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Navigating the Energy Intensity Landscape: The Role of Financial Development in Middle-Income Countries

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Abstract:

This study empirically investigates how financial development dynamically affects energy intensity across 71 middle-income countries (MICs) between 1990 and 2021. MICs, significant contributors to global population and output, face escalating energy demand due to rapid industrialization and urbanization, necessitating a deeper understanding of energy efficiency drivers. The research also controls for trade openness, industrial value added, and economic growth. The two-step System Generalized Method of Moments (System GMM) dynamic panel data methodology is used in this study, effectively managing unobserved heterogeneity and endogeneity to yield robust and reliable results. The study's results indicate a significant reduction in energy intensity due to financial development over both the short and long terms. Additionally, economic growth contributes to this decline, whereas trade openness and industrial value-added are associated with higher energy intensity. These results underscore the critical importance of strengthening financial systems and market infrastructure. Such development is crucial for providing sufficient and stable financing for clean energy and energy efficiency projects, supported by targeted financial incentive policies. These measures can significantly accelerate MICs' transition to cleaner, more efficient energy patterns, thereby fostering sustainable development.

Keywords: Energy Intensity, Financial Development, GMM system, MICs

1. Introduction

Global economic development is currently faced with the dilemma of maintaining stable economic growth while addressing the challenges of the energy and environmental crises. As global economic activity and population increase, energy consumption rises rapidly. Middle-income countries (MICs) are an interesting focus in this case. Middle-income countries (MICs) play a central role in the global landscape as they account for around 75% of the world's population and are home to 62% of the global poor (UN SDG, 2024). Economically, MICs contribute substantially to global output, with a Gross Domestic Product (GDP) of 36,88 trillion USD, representing about one-third of the total global GDP of 106,17 trillion USD in 2023 (The World Bank, 2024). MICs are also undergoing rapid industrialization and urbanization. These processes increase energy demand, which leads to high energy intensity. Energy intensity is measured as the ratio of energy consumption to GDP, indicating the efficiency of energy use in generating economic output. Data from the Energy Information Administration (EIA) (2023) shows that in 2021, primary energy intensity per GDP in MICs reached 4,93 MJ/$2017 PPP GDP. Interestingly, despite MICs' efforts to improve energy efficiency, the average energy intensity of these countries is in the middle, higher than high-income countries at 4,08 MJ/$2017 PPP GDP but lower than low-income countries at 7,16 MJ/$2017 PPP GDP. Nonetheless, irrespective of its position, this inefficient energy consumption pattern risks accelerating resource depletion, increasing greenhouse gas emissions, and worsening environmental issues. This ultimately jeopardizes the prospects for sustainable development. Consequently, reducing energy intensity is vital for addressing climate change, safeguarding national energy security against global price fluctuations, enhancing economic competitiveness, and achieving Sustainable Development Goals (SDGs) 7 and 13.

Achieving sustainable development and energy security necessitates thoroughly examining factors impacting energy intensity. In contemporary economies, financial development is a critical element that molds energy consumption behaviors. A mature financial system, operating through its banking sector and capital markets, is fundamentally expected to enable efficient capital allocation, spur investment, and support innovation (Chen et al., 2019). Achieving sustainable development and energy security necessitates thoroughly examining factors impacting energy intensity. In contemporary economies, financial development is a critical element that molds energy consumption behaviors. A mature financial system, operating through its banking sector and capital markets, is fundamentally expected to enable efficient capital allocation, spur investment, and support innovation (Yakubu et al., 2024).

Financial development can influence energy intensity through several key channels within the energy sector. Firstly, improved access to financing can stimulate investment in more efficient production technologies, including renewable energy solutions. Secondly, enhanced economic activity, often fueled by financial development, particularly in heavy industries, might paradoxically lead to increased energy consumption. However, in high-income and non-OECD countries, financial development has been observed to effectively lower energy intensity by promoting investment in low-energy technologies (Canh et al., 2020; Chen et al., 2019). The literature presents a mixed view on the relationship between financial development and energy intensity. For instance, Donou-addons et al. (2025)) suggest that financial markets can increase energy intensity, a finding echoed by Sadorsky (2010) in developing countries, where financial expansion may hinder energy intensity reduction efforts. Furthermore, the impact of financial development is time-dependent; it might initially raise intensity but later decrease with R&D (Jafary et al., 2024), or its significance could diminish due to financial sector volatility (Feng et al., 2024). These varied effects underscore a fundamental dilemma: how to effectively balance the pursuit of economic growth, often spurred by financial development, with the crucial goal of achieving energy efficiency. Given their substantial reliance on conventional energy sources, this is a remarkably complex challenge for middle-income countries (MICs).

Results from various studies also reveal that the observed relationships are often ambiguous and strongly influenced by a region's specific conditions and geographical context. For example, differences in development effects in the context of developing countries, such as Adom et al. (2020) in Ghana, Ma & Fu (2020) in developing countries, and Yakubu et al. (2024) in the MENA region. In addition, the endogeneity issue that financial development may be affected by energy intensity or that there are unobserved variables that may affect both is often not adequately addressed in previous studies. For example, Wen et al. (2023) used the continuously updated and fully modified (CUP-FM) approach, Adom et al. (2020) used the FMOLS method to see the long-term influence on energy intensity, and the Panel Smoothing Transition regression (PSR) method used by Jafary et al. (2024). Previous studies rarely address the dynamic interaction and potential endogeneity between financial development and energy intensity. This gap needs to be filled for a more accurate understanding of policy implications.

This study addresses a research gap by examining the relationship between financial development and energy intensity in middle-income countries (MICs). This research focuses on the long-term dynamic effects, using a comprehensive 30-year dataset (1995-2023) and the System Generalized Method of Moments (System GMM) to handle endogeneity and dynamic influences. Targeting MICs offers critical insights into how financial systems interact with energy use during their economic and energy transitions, enabling the design of context-appropriate policies. Ultimately, our findings will clarify how financial development shapes energy intensity, guiding countries to develop strategies for sustainable economic growth and climate change mitigation.

2. Literature Review

Energy Intensity and Financial Development

Energy intensity is a crucial metric for evaluating energy use efficiency, applicable to both production processes and broader economic output (Engell et al., 2019; Hossfeld et al., 2024). It is quantified as energy consumed per production unit in industrial settings, acting as a key performance indicator. When considering economic output, energy intensity is measured as the energy used per unit of Gross Domestic Product (GDP), reflecting an economy's overall energy efficiency. A lower energy intensity figure signifies greater energy efficiency, as less energy is needed to generate each unit of GDP (Sim & Sek, 2024). Financial development encompasses enhancing and expanding a nation's financial institutions, markets, and overall financial system (Mollaahmetoğlu & Akçalı, 2019). This concept is vital for enabling efficient resource allocation, fostering economic growth, and improving financial stability. As outlined by Svirydzenka (2016), its core dimensions include the depth (size and liquidity of financial markets relative to the economy), accessibility (ease with which individuals and businesses obtain financial services like credit, savings, and insurance), and efficiency (effectiveness in resource allocation and risk management, considering intermediation costs and institutional performance) of financial entities.

Based on the Financial Sector Assessment Handbook from IMF (2005) efficient financial development will affect energy use in several mechanisms (1) Increased energy investment and infrastructure, a strong and developed financial system will facilitate the funding of energy infrastructure projects, such as power generation, transmission, and distribution, thereby increasing national energy capacity and efficiency, (2) Access to Credit for clean energy technology, access to finance allows investors and energy companies to access capital for clean energy technology and energy efficiency, which can change energy use patterns and intensity, (3) Increased access to financial services will improve energy consumption and distribution patterns. With access to financial services (e.g., microcredit, insurance, savings accounts), companies and households can make investments in more efficient energy, such as installing solar panels at home or upgrading industrial machinery and equipment to be more energy efficient, (4) Financial development can support the implementation of energy policies oriented towards reducing energy intensity, such as clean energy subsidies or market-based incentive mechanisms, by providing the financial infrastructure necessary for the implementation of these policies.

Referring to endogenous growth theory, technological innovation and human capital development are the main drivers of long-term economic growth. The role of financial development here is to facilitate the process; by allocating financial assistance to productive projects, the financial system can effectively reduce the cost of risky financing (Hussein et al., 2025; Mohamed et al., 2022; Yeo & Lee, 2020). This creates an environment conducive to the investment needed for sustainable growth. Financial development can generate engineering effects (reduction in energy intensity through technological improvements) his creates an environment conducive to the investment needed for sustainable growth. Financial development can generate engineering effects (reduction in energy intensity through technological improvements) (Chen et al., 2019; Emir, 2022; Uddin et al., 2022). For example, for MSMEs that initially struggle to access financing to adopt new technologies or improve energy efficiency, financial development can relax these constraints and enable them to invest in more efficient equipment. Specific policies issued by the financial sector to create financial institution efficiencies and promote green financing can help reduce the impact of high energy intensity (Adom et al., 2020; Wen et al., 2023). Assi et al. (2020) also mentioned that financial development reduced energy intensity in countries with high economic freedom. From the explanation of the concept of financial structure and several previous studies, the following research hypothesis is generated:

H1: Financial development has a negative influence on energy intensity

3. Method

To investigate the effect of financial development on energy intensity within middle-income countries (MICs), this study utilizes a quantitative empirical framework outlined herein. The analysis relies on panel data from a chosen cohort of MICs, covering the years 1995 to 2023. The consistent availability and accuracy of comprehensive data for all relevant variables primarily drove the selection of this timeframe. Similarly, 71 MICs were selected as the research object due to their consistent data availability throughout the entire study period and to ensure robust statistical power, representing a broad and relevant sample of this economic group. Data were meticulously collected from reputable international databases, including the Energy Information Administration (EIA), the International Monetary Fund (IMF), and the World Bank. Table 1 presents detailed information about the variables utilized in this study

Table 1. Variable Definition

Variable	Operational Definition	Unit	Source
Energy Intensity (IE)	The ratio of primary energy consumption to Gross Domestic Product (GDP)	MJ/$2017 PPP GDP	Energy Information Administration (EIA), World Bank
Financial Development Index (FD)	A composite index reflecting the depth, access, and efficiency of a country's financial institutions and markets.	Index	International Monetary Fund (IMF)
Trade Openings (TO)	Total trade (exports plus imports) as a percentage of GDP	% of GDP	World Bank
Industry Value Added (INDS)	Industry (including construction) value added as a percentage of GDP	% of GDP	World Bank
GDP Growth (GROWTH)	Annual percentage growth rate of Gross Domestic Product.	%	World Bank

The research model was constructed by integrating and adapting specifications from Jafary et al. (2024) and Y. Ma et al. (2022). These studies were the foundation for formulating a dynamic panel model to analyze the relationship between financial development and energy intensity. In this study, energy intensity is selected as the dependent variable; financial development is the primary independent variable; and industrial value added, trade openness, and economic growth function as control variables.

The System Generalized Method of Moments (System GMM) is chosen for estimation due to its distinct advantages in addressing key econometric challenges inherent in dynamic panel data. First, this method effectively handles the potential endogeneity between independent and dependent variables (Arellano & Bond, 1991), which is crucial given that financial development and energy intensity might exhibit bidirectional causality. Second, System GMM is adept at capturing the dynamic nature of energy intensity, where previous levels significantly influence its current level. Most importantly, System GMM is preferred over the simpler Difference GMM estimator because System GMM overcomes the problem of weak instruments and reduces finite-sample bias, especially when the dependent variable (energy intensity) is highly persistent or approximates a random walk (Blundell & Bond, 1998). While Difference GMM is effective for endogeneity, it tends to be less efficient when instruments are weak, which often occurs with highly persistent macroeconomic data. Thus, applying System GMM is expected to yield more robust and reliable estimates, providing stronger inferences about the complex relationship under investigation. The general form of the model to be estimated is as follows:

$$\mathrm{IE_{it}} = \beta_0 + \beta_1 \mathrm{IE_{it-1}} + \beta_2 \mathrm{FD_{it}} + \beta_3 \mathrm{TO_{iT}} + \beta_4 \mathrm{INDS_{it}} + \beta_5 \mathrm{GROWTH_{it}} + \mathrm{a_i} + \delta_t + \epsilon_{\mathrm{it}} \qquad (1)$$

where, IE_{it} the energy intensity for a i country in a t year, including IE_{it-1} as a lagged variable, captures the energy intensity dynamics. FD is a financial development index variable, TO is a trade openness variable, INDS is an industry variable, and GROWTH is economic growt, a_i is an unobserved individual (country) specific effect that is time-invariant, δ_t is a time-specific effect that controls for standard shocks that affect all countries in a given period, and ϵ_{it} is the error

The GMM method consists of the first difference and system GMM, where the system GMM is more robust in overcoming weak instruments than the first difference method. Furthermore, the GMM system, especially the two-step model, can provide efficient results and is more robust to autocorrelation and heteroscedasticity than the one-step model (Blundell & Bond, 1998; Roodman, 2009). In order to determine the validity of the System, GMM estimates will be evaluated through a series of diagnostic tests, namely (Blundell & Bond, 1998; Fukase, 2010).

(1) The Sargan/Hansen test is intended to test the validity of over-identifying restrictions (null hypothesis: the instrument used is valid). A non-significant p-value (generally > 0.10) is desired to confirm the instrument's validity. (2) The Arellano-Bond Autocorrelation Test (AR(1) and AR(2)) is aimed at testing the presence of autocorrelation in the error term. It is expected that there is first-order autocorrelation (AR(1) is significant), but there should be no second-order autocorrelation (AR(2) is insignificant) for the GMM estimation to be consistent.

4. Findings and discussion

The analysis starts with presenting descriptive statistics for all variables included in this study. The comprehensive panel dataset, comprising 71 Middle-Income Countries (MICs) from 1990 to 2021, yielded 2,272 observations. Energy Intensity (EI) had an average value of 1.599 with a standard deviation of 1.3535, indicating substantial variability across observations. The wide range of EI values, from a minimum of 0.14 to a maximum of 13.82, further highlights the heterogeneity in energy use efficiency among these MICs.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Median	Std. Dev	Minimum	Maximum	Skewness	Kurtosis
IE	2.272	1,599027	1,165	1,352543	0,14	13,82	0,0000	0,0000
FD	2.272	0,251919	0,21	0,1965419	0	0,86	0,0000	0,1221
TO	2.272	75,93927	72,01	35,25577	-2,99	224,15	0,0000	0,0000
INDS	2.272	30,75872	28,24	13,02483	2,76	126,3	0,0000	0,0000
GROWTH	2.272	3,731083	4,2	7,390684	-50,34	149,97	0,0000	0,0000

Source: Processed Data (2025)

On the primary independent variable, Financial Development (FD), the average index stands at 0,252 with a standard deviation of 0,197. The minimum value of this variable is from 0 to 0,86, with 0 indicating a low level of financial development and higher values indicating a higher level of development. Meanwhile, trade openness (TO) shows a high average of 75,94% of GDP, with a significant variation (standard deviation 35,26) and a range of extreme values from -2,99% to 224,15%, indicating the importance of economic integration for most MCIs.

The variable industry (INDS) contribution to GDP has an average of 30,76% with a standard deviation of 13,02, confirming the industrial sector's substantial role as an economic driver in the region. Finally, economic growth (GROWTH) shows an average annual growth of 3,73%. However, the high standard deviation (7,39) and extensive range (-50,34% to 149,97%) underscore economic growth's significant volatility and disparity among middle-income countries during the study period. Skewness and Kurtosis analysis for all variables recorded 0,0000 or close, indicating a relatively symmetrical data distribution.

A correlation test was performed to provide an initial understanding of the direction and strength of the bivariate linear relationships among variables, preceding estimating a more complex econometric model. Table 3 displays the Pearson correlation matrix for the variables used in this study. The correlation coefficient, ranging from -1 to 1, indicates the relationship's strength and direction. Coefficients approaching 1 signify a strong correlation, whereas values near 0 suggest a weak or negligible correlation (Patil & Franken, 2022; Yay, 2022). For practical interpretation, correlations below 0.3 are generally considered either insignificant or very weak.

Table 3. Correlation Matrix

Variable	IE	FD	TO	INDS	GROWTH
IE	1,0000				
FD	0,0232	1,0000			
TO	0,1467	0,0582	1,0000		
INDS	0,0959	-0,1098	0,3078	1,0000	
GROWTH	-0,1766	-0,0340	0,0770	0,2025	1,0000

Source: Processed Data (2025)

Based on Table 3, the variables used in the study have a low to moderate correlation, such as the trade openness (TO) variable of 0.3078. The value between these variables generally does not indicate a multicollinearity problem. However, the GMM analysis that will be conducted can provide more robust estimation results related to the potential problem, except for the relationship between a variable and itself, which shows a value of 1.

This study incorporates a pre-estimation test—specifically, the Pedroni Panel Cointegration Test—before conducting the dynamic model analysis using System GMM. The primary purpose of the Pedroni Test is to ascertain whether a cointegrating relationship exists among energy intensity, financial development, and the control variables. Detecting cointegration is crucial, as it signifies a long-run equilibrium relationship between these variables, thereby supporting the appropriateness of a dynamic model analysis (Neal, 2014; Petrova, 2020).

Table 4. Pedroni test

	Statistic	**p-Value**
Modified Phillips-Perron t	3,5273	0,0002
Phillips-Perron t	-3,8444	0,0001
Augmented Dickey-Fuller t	-2,3813	0,0086

Source: Processed Data (2025)

Table 4 displays the results of the Pedroni Panel Cointegration Test. The p-values for all three statistics (Modified Phillips-Perron t, Phillips-Perron t, and Augmented Dickey-Fuller t) are 0.0002, 0.0001, and 0.0086, respectively. Since these p-values are well below the 0.05 (and even 0.01) significance level, the null hypothesis of no cointegration is rejected. This confirms that the variables in this study share a stable, long-run equilibrium relationship. Cointegration is validated using a dynamic panel data model, specifically System GMM, which can capture both short-run dynamics and long-run convergence.

Following this, the dynamic panel model was estimated using the System GMM. This approach handles potential endogeneity and individual-specific effects within the relationship between financial development and energy intensity in MICs. Table 5 summarizes the short-run estimated coefficients, standard errors, z-statistics, p-values, and diagnostic test results.

Table 5. GMM Two-Step System Estimation Results

Dependent Variable	**Sys. GMM**			
IE	**Coefficient**	**Std. err.**	**z**	**Prob.**
IEt-1	0,9318799***	0,0006577	1416,78	0,000
FD	-0,1065297***	0,0190032	-5,61	0,000
TO	0,0001645***	0,0000397	4,14	0,000
INDS	0,0038551***	0,000094	41,01	0,000
GROWTH	-0,0136497***	0,0000717	-190,40	0,000
Constant	0,0267382***	0,007044	3,80	0,000
Wald Test	1,64e+07***			
Number of Obs	2.201			
Number of Groups	71			
Sargan	67,27178			
Sargan Prob.	1,0000			
AR(1)	-1,7247			
AR(1) Prob.	0,0846			
AR(2)	1,0285			
AR(2) Prob.	0,3037			

Note: ***, ** and * indicates significant at 1%, 5% and 10% level of significance based on t-statistics
Source: Processed Data (2025)

As shown in Table 5, the lagged dependent variable (IEt-1) has a coefficient of 0.93, which is statistically significant at the 1% level (p-value 0.000). This positive coefficient indicates strong persistence in energy intensity across MICs; last year's energy intensity significantly and positively influences the current year's level. Furthermore, the Financial Development (FD) variable exhibits a coefficient of -0.11 with a p-value of 0.0000 (well below the 1% significance level). This suggests that an increase in financial development significantly reduces energy intensity in the short run. Quantitatively, a one-unit increase in the financial development index is associated with an approximate 0.107 unit decrease in energy intensity, assuming other factors remain constant. This finding supports the notion that financial development in MICs plays a crucial role in enhancing energy use efficiency.

Related control variables such as trade openness (TO), Industry (INDS), and economic growth (GROWTH) also show a significance level of 1% but have different directions of influence on energy intensity. The coefficient of Trade Openness (TO) is 0,0001645, and the coefficient of Industry is 0,0038551, meaning that trade openness and Industry can increase energy intensity in the short term. At the same time, Economic Growth (GROWTH) shows the opposite direction of influence. Economic growth is significantly negatively correlated with energy intensity in the short term. As the economy grows, there is a shift towards more efficient sectors or the adoption of better technology. The constant coefficient of 0,0267382 (significance 0,0000<α=1%) represents the baseline value of energy intensity when all explanatory variables are zero.

To confirm the validity of the GMM results, both the Sargan Test and the Arellano-Bond Autocorrelation Test were performed. The Sargan test's p-value of 1.000, greater than 0.05, confirms the instruments' validity. For the Arellano-Bond tests, the p-value for AR(1) is 0.0846, which is significant at the 10% level, indicating first-order autocorrelation in the differenced error term. Crucially, the AR(2) p-value is 0.3027, which is insignificant (greater than 0.10), confirming the absence of second-order autocorrelation in the error term and thus supporting the consistency of the GMM estimator.

Due to the nature of the dynamic model in PLS estimation, it tends to provide upward-biased coefficients, while FEM tends to be downward-biased. The GMM system is designed to provide unbiased and consistent estimates, so further tests are needed to strengthen the reliability of the GMM system results by comparing the coefficient of the lagged dependent variable (IEt-1) with the PLS and FEM models.

Table 6. Comparison of Lag Coefficients of Dependent Variables with PLS, Two-Step System GMM and FEM Methods

Variables	Coefficient		
	Pooled Least Square (PLS)	**Two-Step System GMM**	**Fixed Effect Model**
IEt-1	0,94069956	0,93187991	0,91435765

Note: ***, ** and * indicates significant at 1%, 5% and 10% level of significance based on t-statistics
Source: Processed Data (2025)

Table 6 shows that the lag variable coefficient of PLS (0,94069956) is higher than that of System GMM (0,93187991), and the coefficient of FEM (0,91435765) is lower than that of System GMM. The GMM coefficient falls between the two biased methods, which is consistent with the known biased nature (PLS tends to be upward biased and FEM downward biased) of dynamic models. This position reinforces confidence in the reliability of GMM estimates, as the method is theoretically designed to produce unbiased and consistent estimates for dynamic models with endogeneity.

Based on the short-term GMM system estimation, the long-term effects of the independent variables on energy intensity can be calculated. This long-term effect measures the cumulative impact after all the dynamic adjustments. Table 7 presents the calculated long-term coefficients

Table 7. GMM Two-Step System Estimation Results Long-Term GMM Two-Step System Estimation Results

Dependent Variable	Sys. GMM			
IE	**Coefficient**	**Std. err.**	**z**	**Prob.**
FD	-1,563852***	0,2669065	-5,86	0,000
TO	0,0024146***	0,0005838	4,14	0,000
INDS	0,0565932***	0,0011385	49,71	0,000
GROWTH	-0,2003776***	0,0020697	-96,81	0,000

Note: ***, ** and * indicates significant at 1%, 5% and 10% level of significance based on t-statistics
Source: Processed Data (2025)

The long-run effects were calculated by dividing the short-run coefficients by (1−coefficient of IEt-1). Based on the IEt-1 coefficient of 0.93187991 from Table 5, the long-run adjustment factor is approximately 14.67. The long-run coefficient for Financial Development (FD) is -1.563852, significant at the 1% level (p-value = 0.0000). This indicates that, over the long term, increased financial development substantially reduces energy intensity. For Trade Openness (TO), the long-run coefficient is 0.0024146, which is also significant at the 1% level, suggesting a minimal positive effect on energy intensity. The long-run coefficient for Industrial Value Added (INDS) is 0.0565932 (p-value = 0.0000), highlighting that industrial sector growth will significantly increase energy intensity in the long run without policy intervention. Furthermore, the long-run coefficient for Economic Growth (GROWTH) is -0.2003776, significant at the 1% level, implying a greater negative impact on energy intensity over the long term.

This study provides insights into the dynamics of energy intensity in middle-income countries (MCIs), a group of countries that play a crucial role in the global economy and population. The contribution of this study lies in the comprehensive analysis using System GMM methodology that can robustly identify the short- and long-run effects of financial development and control variables (trade openness, Industry, and economic growth) on energy intensity. The use of dynamic models, along with panel cointegration tests and valid GMM diagnostic tests, has been included in the study to increase confidence in the reliability of the empirical findings presented. The research findings indicate a dynamic and complex relationship between the independent and dependent variables.

Effect of Financial Development on Energy Intensity

Based on the results of the data analysis, it was found that Financial Development consistently contributes to energy intensity reduction in both the short and long run. The long-term coefficient was found to have a much larger effect on development than in the short term, suggesting that the positive impact of financial development on energy efficiency accumulates over time. This finding is consistent with the hypothesis that an efficient financial system facilitates long-term investment in more energy-efficient technologies and structural changes in the economy. The results obtained are in line with the literature from Chen et al. (2019), Emir (2022), and Uddin et al. (2022), which state that an improved (efficient) financial system can facilitate investment, energy-efficient technologies, encourage green innovation, and enable economic restructuring to less energy-intensive sectors.

Based on the contribution of Financial Development in reducing energy intensity in MICs both in the short and long term, there are several important implications. First, it is important to strengthen the financial system and financial market infrastructure to provide sufficient and stable funding for clean energy and energy efficiency projects. Second, creating financial incentive-based policies, such as tax incentives, is crucial to encourage investment in energy-efficient and renewable energy technologies. Third, strengthening energy and financial market institutions and regulations is also needed to enable a more efficient and sustainable energy transition. Countries can accelerate the transition to cleaner and more efficient energy patterns through a mature and developed financial system, thereby lowering energy intensity and supporting sustainable development. These points are part of a comprehensive strategy to integrate financial development, energy sustainability, and inclusive economic growth. Given the high inertia in energy intensity, policies must be long-term, consistent, and comprehensive.

5. Conclusion and recommendation

Utilizing a System GMM dynamic panel model, this study empirically investigated the influence of financial development on energy intensity in 71 middle-income countries (MICs) between 1990 and 2021. The findings confirm that financial development significantly lowers energy intensity across MICs in the short and long term. The long-run impact is more substantial, suggesting that as financial systems mature and become more efficient, their contribution to sustainable energy efficiency improvements grows. Similarly, economic growth demonstrates a significant inverse relationship with energy intensity, indicating that economic expansion in MICs often coincides with a transition towards more efficient energy consumption. In contrast, trade openness and industrial sector growth increased energy intensity, highlighting their role in potentially escalating energy demands within these economies.

While this study provides important insights into the impact of financial development on energy intensity in MICs, several limitations affect the validity and generalizability of the findings. Firstly, using aggregate energy intensity hinders identifying specific transmission mechanisms at the sectoral level due to a lack of detailed sectoral data for energy efficiency analysis across various industries or other sectors, making micro-level policy recommendations difficult. Secondly, the composite financial development index may not fully capture the diverse dimensions and quality variations of financial systems across countries, which limits the specificity of financial policy implications. Thirdly, even though System GMM addresses endogeneity, risks of bias in GMM instruments (if weak or correlated with the error term), external validity beyond the MICs sample, and potential over-identification in the Sargan test, necessitate caution in interpretation. These limitations suggest that these findings serve as valuable input for future, more detailed research, both at the sectoral level (e.g., Industry or renewable energy) and in testing moderating variables like renewable energy investment.

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