“Testing the moderating role of regulatory quality in the relationship between financial institutions’ depth, access, and efficiency and energy intensity in GCC countries”

AUTHORS	Tariq Qaysi

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Tariq Qaysi (Saudi Arabia)

TESTING THE MODERATING ROLE OF REGULATORY QUALITY IN THE RELATIONSHIP BETWEEN FINANCIAL INSTITUTIONS' DEPTH, ACCESS, AND EFFICIENCY AND ENERGY INTENSITY IN GCC COUNTRIES

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Tariq Qaysi, Ph.D. in Finance, Assistant Professor, Dean of the College of Business Administration, Department of Finance, Prince Sattam bin Abdulaziz University, Saudi Arabia.

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Abstract

Financial institutions can play a critical role in promoting energy efficiency by facilitating investment in energy-saving technologies and infrastructure, as per the Sustainable Development Goals (SDGs). This study aims to investigate the impact of Financial Institutions' Depth (FID), Access (FIA), and Efficiency (FIE) on Energy Intensity (EI) in the GCC countries from 2000 to 2021 within the Environmental Kuznets Curve (EKC) framework. To add novelty to the analysis, regulatory quality's moderating role is also tested in the relationship between FID, FIA, FIE, and EI. Given the financial, economic, and institutional interconnectedness of the GCC region, second-generation panel econometric techniques, such as Cross-sectional Dependence (CD) unit root tests, cointegration, and Autoregressive Distributed Lag (ARDL), are employed. The findings confirm the long-run validity of the EKC in all models. In the short term, the EKC is only supported by an FID model. FIA and FID do not directly influence EI in either the short or long run. However, regulatory quality significantly moderated these relationships with long-run coefficients of –0.096 (FID) and –0.063 (FIA). FIE is found to reduce EI with the long-run coefficient of –0.109, and this effect is also moderated by better regulatory quality with the long-run coefficient of –0.087. However, FIE and its interaction with regulatory quality do not significantly impact EI in the short run. The results conclude that regulatory quality directly and consistently reduces EI in all models. These results emphasize the need to improve the financial institutions and regulatory governance to achieve energy efficiency in the GCC region.

Keywords financial institutions, regulatory quality, energy intensity, EKC, SDGs

JEL Classification G20, G28, Q43

INTRODUCTION

Energy Intensity (EI) is defined as the amount of energy usage per unit of production, which is an important indicator of energy efficiency. Reducing EI may achieve long-term environmental goals. However, the GCC is a fossil fuel-dependent region. All GCC countries, except Oman, are among the top 10 countries globally in terms of CO_2 emissions per capita (World Population Review, 2025). GCC economies aim to diversify and transition toward low-carbon growth. In this context, financial institutions may support this transition through efficient resource allocation and capital mobilization toward sustainable projects.

Financial institutions may shape production structures and energy consumption patterns in an economy through credit allocation and technological financing. In a particular case of the GCC region, finan-

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cial institutions may promote energy-intensive oil, gas, and heavy manufacturing sectors. On the other hand, financial institutions would also facilitate financing in energy-efficient technologies and cleaner production sectors. Thus, the impact of financial institutions on EI largely depends on the type of energy projects financed, which can be fossil-fuel-based or renewable.

Keeping in mind a dual role of financial institutions in determining EI, a scientific problem arises as to how different indicators, such as Financial Institutions' Depth (FID), Access (FIA), and Efficiency (FIE), can influence energy consumption patterns and EI. For instance, FID can raise capital-intensive production, which may raise EI. Similarly, FIA can finance energy-intensive consumption and small-scale production. However, FIE has the potential to allocate capital in favor of energy-saving technologies. Moreover, Regulatory Quality (RQ) can moderate the nexus between these financial institutions and EI. An effective regulatory environment can channel financial resources toward sustainable activities. For instance, regulations can impose green lending criteria, obligate environmental risk disclosures, and offer fiscal incentives for Green Financing (GF). In this way, RQ can play a pivotal role in determining the relationship between the financial institutions and EI.

The existing literature has explored the influence of aggregated Financial Development (FD) on the environment by using limited proxies, which ignore the heterogeneity in financial institutions that could have distinct mechanisms to impact EI through FID, FIA, and FIE. Furthermore, RQ's moderating role remains underexplored in the GCC region and is scant in global literature, which can shape the environmental behavior of financial institutions. To fill this gap, the present study performs a comprehensive and disaggregated analysis of the relationship between FID, FIA, and FIE and EI in six GCC countries by assuming the moderating effect of RQ on these relationships.

1. LITERATURE REVIEW AND HYPOTHESES

The nexus between FD and the environment has received increasing scholarly attention. Particularly, the influence of FD on EI has also been tested, which is a key measure of energy efficiency. However, the recent literature expands across multiple strands. Thus, the literature review section is distributed into multiple subsections to do focused-based analysis.

1.1. FD, EI, and carbon intensity nexus

A considerable number of studies have explored the influence of FD on EI, which highlights the importance of FD in determining the environment. However, the findings remain inconclusive. Some studies corroborate energy-intensifying effects of FD, and others report energy-saving effects. For instance, FID may increase energy-intensive industrial activities by financing firms (Bhattarai, 2015). At the household level, FID may also increase energy demand through consumer credit for energy-intensive consumables (Li et al., 2022; Hamid, 2025). FIA may influence EI by accelerating renewable energy adoption or by financing fossil fuel dependence sectors (Demirtas et al., 2025; Quoc et al., 2025). However, FIE can reduce EI by facilitating investments in energy-efficient technologies and sectors (Liu et al., 2023). FIE can also improve financial efficiency by reducing borrowing costs and by enabling green investment instruments (Ghosh & Singh, 2025).

First, the panel studies are discussed, which show the energy-intensifying effects of FD. These studies also discussed the role of globalization and economic growth on EI. For instance, Zaidi et al. (2024a) assessed 16 emerging economies and found that globalization and Gross Domestic Product (GDP) growth reduced EI. However, Financial Inclusion (FI) and stock market capitalization increased it. Thus, FD may raise energy use through increased consumption or inefficient resource allocation. Similarly, Zaidi et al. (2024b) found that FI and natural resource depletion raised EI. However, globalization exerted a mitigating effect. In transition economies, Destek et al. (2024) corroborated that Renewable Energy

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Consumption (REC) reduced carbon emissions. However, EI, financial globalization, and GDP growth raised them.

Conversely, studies also identify FD's role in reducing EI by channelizing investments toward cleaner and energy-efficient sectors. Thus, improving access to finance and better capital allocation, FD helps in promoting green investment and technological upgrading in the business and household sectors. For instance, Pata & Fareed (2023) reported a negative impact of FI on EI in ten energy-efficient economies due to improved investment in energy-saving technologies. Similarly, Rehman and Chen (2025) reinforced this relationship and confirmed bidirectional causality between FI and EI in G7 countries, which showed that FI might support energy-efficient technologies. In a disaggregated analysis and from a broader development perspective, Ma et al. (2022) highlighted that FIA, FID, and FIE reduced EI by transforming industrial structures in 67 developing countries. In a development-based analysis, Canh et al. (2020) reported that FD reduced production-based EI in high-income countries but increased it in other economies. However, FD consistently reduced consumption-based EI in both income groups, which showed divergence in FD's impact on the demand versus supply sides of energy. In a resource-rich region, Eneje et al. (2024) showed that FD mitigated emissions in Africa. In a nonlinear analysis, Zhang et al. (2025) revealed an inverted-U-shaped effect of financial globalization on Carbon Intensity (CI). Thus, financial openness initially increased emissions through fossil fuel investments, but later promoted reductions through green investment and innovation.

Country-specific studies also yield mixed findings and corroborate heterogeneity in the nexus between FD and EI. Thus, the findings vary across national contexts, which suggests that institutional structures, trade openness, and temporal dynamics also shape the nexus between FD and EI. For instance, Adom et al. (2020) reported that FD lowered EI in Ghana in the presence of liberal trade policies and a sound industrial structure. However, Pan et al. (2019) found in Bangladesh that FD raised EI. Moreover, regime-specific variations were also reported. For instance, Ekesiobi et al. (2024) added a temporal dimension to the analysis and showed that FD increased EE in Nigeria in the short run but decreased it in the long run. However, public debt consistently harmed EE.

This subsection concludes that a growing body of literature highlights both pleasant and adverse environmental outcomes of FD. Thus, the evidence remains inconclusive and context-specific, which emphasizes the need to explore the role of institutional factors like RQ to moderate the FD and EI relationship.

1.2. FI, energy poverty, and sustainability behavior

Recent studies have also investigated the role of FI and Artificial Intelligence (AI) in alleviating energy poverty, which shapes sustainable energy behavior. Thus, improved FI may improve clean energy adoption. Kar and Bali Swain (2024) demonstrated that FI significantly reduced energy poverty in 27 Sub-Saharan African countries. FIA was particularly effective in improving access. However, rising EI and oil prices negatively affected it. Similarly, Jin et al. (2024) showed that digital FI reduced rural energy poverty in China. However, cross-provincial disparities in digital infrastructure created spillover challenges. Taghizadeh-Hesary (2025) found that AI reduced fossil fuel consumption in China's industrial sector. However, financial access alone had no significant effect. In a disaggregated analysis of FD, Acheampong et al. (2020) confirmed that FID and FIE reduced CI in developed nations. However, these effects were less effective in frontier markets.

Some recent studies also explored the role of R&D, financial literacy, digital infrastructure, and resource dependence in the connection between FD and environmental performance. These studies corroborate both efficiency gains and rebound effects, which may be due to the stage of FD and technological readiness in any economy. For instance, Ye and Yue (2023) reported that higher financial literacy led to increased energy usage and emissions, which highlighted the unintended rebound effect of improved access to credit. Gao et al. (2025) stated that financial services and industrial agglomeration improved carbon efficiency. However, spatial spillovers remained nonlinear. Sun and Long (2024) extended this discourse by examining five Asian economies and concluded that Renewable Energy Transition (RET) was driven by R&D, and FI further reduced mineral resource dependence. However, they found that digitalization had statistically insignificant effects. This finding contrasts with Liu et al. (2025), who showed that digital infrastructure improved efficiency outcomes by improving material productivity and reducing EI at higher quantiles of FD in 87 developing countries. In the E-7 context, Chen et al. (2024) demonstrated that a level of FD, energy poverty, and natural resource dependence increased emissions. However, high levels of FD helped reverse the trend.

In conclusion, FI and digital infrastructure mostly help reduce energy poverty and enhance efficiency. However, their effects are highly context-dependent and often moderated by structural and technological changes.

1.3. Financial quality, GF, and regulatory moderation

The literature has signified that the efficiency of FD in reducing EI depends on the quality, allocation, and governance of financial flows. Thus, well-regulated financial systems and green finance instruments may improve energy efficiency. For instance, Aller et al. (2018) showed that a well-functioning financial system in Chinese provinces significantly reduced EI, which linked institutional soundness with environmental gains. The moderating role of governance was also reinforced by Xue & Wang (2021), who found that removing financial constraints improved EE only under stringent environmental regulations, which suggested the vital role of RQ. In spatial analysis, Lv et al. (2022) found that FD increased EI, and GF helped reduce it with spatial spillovers across Chinese provinces. Similarly, Zhou et al. (2024) reported that GF enhanced renewable efficiency in China from 2010–2019 in regions with stringent environmental policies. With high FD levels, the authors demonstrated contextual dependencies in GF's effectiveness. Similarly, Huang et al. (2023) found that GF efficiency reduced CI through innovation and energy mix optimization. However, Sai et al. (2023) warned that these benefits were reduced in fossil fuel-intensive economies at higher development levels. Xiao et al. (2024) found that China's GF policy significantly reduced emissions intensity. However, the energy rebound effect diminished its gains.

The literature has investigated the effectiveness of GF for environmental improvement, which is supported by institutional and political frameworks. Thus, the quality of institutions in any economy may gear up RET by directing the local and foreign capital toward clean energy expansion. Shi et al. (2024) used a global dataset from 2005–2018 and found that reducing the CI of loans increased renewable energy output. The study also documented feedback effects, which indicated a virtuous cycle between GF and renewable deployment. Al-Zubairi et al. (2025) noted that REC reduced CO_2 emissions. But political stability unexpectedly increased them. However, the interaction between FD and political stability mitigated this effect in Arab countries. Similarly, Long et al. (2023) emphasized that institutional mechanisms moderated FD's effect on ecological footprints. Yu et al. (2024) also found that FD improved environmental outcomes in developed economies due to carbon pricing and FDI direction. However, FD reduced environmental performance in developing countries.

The subsection exposes that the presence of green instruments and regulatory strength is a necessary condition for FD to achieve sustainability.

1.4. GCC-specific studies and literature gap

Despite being one of the most energy-intensive and financially active regions globally, empirical evidence from the GCC remains limited. The existing GCC literature finds that the environmental effects of FD are heterogeneous, which are shaped by innovation dynamics and energy structures. For instance, Elmonshid et al. (2024) reported that FIE and REC reduced emissions. However, innovation increased them. Hasanov et al. (2024) found asymmetric effects of FD on emissions and positive changes improved outcomes more than negative changes worsened them. Ulussever et al. (2024) revealed that financial institution development did not impact the material footprint. However, energy consumption rose, and technology reduced it. The Environmental Kuznets

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Curve (EKC) hypothesis was also validated, which suggested potential long-term decoupling in the region.

Subsection 1.3 shows that institutional quality is crucial for environmental governance, which can also moderate the relationship between FID, FIA, FIE, and EI. Subsection 1.4 shows that existing studies in the GCC mostly focus on pollution proxies and overlook the importance of EI and financial structure diversity. Moreover, there is a lack of integration between different FD components and institutional quality, which limits understanding of how governance shapes the environmental impact of financial flows in the GCC region.

Addressing these gaps, this study aims to find the direct effect of the disaggregated component of FD and the moderating role of RQ in these relationships by developing the following hypotheses:

H1: The direct effects of FIA, FID, and FIE significantly influence EI in GCC countries.

H2: RQ positively moderates the nexus between FIA, FID, and FIE and EI in GCC countries.

2. METHODOLOGY

The relationship between FD and EI can be understood through the broader lens of economic growth and institutional quality. A foundational framework for this relationship in terms of the EKC is provided by Grossman and Krueger (1991). According to the EKC, GDP growth could have a nonlinear influence on the environment. GDP growth leads to higher energy consumption and pollution, which shows a focus on economic expansion over environmental concerns and is known as the scale effect. However, in later stages of development, public awareness grows, and economies start to invest in energy-efficient production technologies, which can reduce environmental degradation. These changes come up with the technique effect (improved technology and processes) and the composition effect (a shift from energy-intensive industries to cleaner sectors). FD may influence these effects with the different levels of development. Moreover, different components of FD can influence EI through various transmission channels. For instance, FID reflects the accessibility of finance and credit facilities, which can intensify energy use by increasing access to business loans to support industrial and manufacturing expansion (Bhattarai, 2015). In the GCC case, FID can promote energy-intensive oil and gas sectors, which can intensify the scale effect and lead to an increase in EI. On the positive side, FID can enable investments in modern energy-saving machinery (Liu et al., 2023), which can support the technique's effect. Moreover, FID can support sectoral shifts toward less energy-intensive production, which may accelerate the composition effect.

In another dimension of FD, FIA can have dual effects. For instance, an increase in FIA may drive up EI by facilitating consumer and producer credits (Quoc et al., 2025), which can lead to greater demand for energy-intensive products in production and consumption activities (Bhattarai, 2015) and can contribute to the scale effect. However, with environmental incentives, FIA can support REC at both the household and enterprise levels, which can help to reduce EI through green adoption pathways. Moreover, FIE can shape the EI. For instance, FIE may prioritize financing high-return, high-energy sectors such as oil refining, transportation, and large-scale construction in the GCC region (Ulussever et al., 2024), which would increase EI through the scale effect. On the other hand, efficient capital allocation may lower borrowing costs and encourage investment in clean infrastructure and green innovation, which are the present agenda of GCC economies. Thus, FIE can facilitate the issuance of green bonds and support climate finance instruments, which can contribute to the technical and composition effects. On the whole, the effects of FID, FIA, and FIE depend upon the direction of capital flows, the structure of the economy, and the institutional quality. Thus, RQ becomes a critical moderating factor. The strong regulatory institutions can enforce green lending standards, incentivize low-carbon investments, and discourage financing for high-emission industries. Accordingly, RQ can design and implement interest rate subsidies for energy-efficient loans, enforce environmental risk disclosures, and provide tax incentives for green financing, which can shape the direction of FID, FIA, and FIE toward environmental sustainability. Based on the theoretical foundations, the following empirical models are hypothesized to be tested:

$$EI_{it} = f\left(Y_{it},\ Y_{it}^{2},\ FID_{it}\right), \quad (1)$$

$$EI_{it} = f\left(Y_{it},\ Y_{it}^{2},\ FIA_{it}\right), \quad (2)$$

$$EI_{it} = f\left(Y_{it},\ Y_{it}^{2},\ FIE_{it}\right), \quad (3)$$

$$EI_{it} = f\left(Y_{it},\ Y_{it}^{2},\ FID_{it},\ RQ_{it},\ FID_{it}\cdot RQ_{it}\right), \quad (4)$$

$$EI_{it} = f\left(Y_{it},\ Y_{it}^{2},\ FIA_{it},\ RQ_{it},\ FIA_{it}\cdot RQ_{it}\right), \quad (5)$$

$$EI_{it} = f\left(Y_{it},\ Y_{it}^{2},\ FIE_{it},\ RQ_{it},\ FIE_{it}\cdot RQ_{it}\right), \quad (6)$$

where EI_{it} is the natural log of EI measured by the level of primary energy (MJ/$2017 PPP GDP). Y_{it} is the natural log of GDP per capita in constant 2015 US$. Y_{it}^{2} is the square term of Y_{it}. RQ_{it} is an index of regulatory quality. Data for EI_{it}, Y_{it}, and RQ_{it} are collected from the World Bank (2025). FID_{it}, FIA_{it}, and FIE_{it} are financial institution depth, access, and efficiency indices, respectively. Data for FID_{it}, FIA_{it}, and FIE_{it} are sourced from the IMF (2025). IMF (2025) defines FID as the size of financial institutions relative to the economy. For instance, FID comprises private-sector credit, pension fund assets, mutual fund assets, and insurance premiums as ratios to GDP. Thus, FID indicates a greater availability of risk-sharing financial resources. FIA is estimated based on the number of bank branches and ATMs per 100,000 adults. Thus, a higher FIA shows a broader FI and easier access to credit and payment facilities. FIE is captured by net interest margin, lending-deposit spread, non-interest income to total income, overhead costs to total assets, return on assets, and return on equity, which represents the ability of a financial institution to provide financial facilities at lower costs with a high level of profitability. A higher FIE shows better cost management and capital allocation. Data are taken for six GCC countries for the period 2000–2021. Some series are interpolated and extrapolated to find the missing observations. In equations (1)-(3), FD indicators are regressed in different models to avoid possible multicollinearity between FID, FIA, and FIE, as these indicators are interconnected. To test the moderating effect of RQ, equations (4)-(6) are hypothesized to check the direct effect of RQ on EI and the moderating effect of RQ on the relationship between financial institution indicators and EI. For this purpose, the interaction terms ($FID_{it}\cdot RQ_{it}$, $FIA_{it}\cdot RQ_{it}$, and $FIE_{it}\cdot RQ_{it}$) are introduced in equations (4)-(6).

GCC countries are interconnected due to their similar economic policies and geographical location. Therefore, the CD can be expected in the variables and models of the GCC countries. For this purpose, the following Pesaran's (2021) CD test is applied for a series from country *i* to *j*:

$$CD_{adj} = \frac{\left[\sqrt{\frac{2}{N\left(N-1\right)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}q_{ij} - \mu\right]}{\sigma}, \quad (7)$$

where q_{ij} is a parameter from country *i* to *j*. μ and σ represent the mean and standard deviation of q_{ij}. This test will be applied to the panel series and error terms of the regressions in equations (1)-(6). CD_{adj} is the adjusted version of the CD test. This adjusted version is chosen due to various advantages over other CD tests. For instance, this test reduces size distortions in large panels by introducing a bias correction mechanism. It has more power to detect CD in the presence of weak CD compared to other CD tests. Moreover, it may perform better to detect the CD in the residuals of models (Pesaran, 2021). After testing the CD, Slope Heterogeneity (SH) will be tested by using Pesaran and Yamagata's (2008) methodology:

$$\Delta = \sqrt{N}\left(\frac{M_N - k}{\sqrt{2k}}\right), \quad (8)$$

$$\Delta_{adj} = \sqrt{N}\left(\frac{M_N - E\left(M_N\right)}{\sqrt{Var\left(M_N\right)}}\right), \quad (9)$$

where M_i is the slope of economy *i*. M_N represents the average slope of all GCC economies. $E\left(M_N\right)$ and $\sqrt{Var\left(M_N\right)}$ represent the mean and variance of M_N. k shows the number of parameters. Both equations 8 and 9 will be tested with the null hypothesis of homogeneous slope, and SH will be proved by the rejection of the null hypothesis. In the next step, the stationarity of all series, mentioned in equations (1)-(6), will be tested by using Pesaran's (2007) CADF test by using the following equation:

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$$\Delta w_{it} = g_0 + g_{1i} w_{it-1} + g_{2i} \overline{w} + g_{3i} \overline{\Delta w_t} + \sum_{j=1}^{k} g_{4ij} \Delta w_{it-j} + u_{it}. \quad (10)$$

A null hypothesis (g_{1i}=1) of non-stationarity will be tested to verify the stationarity in a series. Later, the results of this test will be verified with the following test statistics:

$$CIPS = \frac{1}{N} \sum_{i=1}^{N} CADF_i, \quad (11)$$

where N is the number of countries. After verifying the stationarity of the series on the level and first differences, Westerlund's (2007) test will be utilized to verify the cointegration in equations (1)-(6). This test has numerous advantages over other cointegration techniques. It has better power to link the theory with empirical testing as it tests cointegration by accounting for CD due to common energy, climate, and economic policies through bootstrapping methods. Moreover, it also allows heterogeneous slopes in the model, as different countries could have different speeds of adjustment. Thus, this cointegration technique allows both CD and SH in the model and provides robust conclusions in the presence of both. Moreover, it performs well in the presence of a small sample size of time series in a panel, as in our small sample case. Thus, it has better power and size properties compared to other cointegration techniques (Westerlund, 2007). This test is applied with the following test statistics:

$$G_t = N^{-1} \sum_{i=1}^{N} \frac{\widehat{\Omega}_i}{\widehat{\sigma}_i}, \quad (12)$$

$$G_a = N^{-1} \sum_{i=1}^{N} T \widehat{\Omega}_i, \quad (13)$$

$$P_t = \frac{\sum_{i=1}^{N} \widehat{\Omega}_i}{\sqrt{\sum_{i=1}^{N} \widehat{\sigma}_i^2}}, \quad (14)$$

$$P_a = \sum_{i=1}^{N} T \widehat{\Omega}_i. \quad (15)$$

In equations (12)-(15), $\widehat{\Omega}_i$ is the error correction parameter, and $\widehat{\sigma}_i$ is the standard deviation. In equations (13) and (15), T represents time. In equations (12) and (13), the results capture the cointegration in at least one country in the panel. However, equations (14) and (15) show the common cointegration across the panel. At the end, the long and short-run effects will be estimated by using Chudik et al.'s (2017) CD-ARDL in the following way:

$$\Delta y_{it} = a_{1i} y_{it-1} + a_{2i}' x_{it-1} + b_1 \overline{y_{t-1}} + b_2 \overline{x_{t-1}} + \sum_{j=1}^{k} b_{3ij} \Delta y_{it-j} + \sum_{j=0}^{k} a_{4ij}' \Delta x_{it-j} + e_{it}, \quad (16)$$

where y_{it} represents the EI variable, and x_{it} shows a vector of all independent variables of the assumed models in equations (1)-(6). Moreover, $\overline{y_t}$ and $\overline{x_t}$ are cross-country averages of the variables. $a_{1i} y_{it-1}$ and $a_{2i}' x_{it-1}$ are long-run error correction terms, which could validate the cointegration. Moreover, $\sum_{j=1}^{k} b_{3ij} \Delta y_{it-j}$ and $\sum_{j=0}^{k} a_{4ij}' \Delta x_{it-j}$ estimate the short-run effects.

3. RESULTS

Table 1 shows the correlation matrix, and EI_{it} has a negative correlation with all variables except Y_{it}. Thus, all hypothesized FD indicators are expected to reduce EI. Moreover, a negative correlation between EI_{it} and Y_{it}^2 shows a tendency of the validity of the EKC in this relationship. Y_{it} and Y_{it}^2 have a strong correlation, which is added in the model to validate the EKC. Interestingly, each FD indicator shows a strong correlation with other FD indicators. Thus, all FD indicators are regressed in separate models to avoid multicollinearity.

Table 1. Correlation matrix

Variable	EI_{it}	Y_{it}	Y_{it}^2	FID_{it}	FIA_{it}	FIE_{it}	RQ_{it}
EI_{it}	1						
Y_{it}	0.113	1					
Y_{it}^2	–0.114	0.999	1				
FID_{it}	–0.396	0.103	0.107	1			
FIA_{it}	–0.427	0.187	0.192	0.750	1		
FIE_{it}	–0.183	0.092	0.093	0.618	0.243	1	
RQ_{it}	–0.459	0.145	0.149	0.116	0.209	0.258	1

Table 2 reports CD and SH results. The null hypothesis of no-CD is rejected for EIit. The existence of CD in EIit reflects that all GCC countries are highly dependent on hydrocarbon production and exports (Bhattarai, 2015), and any fluctuations in global oil markets affect all GCC countries similarly in terms of energy consumption and exports. Secondly, all GCC countries are providing energy subsidies, which could raise energy consumption per unit of production in a similar pattern in all countries. Moreover, energy prices also reflect their spillovers in terms of general prices in these economies. On the positive aspects of the energy sector, all GCC countries are targeting renewable energy projects and cross-border investments (Arif & Aldosary, 2023), which may generate spillovers of increasing energy efficiency across the borders of these economies. Similarly, financial institution indicators have also been affected due to the interconnected financial system in GCC countries (Alsharif, 2021). For instance, the financial system is similar in GCC countries due to the commonly adopted Islamic finance principles and central bank practices. Moreover, financial regulations are also similar due to common Basel III adoption and digital banking standards (Alsharif et al., 2019). In addition, many GCC banks are operating their branches in multiple GCC countries, which are responsible for uniform banking operations and standards. Thus, these factors are affecting FID, FIA, and FIE in parallel ways. Regulatory quality also shows significant CD, which is due to common governance structures in GCC countries and influences their regulations for trade, finance, and environmental protection in the same way. In addition, the CD is proven in all hypothesized models. The SH is also proven in all models. Thus, all later estimations are performed considering CD and SH in the models.

Table 2. CD and SH results

Variables	CD test	SH	
		Δ	Δadj
E_{it}	6.354 (0.000)		
Y_{it}	6.698 (0.000)		
Y_{it}^2	1.648 (0.099)		
FID_{it}	7.890 (0.000)		
FIA_{it}	5.641 (0.000)		
FIE_{it}	9.524 (0.000)		
RQ_{it}	8.524 (0.000)		
$FID_{it} \cdot RQ_{it}$	3.641 (0.000)		
$FIA_{it} \cdot RQ_{it}$	2.541 (0.011)		
$FIE_{it} \cdot RQ_{it}$	3.115 (0.000)		
Residuals from regressions			
Model 1	5.871 (0.000)	29.249 (0.000)	31.597 (0.000)
Model 2	8.541 (0.000)	28.211 (0.000)	30.617 (0.000)
Model 3	6.524 (0.000)	32.111 (0.000)	33.824 (0.000)
Model 4	4.992 (0.000)	32.418 (0.000)	34.159 (0.000)
Model 5	7.497 (0.000)	35.514 (0.000)	38.242 (0.000)
Model 6	7.021 (0.000)	39.512 (0.000)	41.109 (0.000)

Note: p-values are in parentheses.

Table 3 shows the results of unit root analyses. Both CIPS and CADF tests corroborate that all variables are non-stationary at their level with insignificant test statistics. Though stationarity is proved in all variables at their first differences with significant test statistics at 1% level of significance. Thus, the order of integration is one in all models.

Table 3. Panel unit root analyses

Variable	Level		First Difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
CIPS Test				
EI_{it}	–1.991	–2.049	–2.974***	–3.113***
Y_{it}	–0.574	–0.659	–2.801***	–2.967***
Y_{it}^2	–0.452	–0.584	–2.974***	–3.015***
FID_{it}	–1.154	–1.241	–3.261***	–3.333***
FIA_{it}	–2.649	–2.054	–4.216***	–4.637***
FIE_{it}	–1.112	–0.947	–3.246***	–3.321***
RQ_{it}	–0.954	–0.341	–3.011***	–2.916***
$FID_{it} \cdot RQ_{it}$	–1.634	–1.245	–4.114***	–3.964***
$FIA_{it} \cdot RQ_{it}$	–1.568	–1.422	–3.874***	–3.541***
$FIE_{it} \cdot RQ_{it}$	–1.146	–0.917	–2.987***	–2.714***
CADF Test				
EI_{it}	–2.214	–2.193	–5.632***	–6.016***
Y_{it}	–0.796	–0.892	–4.654***	–4.924***
Y_{it}^2	–0.643	–0.806	–5.074***	–4.846***
FID_{it}	–1.651	–1.792	–7.556***	–6.951***
FIA_{it}	–1.964	–2.324	–6.874***	–6.225***
FIE_{it}	–0.763	–0.562	–4.987***	–5.264***
RQ_{it}	–1.111	–0.597	–6.574***	–6.987***
$FID_{it} \cdot RQ_{it}$	–2.013	–1.938	–6.217***	–5.816***
$FIA_{it} \cdot RQ_{it}$	–1.931	–1.619	–5.024***	–5.647***
$FIE_{it} \cdot RQ_{it}$	–0.267	–0.369	–4.689***	–5.012***

Note: *** shows a 1% significance level.

Table 4 shows the results of four test statistics of Westerlund cointegration. This technique is preferred over other cointegration tests as it takes care of CD and SH in the estimations. Table 2 proves the significance of CD and SH in all models. Thus, ignoring CD and SH in cointegration analysis could mislead the conclusion in the models. The results show that the cointegration is proved with significant *Gt*, *Pt*, and *Pa* statistics in Model 1, Pt and Pa statistics in Model 2, *Gt*, *Pt*, and *Pa* statistics in Model 3, *Gt*, *Pt*, and *Pa* in Model 4, and all four statistics in Models 5 and 6. Thus, all hypothesized models are strongly cointegrated.

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Table 4. Westerlund cointegration

Statistics	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Gt	−1.955 (0.093)	−2.289 (0.120)	−2.363 (0.060)	−2.484 (0.050)	−2.598 (0.040)	−2.614 (0.035)
Ga	−6.657 (0.120)	−5.972 (0.180)	−5.711 (0.260)	−6.136 (0.100)	−6.895 (0.078)	−7.212 (0.065)
Pt	−4.969 (0.040)	−7.073 (0.000)	−5.571 (0.020)	−5.864 (0.015)	−6.152 (0.010)	−6.496 (0.008)
Pa	−6.542 (0.060)	−9.624 (0.000)	−6.364 (0.080)	−7.112 (0.045)	−7.962 (0.032)	−8.194 (0.025)

Note: p-values are in parentheses.

Table 5 shows the results of CS-ARDL. In the long run, Y_{it} has a positive effect on EI, and Y_{it}^2 has a negative effect in all models. Consequently, the EKC hypothesis is authenticated in all models. In Models 1 and 2, FID_{it} and FIA_{it} have insignificant effects on *EI*. However, in Model 3, FIE_{it} has a negative effect on EI. Thus, FIE helps to reduce EI directly. Overall, the long-run results show that the hypothesis *H1* is only supported in Model 3 with a negative and significant effect of FIE on EI. However, this hypothesis could not be validated in the models of FID and FIA. Moreover, Models 4-6 are regressed to test the moderating effect of RQ on the relationship between financial institution indicators and EI. At first, RQ_{it} has negative and significant effects on EI in Models 4-6. Thus, RQ directly helps to improve the environment by reducing EI. Secondly, it also significantly moderates the effects of FID, FIA, and FIE on EI with negative coefficients in Models 4-6. Thus, RQ helps FID, FIA, and FIE to reduce EI, which improves the environmental benefits of FID, FIA, and FIE in the GCC region. Thus, the hypothesis H2 is supported in all tested Models 4-6 with negative and statistically significant coefficients of $FID_{it} \cdot RQ_{it}$, $FIA_{it} \cdot RQ_{it}$, and $FIE_{it} \cdot RQ_{it}$.

Table 5. CD-ARDL results

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Long run						
Y_{it}	36.981 (0.068)	47.214 (0.067)	41.816 (0.056)	35.422 (0.078)	49.786 (0.078)	40.237 (0.048)
Y_{it}^2	−1.769 (0.071)	−2.252 (0.059)	−2.035 (0.043)	−1.687 (0.045)	−2.396 (0.036)	−1.954 (0.026)
FID_{it}	−0.176 (0.578)			−0.192 (0.425)		
FIA_{it}		−0.126 (0.456)			−0.139 (0.333)	
FIE_{it}			−0.109 (0.029)			−0.121 (0.010)
RQ_{it}				−0.256 (0.045)	−0.128 (0.011)	−0.179 (0.000)
$FID_{it} \cdot RQ_{it}$				−0.096 (0.001)		
$FIA_{it} \cdot RQ_{it}$					−0.063 (0.039)	
$FIE_{it} \cdot RQ_{it}$						−0.087 (0.001)
Short run						
Y_{it}	56.254 (0.054)	70.021 (0.122)	62.349 (0.196)	54.964 (0.001)	71.364 (0.194)	63.657 (0.184)
Y_{it}^2	−2.735 (0.076)	−3.350 (0.145)	−2.965 (0.167)	−2.622 (0.007)	−3.421 (0.135)	−3.141 (0.128)
FID_{it}	−0.254 (0.365)			−0.319 (0.465)		
FIA_{it}		−0.194 (0.354)			−0.211 (0.246)	
FIE_{it}			−0.187 (0.124)			−0.193 (0.275)
RQ_{it}				−0.354 (0.001)	−0.179 (0.055)	−0.231 (0.000)
$FID_{it} \cdot RQ_{it}$				−0.159 (0.024)		
$FIA_{it} \cdot RQ_{it}$					−0.143 (0.000)	
$FIE_{it} \cdot RQ_{it}$						−0.134 (0.121)
ECT_{t-1}	−0.697 (0.000)	−0.611 (0.000)	−0.571 (0.000)	−0.752 (0.000)	−0.691 (0.000)	−0.584 (0.000)

Note: p-values are in parentheses.

In the short run, ECT_{t-1} has a negative coefficient in all models. Thus, short-run relationships are proven in all estimated models. Y_{it} raises, and Y_{it}^2 reduces EI in Models 1 and 4. So, the EKC is validated in the models of FID with and without the moderating effect of RQ. However, the effects of Y_{it} and Y_{it}^2 are statistically insignificant in Models 2, 3, 5, and 6. Accordingly, the EKC is not authenticated in the models of FIA and FIE. In Models 1-3, the effects of FID, FIA, and FIE are found to be statistically insignificant. Therefore, the hypothesis H1 is not validated in these models. In Models 4-6, RQ has negative and statistically significant coefficients, which validates the hypothesis H2. Thus, RQ directly helps to reduce EI in the short run. However, the effects of FID, FIA, and FIE are found to be statistically insignificant in Models 4-6. Thus, FID, FIA, and FIE could not directly reduce EI. However, RQ moderates the effects of FID and FIA on EI. Thus, RQ helps FID and FIA to reduce EI. Nevertheless, RQ could not moderate the effect of FIE on EI.

4. DISCUSSION

The results corroborate the existence of the EKC in all models in the long run. Similarly, Hasanov et al. (2024) have also validated the existence of the EKC in the nexus between economic growth and carbon emissions in the GCC region. The results of the present research explain that the initial economic growth increases EI. However, EI is reduced after reaching a certain growth level. This result validates the economic diversification efforts of the GCC countries. For instance, financial, tourism, and digital sectors are growing in the GCC countries as per their diversification policies, which are less energy-intensive compared to the oil and industrial sectors. Moreover, some GCC countries are heavily investing in renewable energy as per their local national goals, like Vision 2030, 2040, and 2050 of all GCC countries (Arif & Aldosary, 2023). Thus, structural transformation, RET, and policy reforms are enabling the economic growth of these countries to reduce EI in the GCC region.

Regulatory quality consistently helps to reduce EI in the GCC region. It shows that increasing RQ helps to implement energy efficiency standards in the industrial and household sectors. RQ can help in the coordination of ministries of energy, finance, environment, and industry to work together to develop energy strategies to improve energy efficiency as per national plans of GCC countries, such as the UAE's Energy Strategy 2050 (Arif & Aldosary, 2023). These plans emphasize energy management and industrial diversification, which can contribute to increasing energy efficiency. Moreover, RQ can also attract investment in clean technologies and sectors.

The results show that FID cannot directly affect EI but has a pleasant effect in the presence of RQ. The direct insignificant effect of FID on EI contradicts the results of Acheampong et al. (2020), who reported that FID reduced CI. The result of the present research reflects that financial resources can be moved to energy-intensive construction and petrochemical sectors in GCC countries in the absence of a regulatory framework, which are inherently dependent on fossil fuels. However, FID's interaction with RQ reduces EI. This result is consistent with the findings of the existing literature, which validates that RQ enables FD to reduce EI through stronger institutional support (Aller et al., 2018), political stability (Al-Zubairi et al., 2025), and effective environmental regulations and carbon pricing (Xue & Wang, 2021; Yu et al., 2024; Zhou et al., 2024). This result implies that strong governance frameworks are necessary to produce the environmental benefits of FID in the GCC region. For instance, a strong RQ would allocate financial resources towards productive, innovative, and cleaner sectors by introducing environmental standards and green disclosure requirements. Thus, RQ can ensure that financial resources are not moving to energy-inefficient projects by evaluating long-term environmental and energy-related risks associated with energy-intensive investments.

Similarly, FIA could not directly affect EI. This insignificant effect of FIA on EI is consistent with the finding of Taghizadeh-Hesary (2025), who corroborates an insignificant effect of FIA on fossil fuel consumption. However, this result contradicts the findings of Ma et al. (2022), who reported that FIA significantly reduced EI. However, FIA's interaction with RQ reduces EI in the current GCC results. In the absence of an effective regulatory framework, improving FIA with increasing availability of credit may promote energy-intensive activities in the

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GCC region. For instance, FIA usually increases the credit availability to the household sector and SMEs. Thus, FIA without a regulatory framework could not promote energy-efficient technologies in the production and consumption activities. In GCC countries, the household sector mostly takes loans for the construction of houses and for buying energy-intensive heavy cars. Moreover, SMEs usually ignore their environmental responsibility for the sake of short-term profits from their investments. However, RQ can force financial institutions to provide loans for energy-efficient technologies and discourage financing for energy-intensive sectors. Moreover, regulators can provide financial and non-financial incentives to producers and consumers to spend the loans on environmentally friendly production and consumption activities. Thus, RQ can align the national and international environmental goals with the financing activities of the financial institutions.

The long-run results show that both FIE and its interaction with RQ help reduce EI. Likewise, the existing literature has also corroborated the negative direct effect of FIE on EI (Ma et al., 2022), on CI (Acheampong et al., 2020), and carbon emissions (Elmonshid et al., 2024). Furthermore, some studies have also reported the negative effect of aggregated FD on EI (Canh et al., 2020; Adom et al., 2020). Thus, FIE, with effective resource allocation, low costs, and efficient risk management, helps to promote environmental outcomes of financing. For instance, efficient financial institutions would finance productive and low-energy-intensive sectors. Moreover, they can support renewable energy projects and reduce borrowing costs for green and energy-efficient technologies. Furthermore, RQ also moderates this relationship. Thus, RQ motivates financial institutions to enhance their operational performance by adopting the digitalization of financing services, respecting risk-based regulation, and encouraging green banking practices. However, in the short run, FIE could not affect EI, and RQ could not moderate this relationship. This result explains that FIE needs a long time to have its pleasant effect on energy efficiency.

CONCLUSION AND POLICY IMPLICATIONS

Financial institutions not only support economic growth but also have the potential to reduce EI by financing energy-efficient technologies. Thus, this study intends to analyze how FID, FIA, and FIE influence EI in the EKC framework in the GCC region for the period 2000–2021. Moreover, the moderating role of regulatory quality in these relationships is also investigated. Due to the economic and policy integration of GCC countries, CD is anticipated and addressed using second-generation CD econometric techniques. The long-run EKC hypothesis is validated in all models. Thus, economic growth initially raises EI but later contributes to its reduction. FID and FIA alone do not significantly impact EI. However, regulatory quality moderates these relationships and helps FIA and FID in reducing EI. Moreover, regulatory quality also independently reduces EI. In addition, FIE reduces EI independently, and regulatory quality significantly moderates this relationship. The short-run EKC is corroborated only in the FID model. FID and FIA could not independently impact EI, but regulatory quality moderates these short-run relationships, which is consistent with long-run findings. However, FIE and its interaction with regulatory quality do not exhibit significant short-run effects. The study concludes that efficient financial institutions and regulatory quality support energy-saving investments and discourage energy-intensive activities in the GCC region in the long run.

The results underscore the crucial role of FIE in reducing EI in the GCC region independently in the long run. Thus, FIE-driven reforms can serve national sustainability agendas of GCC countries such as Saudi Arabia's Vision 2030 and the UAE's Net Zero 2050 Strategy. Moreover, the results show that regulatory quality positively moderated the nexus between FIE and EI. Thus, the most effective policy instruments are regulatory tools instead of broader fiscal incentives. For instance, regulators may introduce obligatory green lending criteria and financing screening standards, which can adjust national ecological targets in credit allocation from the financial sector. Moreover, policymakers should further focus on enhancing the operational and technological efficiency of the financial institutions by promoting digitalization and automating financial services. The findings disclose that FIA and FID do not have a direct impact on EI. However, regulatory quality helps FIA and FID to reduce EI in the region. Therefore, regulators in the GCC should implement and enforce green financing regulations to have a positive environmental effect of financial inclusion. Moreover, regulators should introduce targeted incentive schemes for green borrowing. Lastly, the presence of CD in GCC models suggests that GCC countries should establish a regional green finance agency to harmonize green finance standards and promote cross-border green financing initiatives in the GCC region.

The present research investigates the effects of FID, FIA, and FIE on aggregated EI. However, future research on the GCC region may enhance the scope of the study by analyzing the effects of disaggregated FD on firm-level or sector-specific EI. Moreover, future research may also explore the role of digital finance, green finance, and ecological financial policies in shaping EI in the GCC region.

AUTHOR CONTRIBUTIONS

Conceptualization: Tariq Qaysi.
Data curation: Tariq Qaysi.
Formal analysis: Tariq Qaysi.
Funding acquisition: Tariq Qaysi.
Investigation: Tariq Qaysi.
Methodology: Tariq Qaysi.
Project administration: Tariq Qaysi.
Resources: Tariq Qaysi.
Software: Tariq Qaysi.
Supervision: Tariq Qaysi.
Validation: Tariq Qaysi.
Visualization: Tariq Qaysi.
Writing – original draft: Tariq Qaysi.
Writing – review & editing: Tariq Qaysi.

DATA AVAILABILITY

The data supporting the findings of this study are openly available in Zenodo at https://doi.org/10.5281/zenodo.18007489

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