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The Asymmetric Impact of Global Uncertainty on Energy Consumption in the Gulf Cooperation Council Countries: A Panel Nonlinear Autoregressive Distributed Lag Approach

Ahmed W. Elroukh*

Department of Economics and Finance, College of Economics and Political Science, Sultan Qaboos University, Oman.
*Email: a.elroukh@squ.edu.om

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ABSTRACT

This study investigates the relationship between uncertainty and energy consumption in the Gulf Cooperation Council (GCC) countries, focusing on the potential asymmetry in this relationship. Utilizing annual data from 1997 to 2023, the analysis uses both linear and nonlinear panel autoregressive distributed lags (ARDL) models, estimated with the Pooled Mean Group method that assumes long-run homogeneity across the individual countries which is suitable in this framework given the similarity across the GCC countries. The linear ARDL results suggest no significant effect of uncertainty. However, once asymmetries are introduced, the findings show that in the short-run rising uncertainty tends to reduce energy demand, while falling uncertainty has little to no impact. By using a country-specific uncertainty measure and accounting for asymmetric effects, the study offers new insights into energy use dynamics in oil-reliant economies.

Keywords: World Uncertainty Index, Energy Consumption, Gulf Cooperation Council Countries, Panel Nonlinear Autoregressive Distributed Lag
JEL Classifications: C23, D02, D80

1. INTRODUCTION

Understanding how uncertainty affects energy consumption is becoming increasingly important, particularly in oil-exporting economies that are highly exposed to external shocks. In the Gulf Cooperation Council (GCC) countries, where energy consumption is structurally linked to oil revenues, fluctuations in uncertainty can influence consumption through macroeconomic channels such as real income, capital formation, and commodity price volatility.

Prior studies have examined the relationship between uncertainty, typically measured by economic policy uncertainty (EPU) developed by Baker et al. (2016), and energy consumption across various contexts. Findings generally show that heightened uncertainty reduces energy use by dampening investment and economic activity, as evidenced by studies on global samples (Erzurumlu and Gozgor, 2022), resource-rich economies (Adams et al., 2020), and BRICS countries (Atsu and Adams, 2021). More recent work has emphasized asymmetry in this relationship, showing that energy demand may respond differently to rising versus falling uncertainty (e.g., Rong and Qamruzzaman, 2022; Singh et al., 2025). While this literature is growing, little attention has been paid to the Gulf Cooperation Council (GCC) context, despite its high energy intensity and sensitivity to external shocks. The only notable contribution in this region is Hnainia and Mensi (2025), who found a positive long-run effect of EPU on energy consumption in the GCC. However, no existing study has investigated whether this relationship is asymmetric, nor has any employed a country-specific uncertainty measure. This study fills both gaps by extending the work of Hnainia and Mensi (2025) to account for asymmetry and by utilizing the World Uncertainty Index (WUI), developed by (Ahir et al., 2022), as an alternative

measure of uncertainty in the GCC context. The WUI is more appropriate than the global EPU index since the latter is not available for the GCC countries, and its adoption may overlook country-specific uncertainty.

The aim of this study is to investigate the dynamic and potentially asymmetric relationship between uncertainty and energy consumption in the GCC countries over the period 1997-2023. To capture this relationship, the study employs both linear and nonlinear panel autoregressive distributed lag (ARDL) models, estimated using the Pooled Mean Group (PMG) estimator. This approach allows for heterogeneous short-run dynamics while imposing homogeneity on the long-run coefficients, an appropriate strategy given the structural similarities across GCC economies. The analysis uses annual data on per capita energy consumption, the WUI as the main explanatory variable, and controls for GDP per capita, gross capital formation (GCF), and Brent crude oil prices. The nonlinear specification further decomposes WUI into positive and negative changes to assess potential asymmetries in its effect on energy demand.

The main findings of this study reveal that the relationship between uncertainty and energy consumption in the GCC is asymmetric. While the linear panel ARDL model shows no significant impact of uncertainty on energy demand, the nonlinear specification uncovers a significant negative short-run effect of rising uncertainty, with no corresponding impact from declining uncertainty. This suggests that energy consumption contracts in response to increasing uncertainty but does not expand proportionately when uncertainty falls. In both models, GDP per capita consistently exerts a strong positive effect on energy use, while gross capital formation and oil prices influence energy demand primarily in the long run. These results underscore the importance of accounting for asymmetry and using country-specific uncertainty measures like the WUI when analyzing energy dynamics in resource-rich economies.

Following this introduction, the next section reviews relevant literature. Section 3 presents data and descriptive statistics. Section 4 and 5 present the methodology and discussion of results, respectively. Section 6 concludes with policy recommendations.

2. LITERATURE REVIEW

A growing body of research has investigated the macroeconomic effects of uncertainty, particularly through the lens of EPU or its broader variant, the WUI. Within the context of energy economics, studies have increasingly explored the relationship between policy uncertainty and energy consumption. For example, Erzurumlu and Gozgor (2022) employed a panel of 72 countries and found a negative relationship between WUI and energy demand, indicating that uncertainty may reduce energy use by dampening economic activity, investment, and consumption confidence. Similarly, Adams et al. (2020) explored the energy-uncertainty nexus in resource-rich countries and confirmed that higher EPU suppresses energy demand over the long run, particularly in the presence of external financial shocks. Atsu and Adams (2021) investigated the link between EPU, financial development, and energy demand in BRICS countries, finding that increased uncertainty constrains financial flows and thereby suppresses energy investment and use. Xie et al. (2023) highlighted the role of trade policy uncertainty as a transmission channel affecting energy consumption patterns.

Recent literature increasingly adopts nonlinear frameworks to examine whether positive and negative changes in uncertainty have differing impacts. This shift has given rise to applications of the nonlinear autoregressive distributed lag (NARDL) model and other asymmetric approaches. For instance, Rong and Qamruzzaman (2022) employed NARDL to examine the asymmetric effects of EPU and oil prices on renewable energy consumption in major oil-importing countries. Their findings reveal that only positive EPU shocks significantly reduce renewable energy investment, while negative shocks have negligible effects, highlighting the asymmetric behavioral responses of consumers and firms to rising versus falling uncertainty. Singh et al. (2025) also emphasized the nonlinear dynamics between uncertainty and renewable energy consumption in East Asia, where the relationship varied significantly across positive and negative policy shocks. Although these studies primarily focus on renewable energy or broader macroeconomic uncertainty, their methodological frameworks and findings provide a strong rationale for applying asymmetric models, such as NARDL, to understand the energy-uncertainty nexus. Aytac (2023) suggests that global economic policy uncertainties have an asymmetrical relationship with fossil fuel prices where these uncertainties can explain up to 50% of the shocks in energy prices during expansion periods of the global economy. Using a panel NARDL-PMG regression, Zeng and Yue (2022) show that positive uncertainty shocks reduce renewable energy use and increase non-renewable consumption in both the short and long run in BRICS countries. In contrast, negative shocks raise renewable energy use and lower non-renewable consumption in the long run, though these effects are insignificant in the short run.

The GCC region presents a unique context for studying the energy-uncertainty relationship due to its dependence on oil exports. Despite this, only a few empirical studies have specifically addressed the GCC context. One notable contribution is Hnainia and Mensi (2025) which examined the long-run impact of EPU on energy consumption in the GCC countries and found that greater uncertainty tends to increase energy consumption. These results diverge from the more commonly observed negative effect found in global. Adams et al. (2020) also provides relevant insights by focusing on resource-rich economies, including several GCC members. The authors emphasize that such economies exhibit distinct energy consumption patterns under uncertainty.

While numerous studies have examined the role of EPU in shaping energy demand, no previous study employed the WUI, which offers a broader and more comparable measure of country-specific uncertainty. Additionally, to the best of the author's knowledge, no previous study has examined the potential asymmetry in the relationship between uncertainty and energy consumption in the GCC countries. This study contributes to the literature by utilizing the WUI in examining the relationship between uncertainty and energy use. Additionally, the study extends the work of Hnainia and Mensi (2025) to allows for asymmetry in this relationship.

3. DATA AND DESCRIPTIVE STATISTICS

3.1. Data

This study uses annual panel data for the six GCC countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE) from 1997 to 2023. The dependent variable is the log of energy use per capita (kg of oil equivalent), sourced from the World Development Indicators (WDI). The main explanatory variable is the WUI, measured at the country level, from Ahir et al. (2022), averaged from quarterly to annual frequency. Since the WUI is unavailable for Bahrain, the study uses average values of the WUI of the remaining GCC countries as a proxy for Bahrain. Control variables include the log of GDP per capita (constant LCU), gross capital formation (GCF) as a percentage of GDP, both variables' data are from WDI. Additionally the study uses Brent crude oil prices in USD, averaged from monthly data sourced from investing.com.

3.2. Descriptive Statistics

Table 1 summarizes the key variables used in the analysis. The log of energy use per capita has a mean of 9.13 and moderate dispersion, reflecting persistently high energy consumption across the GCC over time. The WUI also shows meaningful variation (mean = 0.11; STDEV = 0.08), suggesting that fluctuations in domestic uncertainty are a relevant feature of the region's economic environment. The log of GDP per capita averages 10.57, while gross capital formation accounts for approximately 27% of GDP, with considerable variation across years, capturing shifts in investment activity within countries over time. Brent crude oil prices range from $13.43 to $112.26 per barrel, underscoring the exposure of GCC economies to global oil market cycles. Given the region's heavy dependence on oil revenues, such volatility has significant implications for public spending, energy pricing policy, and, ultimately, energy demand.

Table 2 presents the correlation matrix. The WUI shows a negative correlation with energy (−0.22), indicating that higher levels of country-specific uncertainty may be linked to reduced energy use, potentially through mechanisms such as dampened economic activity or delayed consumption and investment. Energy consumption is positively associated with GDP (0.45), consistent with established income-energy demand dynamics. Brent oil prices are positively correlated with WUI and weakly correlated with energy consumption.

Table 1: Descriptive statistics

Variable	Mean	STDEV	Min	Max
Energy	9.13	0.42	8.02	9.98
WUI	0.11	0.08	0.00	0.37
GDP	10.57	1.47	8.91	12.70
GCF	26.68	7.84	6.95	48.87
Brent Oil	61.11	30.17	13.43	112.26

Source: Author's calculation using Stata
WUI: World uncertainty index, GDP: Gross domestic product, GCF: Gross capital formation

Table 2: Correlation matrix

Variable	Energy	WUI	GDP	GCF	Brent Oil
Energy	1.00				
WUI	−0.22	1.00			
GDP	0.45	−0.14	1.00		
GCF	0.16	0.04	0.22	1.00	
Brent Oil	0.10	0.30	0.05	0.19	1.00

Source: Author's calculation using Stata
WUI: World uncertainty index, GDP: Gross domestic product, GCF: Gross capital formation

Figure 1 presents the rolling correlation between the log of energy consumption per capita and the WUI for the six GCC countries over the period 2005-2023. The visual patterns suggest that the relationship between uncertainty and energy consumption is time-varying, with correlations shifting between positive and negative values. In several cases, such as Saudi Arabia, Qatar, and Kuwait, uncertainty may act as a suppressor of energy demand. In other periods or countries, the relationship is weaker or even positive, casting doubt on the linearity of this relationship.

Figure 2 plots the average energy consumption per capita against the average WUI for each GCC country over the period 1997-2023. A clear negative association emerges where countries with higher levels of uncertainty tend to exhibit lower average energy consumption. This inverse relationship is particularly evident in the positioning of Oman and Saudi Arabia, which record the highest average WUI values and among the lowest energy consumption levels. In contrast, Qatar, with the lowest average WUI, displays the highest energy use per capita. The pattern suggests that heightened uncertainty may suppress energy demand, potentially due to reduced economic activity or delayed consumption and investment decisions.

4. METHODOLOGY

4.1. Theoretical Background

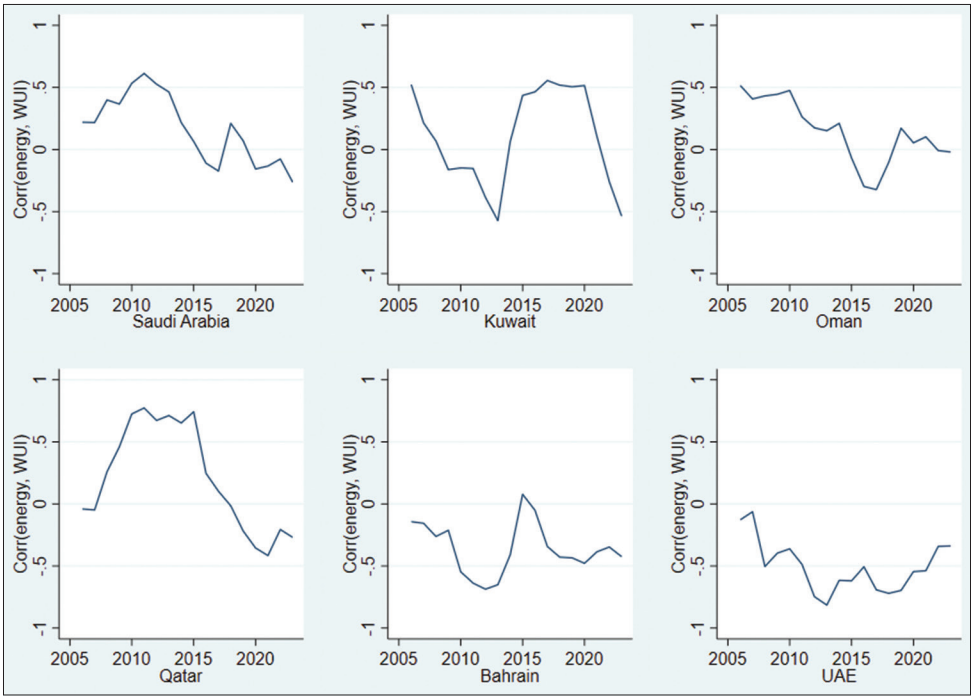
This study analyzes the impact of uncertainty on energy consumption. Beyond the direct effect of uncertainty, prior studies highlight the mediating roles of oil prices, economic growth, and investment in shaping energy consumption. Oil prices influence both public revenues and domestic energy pricing in oil-exporting economies (Avazkhodjaev et al., 2024). GDP has a well-established positive effect on energy demand (Selmey et al., 2024), while investment, typically measured by gross capital formation, drives infrastructure and industrial expansion (Adams et al., 2020; Atsu and Adams, 2021). Uncertainty may suppress energy use indirectly by dampening investment and credit flows, particularly in resource-rich and financially sensitive economies. These findings justify the inclusion of oil prices, GDP, and GCF as control variables in empirical models assessing the impact of uncertainty on energy consumption. That is, this study specifies the following model:

$$Energy_{i,t} = f(WUI_{i,t}, GDP_{i,t}, GCF_{i,t}, Brent_t) \quad (1)$$

4.2. The Linear Panel ARDL

This study utilizes the ARDL framework originally developed by Pesaran and Shin (1996) and later extended to panel data by Pesaran et al. (2001). The panel ARDL model of equation (1) is specified as follows:

Figure 1: Rolling correlation (10-years window) between energy consumption and World Uncertainty Index



Source: Prepared by the author using Stata

Figure 2: Scatter plot of average historical energy consumption and World Uncertainty Index for the Gulf Cooperation Council countries

Source: Prepared by the author using Stata

$$\Delta\ Energy_{i,t} = \beta_0 + \beta_1\ Energy_{i,t-1} + \beta_2 WUI_{i,t} + \beta_3\ GDP_{i,t} + \beta_4\ GCF_{i,t} + \beta_5 Brent_t + \sum_{j=1}^{p} \gamma_j\ \Delta\ Energy_{i,t-j} + \sum_{k=0}^{q} \delta_k\ \Delta x_{i,t-k} + \epsilon_{i,t} \quad (2)$$

Where $Energy_{i,t}$ denotes the logarithm of per capita energy use for country i at time t, while $x_{i,t}$ includes the explanatory variables: $WUI_{i,t}$, $GDP_{i,t}$ $GCF_{i,t}$, and $Brent_t$. The inclusion of first differences Δ captures short-run dynamics. Following Zeng and Yue (2022), the model is estimated using the PMG estimator, which assumes a common long-run relationship across panel members while allowing short-run dynamics and error variances to vary by country. This estimator is well-suited for the GCC context, where economies exhibit structural similarities but differ in short-run responsiveness.

4.3. The Nonlinear Panel ARDL

The linear specification presumes a symmetric link between uncertainty and energy consumption; however, prior studies suggest that the impact of uncertainty may differ depending on its direction. For instance, a rise in uncertainty may constrain energy usage, while a decline may not produce a proportionate increase. To account for such potential nonlinearities, the study adopts the NARDL framework introduced by Shin et al. (2014), which decomposes the uncertainty variable into positive and negative components. The NARDL model is expressed as:

$$\Delta\ Energy_{i,t} = \beta_0 + \beta_1\ Energy_{i,t-1} + \beta_2^{+} WUI_{i,t}^{+} + \beta_2^{-} WUI_{i,t}^{-} + \beta_3\ GDP_{i,t} + \beta_4\ GCF_{i,t} + \beta_5 Brent_t + \sum_{j=1}^{p} \gamma_j\ \Delta\ Energy_{i,t-j} + \sum_{k=0}^{q} \delta_k\ \Delta x_{i,t-k} + \epsilon_{i,t} \quad (3)$$

Where WUI^{+} and WUI^{-} represent the partial sums of positive and negative changes in WUI_t, calculated as: $WUI_t^{+} = \sum_{l=1}^{t} \max(WUI_l, 0)$, $WUI_t^{-} = \sum_{l=1}^{t} \min(WUI_l, 0)$. This decomposition enables the estimation of both short- and long-run asymmetric effects of uncertainty. The presence of asymmetry is formally assessed through Wald tests of the null hypotheses $\beta_2^{+} = \beta_2^{-}$ (long-run) and $\delta_k^{+} = \delta_k^{-}$ (short-run). As with the linear model, the PMG estimator can be applied.

5. RESULTS

To determine the order of integration of the variables, the IPS (Im et al., 2003) panel unit root test is conducted. Results, reported in Table 3, indicate that the WUI is stationary at levels, i.e., I(0), at the 1% significance level. Brent oil prices and GCF appear weakly stationary at levels, significant at the 10% level. In contrast, energy use, GDP per capita, GCF, and Brent oil prices all become strongly stationary after first differencing, confirming that they are integrated of order one, I(1). The presence of variables integrated at both levels and first differences supports the use of the panel ARDL approach, which is specifically designed to accommodate such a mixed order of integration, provided none of the variables are I(2).

5.1. Linear Panel ARDL Results

The results from the linear panel ARDL model (Table 4, Panel A) reveal that the WUI does not exert a statistically significant impact on energy consumption in the long run. This insignificance may reflect the nonlinear or asymmetric nature of the uncertainty-energy relationship, where positive and negative uncertainty shocks may produce offsetting effects in a linear framework. In contrast, GDP per capita exerts a strong and statistically significant positive effect on energy consumption, with a coefficient of 0.539, supporting the well-documented income-energy nexus in high-income, resource-rich economies. GCF also shows a significant positive impact (0.007), consistent with the notion that investment activity stimulates energy demand through industrial expansion and infrastructure development. Additionally, Brent crude oil prices are positively associated with energy consumption (0.001), indicating that oil price upswings, despite often dampening global demand, may increase energy use in the GCC due to higher fiscal revenues, relaxed domestic energy subsidies, and expanded government expenditure.

In the short run (Panel B), WUI continues to exhibit no statistically significant effect on energy use, reinforcing the linear model's limitation in capturing the true influence of uncertainty. GDP retains a strong positive impact (0.401), reflecting short-run income effects and consumption smoothing behavior. The impact of GCF and Brent oil prices is statistically insignificant in the short term, suggesting that investment-related energy demand and oil market dynamics may take longer to influence consumption patterns.

The error correction term (ECT) in the ARDL model is negative and statistically significant (−0.319), supporting the existence of a valid long-run cointegrating relationship among the variables. Its magnitude, being <1 in absolute terms, indicates gradual adjustment of energy consumption toward equilibrium following short-run deviations, at an annual correction speed of approximately 32%.

Table 3: Results of IPS unit roots test

Variable	At levels	At first difference
Energy	−1.12	−6.08***
WUI	−3.36***	
GDP	−0.08	−5.68***
GCF	−1.35*	−5.53***
Brent Oil	−1.57*	−8.02***

*, **, and *** denotes significance at 10%, 5%, and 1%, respectively. The null hypothesis of IPS test is unit root with individual unit root process
Source: author's calculation using Stata
WUI: World uncertainty index, GDP: Gross domestic product, GCF: Gross capital formation

Table 4: Panel ARDL/NARDL regression results

Variable	ARDL	NARDL
Panel A: Long run estimates		
WUI	0.197 (1.29)	
WUI+		0.539** (2.51)
WUI–		0.549** (2.50)
GDP	0.314** (2.57)	0.313*** (2.70)
GCF	0.007** (2.49)	0.007** (2.46)
Brent Oil	0.001** (2.49)	0.001**** (3.07)
Panel B: Short run estimates		
Δ WUI	−0.036 (−0.62)	
Δ WUI+		−0.265** (−2.11)
Δ WUI–		−0.68 (−0.80)
Δ GDP	0.401*** (4.53)	0464*** (4.03)
Δ GCF	−0.001 (−0.34)	−0.001 (−0.56)
Δ Brent Oil	−0.001 (−1.15)	−0.001 (−1.09)
Constant	1.725*** (2.99)	1.815*** (2.98)
Panel C: Diagnostics		
EC_{t-1}	−0.319*** (−2.95)	−0.329*** (−2.90)
Observations	146	146
Panel D: Hypotheses testing		
$WUI^+ = WUI^-$		1.02
$\Delta WUI^+ = \Delta WUI^-$		17.70***

*, **, and *** denote significance at 1%, 5%, and 10%, respectively. Numbers in parentheses are t-ratios
Source: Author's calculation using Stata
ARDL/NARDL: Autoregressive distributed lags/nonlinear autoregressive distributed lag

5.2. Nonlinear Panel ARDL (NARDL) Results

The NARDL model provides new insight into the asymmetric effects of uncertainty. In the long run (Panel A), positive changes in (WUI^+) significantly reduce energy consumption (−0.265), whereas negative changes (WUI^-) have no significant effect. This finding supports the hypothesis that rising uncertainty dampens energy demand, potentially through delayed investment, consumption hesitation, or contraction in energy-intensive activity, while falling uncertainty does not necessarily stimulate consumption at the same intensity. GDP remains a strong positive determinant (0.549), as does GCF (0.007), mirroring the linear model. Brent prices continue to show a small but significant long-run effect (0.001), affirming that higher oil revenues in the region tend to be associated with higher energy usage.

Short-run estimates (Panel B) reinforce the long-run asymmetry: only positive WUI shocks exert a significant negative impact (−0.265), confirming that uncertainty spikes reduce energy use even in the short term, possibly through immediate behavioral or policy responses. GDP remains significant (0.464), underscoring its robust effect on energy demand. However, GCF and Brent oil do not show statistically significant short-run impacts, suggesting their effects operate primarily over longer horizons.

The NARDL model's error correction term is again negative and significant (−0.329), supporting the presence of a long-run relationship among the asymmetric components and confirming that the system adjusts gradually toward equilibrium following short-run disturbances.

Finally, the Wald test results (Panel D) confirm the presence of short-run asymmetry, significant at 1%, but fail to support long-run asymmetry. This suggests that the influence of uncertainty on energy consumption is more pronounced in the short run, where behavioral reactions to rising uncertainty are immediate and contractionary. In the long run, structural adjustments or policy buffers may mitigate the full impact of uncertainty shocks, dampening asymmetry over time.

6. CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

Uncertainty is an increasingly important factor influencing energy consumption, particularly in oil-dependent economies like those of the GCC. This study examines the asymmetric impact of economic uncertainty on energy consumption using annual data from 1997 to 2023 and estimates both linear and nonlinear panel ARDL models with the PMG estimator. The findings reveal no significant effect of uncertainty in the linear model, but a clear asymmetric short-run effect in the nonlinear specification where energy consumption declines with rising uncertainty, while falling uncertainty has no comparable effect, highlighting the need to account for asymmetry in energy policy analysis.

The findings of this study have profound policy implications. For example, the finding that uncertainty exerts a significant and asymmetric influence on energy consumption in the GCC, particularly in the short run, highlights the importance of reducing policy-induced and institutional uncertainty to stabilize energy demand. Additionally, policymakers should consider integrating uncertainty indicators, such as the World Uncertainty Index, into energy forecasting models to improve planning accuracy under volatile global conditions. The significant long-run impact of GDP and investment on energy use also emphasizes the need for sustained economic growth and strategic capital formation to support energy infrastructure and demand. Additionally, given the region's dependence on oil revenues, efforts to decouple domestic energy consumption from global oil price cycles through fiscal diversification and pricing reforms may help buffer energy markets from external shocks.

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