelation as expected in first-differenced models but non-significant AR (2) results. The Sargan and Hansen tests were both non-significant, thus confirming the validity of the instruments used in the system GMM estimation.

4. Discussion

The study provides empirical evidence of the relationship between financial development and electricity consumption, with economic growth and FDI as control variables in the EMEs, through panel cointegration analysis and an error correction model (ECM). The findings are summarized as follows:

4.1. Error Correction Model

The error correction term (ECT) confirms cointegration and the existence of a stable long-run relationship among the variables. The ECTs for the financial development and electricity consumption models are -0.299 and -0.0538 , respectively. This implies that 29.9% of deviations from the financial development equilibrium and 5.38% from the electricity consumption equilibrium are corrected per period, consistent with the initial findings of [43,49,50].

4.2. Long-Run Relationships

The long-run coefficients indicate that the dependent variables (D.FinDev, D.EC, D.EG, D.FDI) are influenced by the explanatory variables. The models in each column of Table 6 show this. Detailed results are outlined in Appendix A (Tables A1–A4).

Table 6. Pooled Mean Group (PMG) long-run and short-run estimates for the electricity consumption–financial development nexus and robustness check using two-step system GMM.

	PMG	PMG	PMG	PMG	2-Step System GMM
Variables	D.FinDev	D.EC	D.EG	D.FDI	FinDev
Long-Run					
EG	0.0143 ** (−3.27)	1.325 *** (9.88)		−0.0459 (−0.40)	0.0105 ** (0.00407)
EC	0.251 *** (11.34)		1.596 *** (4.59)	0.846 (1.04)	0.0552 ** (0.0204)
FinDev		0.0428 (1.80)	2.422 (1.65)	−3.231 (−1.56)	0.532 *** (0.116)
FDI	0.00109 (1.06)	0.0394 *** (3.97)	0.0120 (0.95)		0.000201 *** (0.0000531)
ECT	−0.299 *** (−5.33)	−0.0538 *** (−3.29)	−0.125 *** (−3.80)	−0.589 *** (−8.57)	
Short-Run					
D.EG	0.0226 (1.04)	−0.0573 (−1.19)		−0.226 (−0.14)	
D.EC	−0.249 * (−2.45)		0.664 (0.67)	3.677 (0.53)	
FinDev		−0.00642 (−0.21)	−0.896 (−0.83)	12.18 (1.12)	
D. FDI	0.000450 (0.34)	−0.00255 (−1.30)	0.0123 (0.71)		
_cons	0.00570 (0.47)	0.0783 *** (3.69)	0.0990 (1.23)	1.775 * (2.49)	
Dummy1					0.00432 (0.00497)
Dummy2					0.0205 *** (0.00333)
N	399	399	399	399	359
Groups	-	-	-	-	20
Instruments	-	-	-	-	14
Arellano Bond AR 1	-	-	-	-	−2.97
Arellano Bond AR 2	-	-	-	-	−0.51
Sargan Test					41.38

Table 6. Cont.

	PMG	PMG	PMG	PMG	2-Step System GMM
Variables	D.FinDev	D.EC	D.EG	D.FDI	FinDev
Hansen Test	-	-	-	-	9.69
Hausman	44.75 ***	39.55 ***	64.80 ***	9.42 *	

Source: Author's compilation using STATA. Notes: Standard errors or t-statistics in parentheses ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. PMG = Pooled Mean Group estimator; GMM = two-step system GMM with Windmeijer-corrected standard errors; ECT = error correction term; EC = electricity consumption (billion kWh); EG = GDP per capita; FinDev = financial development index; FDI = foreign direct investment (% of GDP; Dummy1 = post-COVID-19 (2020 onwards); Dummy2 = global financial crisis (2009–2010).

Electricity consumption (ED) on financial development (FinDev): The coefficient is positive and significant at 0.251 ***. A unit increase in electricity consumption leads to a 2.51% increase in financial development. This suggests that electricity access deepens financial markets in EMEs. Energy markets play a key role in deepening financial markets, banking penetration, and capital accumulation, consistent with empirical findings by [51–53].

Financial development (FinDev) on electricity consumption (EC): Financial development has a positive but insignificant effect on electricity consumption with a coefficient of 0.0428 ($p > 0.05$, $t = 1.80$). While financial development is critical for energy infrastructure investment, its long-run impact is not robust.

Economic growth (EconGR) on electricity consumption (EC): Economic growth significantly affects electricity (EC), as indicated by a positive coefficient of 1.325 ***. Economic growth leads to increases in output and consumption, thus driving electricity consumption.

FDI effects: significantly influences electricity consumption but has no significant effect on financial development or economic growth. The FDI model shows weaker long-run relationships, with no significant coefficients for the explanatory variables.

4.3. Short-Run Relationships

Electricity consumption (D.EC) on financial development (D.FinDev): The short relationship between electricity consumption negatively affects financial development in the short run. This differs from the long-run findings, as in the short term, electricity consumption harms financial development. This may be due to the diversion of resources from the financial sector [12].

Financial development (Fin_Dev1) on electricity consumption (D.EC): The effect is negative and insignificant (coefficient = -0.00642 , $p > 0.05$, $t = -0.21$), indicating no robust short-run impact.

The short-run results reveal transitional frictions in EMEs, where energy market changes take time to translate into financial market responses.

4.4. Structural Considerations and Sectoral Heterogeneity

Although the results confirm a positive long-run relationship between electricity consumption and financial development in emerging market economies (EMEs), the present study does not disentangle the structure or efficiency of electricity use. This omission has a significant impact, as the electricity consumption structure can affect its relationship with financial markets. In economies dominated by energy-intensive heavy manufacturing, such as Russia, an increase in electricity demand is not directly linked to financial systems [54]. Conversely, in service-oriented or tech-driven economies, for example, parts of Southeast Asia, there may be a substantial finance-energy nexus because electricity growth is driven by sectors closely linked to financial markets. The composition of foreign direct

investment (FDI) inflows may further shape the electricity–finance nexus if capital targets energy infrastructure rather than extractive or manufacturing sectors [55–58]. The use of aggregate country-level data has a problem of hiding these structural differences. This study establishes the broad long-run nexus; sector-specific and efficiency-related patterns may differ significantly across economies.

4.5. Implications for Future Research

Future research should consider the following: First, identify sector-specific finance–energy linkages by disaggregating electricity consumption into industrial, residential, and service sectors. Second, incorporate energy efficiency and technological adoption to capture the quality, rather than the quantity, of energy use. Third, expand the study sample to include advanced economies for a comparative basis to test the universality or context-specific nature of the findings. Finally, test regional heterogeneity to investigate whether geographic and institutional factors moderate the energy–finance nexus.

5. Conclusions and Policy Implications

This study is a significant contribution to the electricity finance discourse, as it provides robust empirical evidence from a sample of 20 emerging market economies (EMEs) over the period 2000–2020. The study employed panel cointegration and error correction techniques. The results of the analysis reveal a significant long-run positive relationship between electricity consumption and financial development. A two-step system GMM was used to address endogeneity and simultaneity bias and confirmed the persistence of the significant positive relationship.

The results have significant policy implications, as they underscore the importance of energy infrastructure investments in supporting the expansion of the financial sector in EMEs. The degree and significance of the coefficients imply that improvements in electricity availability and reliability can directly enhance financial sector depth and stability, while sustained economic growth reinforces these gains.

In light of these empirical insights, policymakers in EMEs should prioritize targeted actions. First, EMEs should channel resources toward energy–finance infrastructure. Electricity grid modernization, renewable energy expansion, and intelligent metering systems will directly strengthen financial development. Second, innovative energy finance products are crucial for harnessing the potential benefits of this nexus. Green bonds, energy efficiency credit lines, and public–private partnerships can both finance energy projects and catalyze broader economic growth. Third, cross-border electricity trade and harmonized regulatory frameworks can reduce dependence on volatile domestic supply, thereby stabilizing the financial sector by mitigating energy price fluctuations. Fourth, extending microfinance and mobile banking to newly electrified areas can amplify development gains. Finally, policy interventions should focus not only on expanding electricity access but also on improving the efficiency and sectoral allocation of electricity use. For EMEs, this could involve incentivizing high-productivity sectors, promoting energy-efficient technologies, and linking power sector planning with financial sector strategies. This integrated approach can ensure that increases in electricity consumption yield sustainable and inclusive financial development.

By grounding these recommendations in the statistically significant relationships identified in the analysis, policymakers can design interventions that address immediate infrastructure needs while promoting financial sector growth. These measures are particularly urgent in the context of post-COVID-19 recovery and global energy market volatility, where coordinated energy–finance strategies can enhance resilience, security, and inclusivity.

Despite the robustness of the findings, certain limitations should be acknowledged. First, although the panel ARDL–PMG and GMM estimators control for heterogeneity and endogeneity, unobserved structural differences across countries (e.g., institutional quality, political stability) may still bias results. Second, aggregating EMEs into a single panel may obscure critical regional variations, as energy and financial systems evolve differently in Asia, Africa, and Latin America. Third, as the dataset ends in 2020, the analysis does not fully capture the post-COVID-19 recovery phase or recent energy price shocks. Future research could expand the dataset, incorporate additional institutional and environmental variables, and examine region-specific or sectoral models to refine the understanding of the electricity–finance nexus.

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Appendix A

Table A1. Causal and cointegrating relationships—FinDev.

	PMG D.FinDev	MG D.FinDev	DFE D.FinDev
Long-Run			
EG	−0.0143 ** (−3.27)	−0.163 * (−1.96)	0.0129 (1.40)
EC	0.251 *** (11.34)	0.694 ** (3.17)	0.266 *** (5.69)
FDI	0.00109 (1.06)	0.00658 (1.51)	0.00169 (1.43)
ECT	−0.299 *** (−5.33)	−0.559 *** (−8.61)	−0.215 *** (−7.09)
Short-Run			
D.EG	0.0226 (1.04)	0.0877 * (2.22)	−0.00439 (−1.08)
D.EC	−0.249 * (−2.45)	−0.325 *** (−3.95)	−0.0197 (−0.33)
D.FDI	0.000450 (0.34)	−0.00112 (−0.77)	−0.000232 (−1.03)
_cons	0.00570 (0.47)	−0.0218 (−0.15)	−0.0422 (−1.66)
N	399	399	399

t statistics in parentheses; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table A2. Causal and cointegrating relationships—EG.

	PMG D.EG	MG D.EG	DFE D.EG
ECT			
FinDev	2.422 (1.65)	5.084 (0.69)	0.487 (0.18)
EC	1.596 *** (4.59)	−0.115 (−0.05)	−0.410 (−0.35)
FDI	0.0120 (0.95)	0.159 (0.99)	0.0203 (0.92)
SR			
ECT	−0.125 *** (−3.80)	−0.423 *** (−10.70)	−0.143 *** (−6.01)
D.FinDev	−0.896 (−0.83)	−1.157 (−0.76)	−0.317 (−0.51)
D.EC	0.664 (0.67)	1.296 (1.11)	−0.296 (−0.40)
D.FDI	0.0123 (0.71)	0.000636 (0.03)	−0.00254 (−0.91)
_cons	0.0990 (1.23)	1.470 (0.88)	0.879 ** (2.82)
N	399	399	399

t statistics in parentheses; ** $p < 0.01$; *** $p < 0.001$.

Table A3. Causal and cointegrating relationships—ED.

	PMG D.EC	MG D.EC	DFE D.EC
ECT			
FinDev	1.325 *** (9.88)	−1.195 (−0.49)	0.605 (1.51)
EG	0.0428 (1.80)	0.293 (1.86)	−0.00245 (−0.08)
FDI	0.0394 *** (3.97)	−0.0169 (−1.18)	−0.0000985 (−0.03)
SR			
ECT	−0.0538 *** (−3.29)	−0.193 *** (−4.22)	−0.0578 *** (−5.23)
D.FinDev	−0.0573 (−1.19)	−0.118 (−1.39)	−0.00825 (−0.19)
D.EG	−0.00642 (−0.21)	−0.0604 (−1.45)	−0.00151 (−0.44)
D.FDI	−0.00255 (−1.30)	−0.000947 (−0.57)	0.0000484 (0.25)
_cons	0.0783 *** (3.69)	0.0779 (0.51)	0.126 *** (6.13)
N	399	399	399

t statistics in parentheses; *** $p < 0.001$.

Table A4. Causal and cointegrating relationships—FDI.

	PMG D.FDI	MG D.FDI	DFE D.FDI
ECT			
FinDev	−3.231 (−1.56)	13.86 (1.69)	−5.132 (−0.37)
EG	−0.0459 (−0.40)	4.792 (1.47)	0.283 (0.33)
EC	0.846 (1.04)	40.34 (0.85)	2.386 (0.41)
SR			
ECT	−0.589 *** (−8.57)	−0.842 *** (−11.45)	−0.700 *** (−10.67)
D.FinDev	12.18 (1.12)	−0.872 (−0.22)	15.24 (1.01)
D.EG	−0.226 (−0.14)	−1.929 (−1.26)	0.0108 (0.01)
D.EC	3.677 (0.53)	−7.589 (−0.42)	3.628 (0.21)
_cons	1.775 * (2.49)	−63.98 (−1.11)	−1.015 (−0.13)
N	399	399	399

t statistics in parentheses; * $p < 0.05$ and *** $p < 0.001$.

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