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between Economic Policy Uncertainty and Energy Consumption in Gulf Countries: An Empirical Analysis

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The role of institutional factors in shaping the relationship between economic policy uncertainty and energy consumption in Gulf countries: An empirical analysis

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ABSTRACT:

The main objective of this paper is to examine how institutional factors mediate the impact of Economic Policy Uncertainty (EPU) on energy consumption in Gulf countries. Using the dynamic Panel Autoregressive Distributed Lag (PARDL) method, over a period stretching from 1996 to 2021, we found that, only in the long term, EPU has a positive and significant impact on energy consumption, suggesting that increased EPU leads to increased energy use. Furthermore, we found that, only in the long term, government effectiveness and regulatory quality have positive and significant effect on energy consumption. Accordingly, the two institutional factors play a moderating role of the EPU-energy consumption nexus. These findings have profound policy implications, highlighting the importance of considering the time dimension when formulating energy and economic policies in Gulf countries. Policymakers should take into consideration the nature of these relationships to make informed decisions that promote energy efficiency and economic stability in the region.

Keywords: Economic Policy Uncertainty; Energy Consumption; Institutional Factors; Gulf Countries, Dynamic PARDL.
Jel Classification : C23, D02, D80, Q43

1. Introduction:

Aiming for a resilient and stable energy sector in an era marked by growing uncertainty, frequent political shifts has emerged as a global challenge. Recent global events, such as the international financial crisis of 2007-08, the global pandemic of COVID-19, and the Russian-Ukrainian war have significantly raised economic uncertainty and made economic decisions more complex (Caggiano et al. 2020 ; Al-Thaqeb et al. 2020). Economic policymakers are forced to change their policies, plans, and measures more frequently due to discontinuities, turbulence, instability, and times of crisis. For instance, governments adjusted their monetary, budgetary, trade, and other regulatory policies (Shen et al. 2021; Cui et al. 2021; Tang et al. 2023).

Economic policy uncertainty has a negative influence on economic activity, according to a coherent body of empirical research (Hu et et. 2019; Adedoyin et al.2020). According to economics theory, an increase in economic policy uncertainty (EPU) may have a negative impact on economic activity since firms and households postpone investment and purchases, respectively (Bloom, 2014; Al-Thaqeb et al. 2019). Recent empirical studies have confirmed that economic uncertainty has a significant impact on households and firm economic activities, processes, and phenomena such as inflation expectation (Istiak et al .2019), consumption or saving behavior (Adams et al. 2020), oil prices (Hailemariam et al. 2019), investment decisions (Kong et al. 2022), carbon emissions and the environment (Tee et al. 2023 ; Iqbal et al. 2022). As a result, it is plausible to assume that it will impact energy consumption (Pirgaip et al.2020). Delaying the implementation of planned energy efficiency and conservation projects and activities, as well as the acquisition of more efficient energy products and services, should have an effect on energy consumption. Economic activity, as measured by growth, is an outcome of energy consumption, particularly when the economy is energy-dependent.

The Gulf Cooperation Council (GCC) is a political and economic alliance of six Middle Eastern countries, namely Saudi Arabia, Kuwait, the United Arab Emirates (UAE), Qatar, Bahrain, and Oman. The GCC was established in Riyadh, Saudi Arabia, in May 1981. In recent decades, the economies of the Gulf Cooperation Council (GCC) members have grown considerably. The most recent estimates of the GCC countries' combined population in 2020 is 58.6 million, with a combined economy of more than 1.6 trillion dollars in 2019 (Al-Marzouqi and Arabi, 2022). According to the new World Bank Gulf Economic Update (GEU), economies of the Gulf Cooperation Council (GCC) are expected to grow by 6.9% by 2023.

The Gulf Cooperation Council (GCC) economies rely heavily on hydrocarbons to produce energy. Domestically burning massive volumes of these fossil fuels is not a sustainable practice. The export of hydrocarbons, such as crude oil, petroleum products, and other liquids and natural gas, has boosted economic growth and brought these countries significant progress and prosperity. In GCC countries, the energy sector is critical to achieving economic and social growth, as well as contributing to GDP. However, the sector has two major negative consequences on achieving sustainable development goals: suffering resulting from the small share of renewable energy sources in energy production and the high consumption pattern; the second negative effect is on the environment. Consumption in the Gulf Cooperation Council (GCC) differs from that of most technologically advanced countries; as the world gains greater economic growth from each barrel, the GCC is heading in the other direction (Wogan et al. 2019).

Energy is often considered the pivotal force driving social progress (Kumar 2020). Nevertheless, the use of energy carries significant environmental effects, mainly linked to CO2 emission, a potent greenhouse gas responsible for global warming (Islam et al. 2023). Consequently, one of the most pressing concerns within the global warming discourse revolves around the escalating levels of Carbon dioxide (CO2) and their intricate connection to energy consumption and economic growth (Waheed et al. 2019). Aware of these environmental challenges, numerous nations have initiated efforts to diversify their energy portfolios and transition towards greener economies or sustainable growth models.

In the face of the sustainability challenges outlined earlier, it becomes evident that the role of institutional factors is not just relevant but paramount in effectively addressing these pressing issues (Godil et al. 2021; Vatamanu et al. 2023). While the Gulf countries have achieved remarkable economic growth and development through their vast energy resources, they now stand at a crossroad, grappling with the urgent need for sustainability. These institutional factors, encompassing government policies, regulations, and governance structures, play a central role in shaping the path forward.

Several recent studies have investigated the effect of economic policy uncertainty on energy consumption, primarily within the context of a carbon dioxide (CO2) or growth functions (Adams et al.2020; Adedoyin et al. 2020; Abbasi and Adedoyin, 2021; Liu et al. 2021; Pirgaip et al. 2020; Wang et al. 2022). However, the specific impact of institutional factors on this relationship has received little attention in the existing literature. While there have been numerous studies on EPU and energy consumption, a few have dug into the complicated details of this relationship inside the Gulf countries, where economic and geopolitical realities differ significantly from other regions. This study gap not only raises issues on the specific drivers of energy consumption in the GCC countries, but also highlights the need for a thorough investigation of how institutional factors may impact this relationship.

This paper delves into the multifaceted role of institutional factors, specifically governance effectiveness and regulatory quality, in shaping the intricate relationship between EPU and energy consumption in the GCC countries. We explore how these institutional elements mediate the impact of economic uncertainties on energy consumption patterns. By doing so, we aspire to provide valuable insights for policymakers, energy planners, and researchers, offering a nuanced understanding of the dynamics that underpin energy consumption in this critical region.

To the best of our knowledge, this study is one of the few that addresses EPU in terms of energy consumption in the Gulf countries, while taking into account the role of institutional factors in moderating and shaping this relationship. Bearing on these insights, our aim is to significantly contribute to the Gulf countries' sustainable development and energy strategies. Our study seeks to address several relevant research questions that underscore the multifaceted dynamics at play within the Gulf countries: (1) What is the impact of economic policy uncertainty on energy consumption in the GCC countries? (2) How do institutional factors within the Gulf countries affect the relationship between economic policy uncertainty (EPU) and energy consumption? And (3) What are the policy implications of these findings?

This study contributes to the previous literature as follows. First and foremost, we use the Panel ARDL framework, along with the Dumitrescu and Hurlin panel causality test, to comprehensively examine the relationships between Economic Policy Uncertainty, energy consumption, and CO2 emissions. This methodological approach enhances the robustness of our findings and contributes with valuable insights into the methodology used in similar studies. Second, none of the previous studies has tried to see how institutional factors mediate or moderate the EPU-energy consumption nexus, and especially in the GCC context. This adds a nuanced dimension to our understanding of how institutions shape the energy-policy landscape in the GCC, shedding light on their significance in mitigating or exacerbating the effects of EPU on energy consumption. Last but not least, we provide empirical evidence that fills the gap for GCC countries that play a pivotal role in the global climate landscape. Our findings offer insights into how this critical region goes through the interplay between economic policy uncertainties, energy use, and environmental sustainability, underscoring the importance of tailored policy responses and institutional strength in achieving sustainable energy transitions and mitigating the impact of EPU on energy consumption and CO2 emissions.

The paper is divided into six sections. The second is the theoretical background that serves to state important existing theories that link our variables. The third is the literature review which provides a comprehensive overview of existing studies in the field. The fourth is the data and methodology section. The results and their discussion are reported in the fifth section. Finally, the sixth section concludes the paper and provides policy implications.

2. Theoretical Background:

Uncertainty theory has become more widely used and applied in a variety of areas. In economic policy, uncertainty refers to government or other authority acts and choices to manage and impact the economy. In addition, uncertainty can depress real economic activity via the *"precautionary savings"* channel as highlighted by Caballero (1990). This occurs when individuals or agents limit their consumption in reaction to increased uncertainty (Leland 1968; Kazarosian 1997; Chun et al. 2023; Huang et al. 2021) Expectedly, industries will use cheap energy for production to make up for low turnover due to EPU. Therefore, as the net income of such industries increases, they might use high-energy production methods that are cleaner and invariably reduce carbon emissions (Adedoyin et al. 2020). As a result, *the Environmental Kuznets Curve (EKC) hypothesis* may be valid regarding the impact of EPU on energy consumption. The EKC hypothesis posits an inverted U-shaped relationship between environmental degradation and economic development, suggesting that as a nation's economy grows, environmental degradation initially increases but eventually decreases after reaching a certain level of development (Lahrech et al., 2023).

In recent years, the EKC hypothesis has been adapted to the energy literature in search of its validation, particularly in the face of increasing Economic Policy Uncertainty (EPU). This latter has emerged as a significant factor influencing the link between economic development, energy consumption, and environmental outcomes. Several studies have validated the EKC hypothesis highlighting the effect of EPU on energy consumption (Adams et al. 2020; Udeagha et al. 2022; Anwar et al. 2023).

In the energy- economic growth nexus, different studies emerged to understand the interplay between these two aspects. Akarca et al. (1980), Kraft and Kraft (1978) and Proops et al. (1984), among others, are the first who studied this relationship. These authors provided contradictory results, prompting the development of four hypotheses. The first one is the *''growth hypothesis",* stating that causality extends from energy use to economic growth. Previous studies have been conducted to investigate this hypotheses. For example, Sadorsky (2009) contends that energy use in all forms, including industrial and domestic, is a fundamental determinant of economic growth and prosperity. As countries grow, so does energy demand. In addition, others proved the validity of this hypothesis (Acheampong 2018; Adams et al. 2018). However, in the reverse way of causality, from economic development to energy consumption the conservation hypothesis is confirmed. The first strand of studies stems from the foundational paper of Kraft and Kraft (1978), which investigated the relationship between energy use and economic growth in the United States. The authors' findings lend support to the *"Conservation hypothesis,"*. In practice, this hypothesis states that energy-saving strategies can be adopted regardless of economic growth concerns. When there is a two-way causality between energy use and economic growth, the *"Feedback hypothesis"* is valid. With bidirectional causality between energy use and economic growth, a new type of relationship may emerge (Aydin, 2019 ; Tugcu et al. 2012). Finally, when there is no causality between energy consumption and economic growth, this is the *"Neutrality hypothesis''*.

3. Literature Review:

3.1. Economic Policy Uncertainty Measurements

The current literature has examined economic policy uncertainty in relation to government taxation, regulatory, environmental, budgetary, and monetary policies (Phan et al., 2021; Al-Thaqeb et al. 2019 ; Pirgaip et al. 2020). Several studies have analyzed the effects of economic policy uncertainty on households, corporations, and economies. These effects are frequently negative (Bloom 2009, 2014; Baker et al. 2016; Jian et al. 2021). Moreover, government intervention can sometimes lead to an increase in economic policy uncertainty. This can occur when government policies are unclear, inconsistent, or subject to sudden changes, leading to confusion and hesitation among businesses and investors (Baker et al. 2016). However, some studies have questioned the extent of the negative impact of EPU on firms. For example, Maquieira et al. (2023) contend that EPU may result in some favorable effects, such as improved innovation and higher production, especially for businesses that are better equipped to adjust to uncertainty. However, more recent research by (Jian et al. 2021) shows that higher EPU causes businesses to make fewer investments, especially in high-tech sectors, which could have a detrimental long-term impact on economic growth.

Economists have used a wide range of proxies because there is no objective way to evaluate uncertainty. As far as we know, economic uncertainty is challenging to comprehend since it cannot be directly observed (Al-Thaqeb et al.2019). EPU, as its name suggests, hones in on the specific domain of economic policies, unraveling the intricate web of uncertainty surrounding decisions that shape budgetary, tax, monetary, and trade policies. It tracks fluctuations in sentiment and mentions related to economic policy in news articles, scrutinizing the nuances of policy-related uncertainty. The EPU Index was developed by Baker et al. (2016). On the other hand, the World Uncertainty Index (WUI) looks at a broader picture of uncertainty. It does not just focus on economic policies; it also considers political and global uncertainties, including events that affect the economy, politics, and society worldwide (Borozan and Borozan, 2022). The WUI combines different measures, such as economic uncertainty and policy-related uncertainty, along with other sources of unrest (Ho and Gan. 2021). This index gives us a complete picture of global uncertainty, showing how economic, political, and social factors all interact on a worldwide scale. The WUI was developed by Ahir et al (2022)

3.2. Economic Policy Uncertainty and Energy Consumption

The previous literature contends that EPU and energy consumption are tightly linked because of fluctuations in energy prices caused by market demand and supply shocks, as well as negative expectations of macroeconomic developments, such as economic growth. These expectations may affect consumer and firm decisions on energy use (Kang et al. 2014; Asafu, 2000). Bearing on well-established previous research proving that CO2 emissions mostly depend on the use of energy for the sake of economic growth (Soytaş et al. 2007 ; Mardani et al., 2019; Apergis et al . 2010 ;Zhou et al., 2011; Özcan, 2013; Salahuddin et al. 2014; Appiah 2018), such a close interrelationship may also exist between EPU and CO2 emissions, even though this concomitance is somewhat blurred. As a matter of fact, the relationship between economic policy uncertainty and energy consumption can be multifaceted and complex.

On the one hand, an intense level of economic policy uncertainty can lead to a hard environment for energy companies, making it difficult for them to make long-term investments and decisions in the face of unclear policies. Balcilar et al. (2019) investigated the relationship between EPU and energy consumption using a sample of 19 OECD countries. The study found that EPU has a negative impact on energy consumption, with higher levels of EPU leading to lower energy consumption. This can be due to households and firms becoming more cautious in their energy consumption behavior during times of uncertainty. These findings are also supported by Pirgaip et al. (2020), who also found evidence of a causal relationship between EPU and energy consumption in G7 countries. Their primary findings indicate that when economic policy uncertainty is high, this will lead to less energy consumption. In essence, EPU may lead to decreased energy use by creating an environment where businesses are hesitant to engage in activities that require significant energy consumption. Bearing on these studies, we can formulate our first hypothesis as follows:

H1: EPU has a negative and significant impact on energy consumption.

On the other hand, under some circumstances, economic policy uncertainty may positively affect energy consumption. For instance, Adams et al. (2020) demonstrated that economic policy uncertainty has a negative impact on environmental quality in both the short and long run, as well as bidirectional causal link between energy consumption and CO2 emissions in resource-rich countries. Wang et al. (2022) discovered that increasing EPU leads to increased CO2 emissions in the long term in the United States, which implies that it increases energy consumption. Similarly, Adedoyin et al. (2020) found that a rise in EPU in the long run is expected to have a negative impact on climate change and generate an unhealthy atmosphere. This is due to an increase in CO2 emissions. We can explain this by the fact that EPU may hinder the development and implementation of comprehensive, long-term environmental policies. Governments facing economic uncertainty may be less likely to allocate resources and political capital towards crafting and enforcing stringent environmental regulations. Then, from the above recent studies, we can formulate our second hypothesis:

H2: EPU has a positive and significant impact on energy consumption.

Finally, another strand of the literature stated that EPU and energy consumption do not have a significant relationship. For instance, Appiah (2021) found that Economic Policy Uncertainty has an insignificant negative effect on Renewable Energy (RE) growth, and there is no evidence of a causal relationship between EPU and RE growth. This implies that, based on their analysis, changes in economic policy uncertainty do not have a substantial or meaningful impact on the growth of renewable energy sources. In other words, fluctuations or uncertainty in economic policies, such as taxation, subsidies, or regulations, do not seem to significantly hinder or promote the development and expansion of renewable energy technologies and industries. Similarly, Abbasi and Adedoyin (2021) found that EPU does not have a significant impact. This leads us to our final hypothesis:

H3: The relationship between EPU and energy consumption is not significant.

3.3. Economic Policy Uncertainty and Institutions

Institutions significantly impact the stability and growth of economies because they provide the framework within which economic decisions and policies are developed (Arvin et al. 2021). On the other hand, EPU is an issue for practically every industry, but it has a significant impact on corporate operations. A government's reckless actions create a significant level of economic policy uncertainty. This leads us to talk about the role of institutions in mitigating the impact of EPU. This may depend on the quality of institutions. In fact, a poor quality of institutions may increase economic policy uncertainty. The moderating effect of governance institutions on the relationship between uncertainty and economic performance has yet to be accounted for. In this regard, we can cite different studies like those of Ekeocha et al., (2023), Ogbonna et al., (2022), and Arvin et al. (2021). One of the recent studies on this matter is that of Ahir et al. (2022). The authors look into the function of institutional quality in supporting or reducing the spread of economic and political instability. The study demonstrates that the influence of uncertainty on output depends on a country's level of institutional quality. Their findings imply that in nations with low institutional quality, economic policy uncertainty has a significant and long-lasting influence on output. However, the effect of uncertainty is smaller and shorter-lived in countries with relatively strong institutional quality. Surprisingly, these findings are true even after controlling for development level and its relationships with uncertainty. This study emphasizes the importance of institutional factors in moderating the relationship between economic policy uncertainty and its repercussions, highlighting the critical role of institutions in fostering economic stability and resilience. Similarly, another study by Farooq et al. (2022) showed that political stability can minimize the detrimental impact of EPU on environmental quality. As with individual relationships, stronger political stability reflects excellent governance, which appears to play a role in reducing CO_2 emissions.

3.4. Energy Consumption and Institutions

In recent decades, numerous studies have highlighted the crucial role of governance as a significant factor influencing economic development. These investigations have consistently demonstrated a strong connection between effective governance and advancements in economic growth. This dynamic relationship underscores the fundamental impact that governance quality can have on a nation's overall economic growth (Fayissa et al .2013; Al-Naser, 2019). The relationship between governance and energy consumption is currently capturing the interest of policymakers and academic scholars. For instance, Chun et al. (2023) conducted an extensive analysis focusing on the Association of Southeast Asian Nations (ASEAN) countries. Their study underscores the positive link between government effectiveness and increased renewable energy consumption. Effective governance in these nations promotes developmental projects to ensure a sustainable energy supply, emphasizing the use of renewable energy sources like solar, wind, and hydro plants. This aligns with the findings of Bellakhal et al. (2019), emphasizing the role of effective governance in renewable energy promotion. This is totally expected because of the fact that effective governments are able to develop and implement energy policies that encourage sustainable practices so that energy consumption will decrease intensively. They can introduce regulations, incentives, and targets that promote energy efficiency and the use of renewable energy sources. Indeed, governments with effective governance are better equipped to implement environmental protection policies, including those related to renewable energy adoption. This ultimately contributes to lower energy consumption and a greener energy mix. Li et al. (2022) contribute to the discussion by highlighting the essential role of governments in environment protection, with a particular emphasis on renewable energy. However, it also raises questions about the varying levels of government effectiveness in achieving environmental goals. While effective governance is essential for environmental sustainability, effectiveness of governmental institutions in different countries remains a topic of debate. Many governments have made renewable energy one of their top priorities in order to reduce environmental degradation (Usman et al., 2020; Wang et al. 2022). The role of government in influencing environmental quality is critical. The mission of the government is to enact and implement policies that promote resource sustainability and identify better ways to achieve environmentally friendly growth (Arslan et al., 2022, Mehmood 2022).

Few studies have examined the impact of governance on the environment, and the results have been mixed. Khan et al. (2021) show that governments' environment-protection effectiveness has not yet reached the desired level. As a result, it does not play a significant role in sustaining environmental quality. Government effectiveness has a negative association with environmental sustainability, according to the conclusions of Lee (2017). Moreover, Burger et al. (2015) address knowledge gaps concerning governance and individual consumption behavior related to energy. Their interdisciplinary framework aims to create a systematic basis for understanding how governance affects energy-related consumption behavior. Finally, Omri and Mabrouk (2020) emphasize the role of effective governance practices and institutional balance in promoting both economic growth and environmentally responsible energy consumption. Their study expands the discussion by pointing out that governments with effective institutions effectively implement environmental regulations, encourage eco-friendly technology adoption, and facilitate technology transfer. These actions contribute to positive environmental outcomes. In contrast, ineffective governance, often associated with corruption, hinders energy efficiency and negatively affects the energy sector.

3.5. The role of institutions in moderating the relationship between EPU and energy consumption

Recent research on the moderating role of institutional factors in the relationship between Economic Policy Uncertainty (EPU) and energy consumption is relatively limited, with only two notable studies. For instance, Jiang et al. (2023) focused on the impact of Economic Policy Uncertainty, institutional quality, and renewable energy consumption on green growth in seven emerging countries. The authors found that EPU had a negative impact, indicating that higher levels of economic policy uncertainty were associated with lower green growth. On the other hand, institutional quality and renewable energy consumption were found to enhance green growth in these countries. This study highlighted the importance of institutional quality in enhancing green growth. Good governance, represented by high institutional quality, can indirectly moderate the impact of EPU on energy consumption by fostering a stable and supportive environment for sustainable practices. Ali et al. (2023) looked into the moderating role of institutional quality in the relationship between Economic Policy Uncertainty and carbon emissions. The findings revealed that an increase in institutional quality effectively mitigated the adverse effects of uncertainties caused by EPU. In simpler terms, the authors investigated how the quality of institutions in a country could act as a buffer against the negative impact of economic policy uncertainty on energy consumption and, consequently, carbon emissions. Strong institutional quality is found to foster a sustainable environment, making it possible for countries to manage the environmental consequences of economic development more efficiently.

4. Model and Data

To comprehensively investigate the intricate relationships between energy consumption, economic policy uncertainty, and institutional factors in the Gulf Countries, this study adopts a rigorous analytical approach. Model specification draws inspiration from the seminal studies of (Ogbonna et al. 2022) as well as (Mensah et al., 2019), both recognized for their pioneering contributions to dynamic panel modeling.

The formulated model takes the following structural shape:

$$\ln\_PEC_{it} = \alpha_i + \alpha_1 EPU_{it} + \alpha_2 INQ_{it} + \alpha_3 \mathrm{INQ}_{it} * EPU_{it} + \alpha_4 CO2_{it} + \alpha_5 Ln\_GDP_{it} + \varepsilon_{it} \quad (1)$$

Where $\ln\_\mathrm{PEC}_{it}$ is energy consumption of country i at time t; EPU_{it} is the world uncertainty index, INQ_{it} represents the two institutional factors, namely government effectiveness and regulatory quality, $INQ_{it} * EPU_{it}$ is the interaction term capturing the combined influence of Economic Policy Uncertainty and institutional factors on the examined outcomes, CO2 denotes CO2 emissions; Ln_GDP_{it} denotes the gross domestic product; ε denotes error term; and $\alpha_1; \alpha_2; \alpha_3; \alpha_4$ are the parameters to be estimated.

This study centers on understanding the roles of coefficients β and α within the derived partial derivative equation. Therefore, the overall impact is calculated by determining the partial derivative of Equation (1) in relation to EPU.

$$\frac{dLn\_PEC_{it}}{dEPU_{it}} = \beta + \alpha INQ_{it} \quad (2)$$

The data for this study covers the 1996-2021 period for 5 of the Gulf countries, which are Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. The data sources are described in Table 1. Bahrain was excluded from the analysis because of the unavailability of the necessary data required for the study.

Table1: Data description and source

Variable	Definition	Source
PEC	Primary energy Consumption per capita Gigajoule per capita	International Energy Agency (IEA) from (https://www.iea.org/)
EPU	World Uncertainty Index	(Ahir et al. 2018) from https:// world uncertaint yindex. com/
GOVE	Government effectiveness	World Bank's World Governance Indicators (WGI) from (https://databank.worldbank.org/source/worldwide-governance-indicators)
REGQ	Regulatory quality	World Bank's World Governance Indicators (WGI) from (https://databank.worldbank.org/source/worldwide-governance-indicators)
CO2	Co2 emissions	World Bank's World Development Indicators (WDI) (https:// datacatalog.World bank.orgdatas et/ world- development- indicators)
GDP	GDP per capita (constant LCU)	World Bank's World Development Indicators (WDI) (https://datacatalog. World bank. org/ datas et/ world- development-indicators)

Source:Authors

We opted for the Panel Autoregressive Distributed Lag (PARDL) model because of its ability to effectively analyze both short-term and long-term dynamics in panel data. The model's adaptability to various units within the panel and its robustness in addressing endogeneity and serial correlation issues were crucial for our comprehensive analysis. Then, the ARDL model is generally characterized by the following form:

$$(Y_i)t = \sum_{j=1}^{a} \gamma_{ij} (yi)_{t-j} + \sum_{j=0}^{b} \delta_{ij} (xi)_{t-j} + \varepsilon_{it} \quad (3)$$

Consequently, it is a common approach to reconfigure equation (3) into an error correction equation:

$$\Delta(Y_i)t = \sum_{j=1}^{a-1} \gamma_{ij}\, \Delta(yi)_{t-j} + \sum_{j=0}^{b-1} \delta_{ij} \Delta(xi)_{t-j} + \varphi_i\, [(yi)_{t-1} - \{\beta_{0i} + \beta_{1i}(xi)_{t-1}\}]\varepsilon_{it} \quad (4)$$

In our context, 'y' represents energy consumption while 'x' denotes the independent variables, including EPU, CO2 emissions, GDP, and the two institutional factors. The short-term coefficients for both the dependent and independent variables are denoted as 'γ' and 'δ', respectively. Additionally, the long-term coefficients are indicated by 'β', and the speed of adjustment is captured by 'φ'. It is noteworthy that 'i' denotes the country under consideration, and ’t’ symbolizes the specific time period in focus.

5. Results and Discussion

5.1. Preliminary Data Assessment

Table 2 presents summary statistics for the variables used in the analysis of the Gulf nations. Energy Consumption (ln_PEC) shows an average of 12.91, suggesting a moderate level of energy consumption across the dataset. The World Uncertainty Index (WUI), with a mean of 0.11, indicates relatively low uncertainty, while Government effectiveness (GOVE) and Regulatory Quality (REGQ) show variability with means of 0.385 and 0.347, respectively. CO2 Emissions (CO2) span from 8.562 to 47.657, showcasing a diverse environmental impact. The Gross Domestic Product variable (Ln_GDP) ranges between 8.909 and 12.595, illustrating economic variations.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ln_PEC	130	12.91	.473	11.6	13.762
WUI	130	.11	.082	0	.374
GOVE	130	.385	.462	-.381	1.505
REGQ	130	.347	.345	-.308	1.107
CO2	130	23.182	9.995	8.562	47.657
L_GDP	130	10.79	1.409	8.909	12.595

Source: Authors

The correlation matrix is represented in Table (3). First, we found strong positive correlation between energy consumption and carbon emissions by 0.9141. This correlation coefficient underscores reliance on fossil fuels for energy generation in the Gulf countries, primarily driven by oil production. Second, we found moderate positive correlation between ln_PEC and GOVE (0. 457). The oil-driven revenue stream might enable investments in governance improvements, yielding more effective institutions and policy-making processes. Furthermore, the correlation coefficient of 0.5335 between Ln_GDP and CO2 emissions highlights the moderate positive correlation between economic growth and environmental impact. Finally, the low positive correlation of 0.1206 between EPU and (GOVE) suggests a potential link between economic policy uncertainty and governance effectiveness in the Gulf countries. While correlation is not very strong, it hints at the importance of stable economic policies in facilitating effective governance.

Table 3: Correlation Matrix and VIF test

Variables	(1)	(2)	(3)	(4)	(5)	(6)	VIF	1/VIF
(1)Ln_PEC	1.000							
(2)EPU	-0.107	1.000					1.132	0.883
(3)GOVE	0.457	0.121	1.000				4.193	0.239
(4)REGQ	0.346	0.181	0.808	1.000			3.131	0.319
(5)CO2	0.914	-0.220	0.340	0.198	1.000		1.456	0.687
(6)Ln_GDP	0.678	-0.133	0.577	0.335	0.533	1.000	2.004	0.499
Mean VIF							2.383	.

Source: Authors

The Variance Inflation Factor (VIF) is a measure used to assess multicollinearity among predictor variables in a regression analysis. The results are presented in Table (3) showing that the mean VIF value of 2.383 for all variables collectively is relatively low. This indicates that there is no substantial multicollinearity issue among the predictor variables in the analysis as a whole.

5.2. Econometric Test Result

Upon conducting a test on residuals, a substantial level of cross-sectional dependence was detected. The null hypothesis (H0) of low cross-sectional dependence has been convincingly rejected at all significant levels, as indicated by the obtained p-values. This outcome demonstrates that there is substantial evidence indicating the presence of interdependence among residuals across the various entities. Consequently, we will respect the outcome of the CD test of residuals, and this led to a crucial decision in the analysis. Considering that first-generation unit root tests may not perform well under cross-sectional dependence, adoption of second-generation panel unit root tests became imperative.

Testing for weak cross-sectional dependence (CSD)

H0: weak cross-section dependence

H1: strong cross-section dependence

Table 4: Cross-sectional dependence test

	CD	CDw	CDw+	CD*
Residuals	3.540	-2.810	22.720	2.190
	(0.000)***	(0.005)***	(0.000)***	(0.025)***

P-values in parenthesis. ***, **, and * indicates 1%, 5%, and 10% significance levels, respectively
References
CD: Pesaran (2015,2021)
CDw: Juodis, Reese (2021)
CD*: Pesaran, Xie (2021) with 4 PC(s)

Source: Authors

Table (5) outlines the main findings of the homogeneity test. The extremely low p-values (both for "Delta" and "adj. Delta") indicate that the null hypothesis of slope homogeneity is rejected for all of the studied variables. This means that the variable's slope coefficients are not the same across different groups or entities in the panel dataset.

Testing for slope heterogeneity (Pesaran, Yamagata. 2008. Journal of Econometrics)

H0: slope coefficients are homogenous

Table 5: Results from the Pesaran-Yamagata's homogeneity test

	Delta	P-Value
	7.164	0.000***
Adj.	8.169	0.000***

P-values in parenthesis. ***, **, and * indicates 1%, 5%, and 10% significance levels, respectively

Source: Authors

To assess stationarity of the variables in the dataset, the panel unit root tests, notably the Covariate Augmented Dickey-Fuller (CADF) and Cross-Sectionally Augmented IPS Test (CIPS) tests, were performed. Table (6) shows that when the variables are considered at their original levels, the null hypothesis of non-stationarity cannot be rejected except for the EPU variable. When the variables are examined at their initial differences, the null hypothesis of non-stationarity is rejected, showing that the variables become stable after differencing. Since the variables show unit roots at their levels but become stationary at their first differences, we conducted a panel cointegration test to investigate the potential long-term relationship among the variables. As a result, we tested cointegration in the presence of slope heterogeneity and cross-sectional dependence.

Table 6: Results from CADF and CIPS panel unit root test

Variables	CIPS		CADF	
	Level	Δ	Level	Δ
Ln_PEC	-1.538	3.350***	0.345	0.026**
EPU	-2.997***	----------	0.312	0.000***
GOVE	-2.201	-4.770***	0.071**	---------
REGQ	-1.596	-4.700 ***	0.880	0.000***
CO2	-1.678	-3.741***	0.325	0.032
Ln_GDP	-1.500	-3.007***	0.710	0.002***

Note: Δ represents the first differences, ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels respectively.

Source: Authors

5.3. Panel ARDL Estimation Results

The results in Table (7) show that economic policy uncertainty impacts positively and significantly energy consumption in the studied Gulf countries, in the presence of GOVE or REGQ, but only in the long run. Specifically, the first column, indicates that an increase by 1% of EPU leads to 6.48% increase in primary energy consumption in the long run at 5% significance level. We confirm the second hypothesis that indicates the presence of a positive relationship between these variables. It is evident that EPU is expected to minimize energy consumption because it has a negative impact on economic activity and consumption. The reverse impact, however, has already been detected (Pirgaip et al. 2020). This finding is also consistent with that of Li et al. (2023), who found a positive relationship between EPU and energy consumption. This impact can be attributed to several factors within the energy sector itself in that the energy industry often requires long-term planning and significant investments for the development of infrastructure, exploration, and technological advancements. In times of heightened uncertainty, businesses within the energy sector may initially postpone or scale down their projects because of a lack of clarity in policy directions, making it challenging for them to commit to substantial investments (Al-Thaqeb et al. 2019). The fact that the impact of EPU is found significant only in the long run results from several factors. First, Gulf countries rely heavily on oil revenues to fund their governments and support their economies. This heavy reliance makes them particularly vulnerable to fluctuations in global oil prices, geopolitical tensions, and economic uncertainties (Tsai et al. 2020). Therefore, they often experience economic policy uncertainty related to global oil markets. Factors like shifts in oil demand, production decisions by OPEC (Organization of the Petroleum Exporting Countries), and geopolitical events in the Middle East can create significant economic policy uncertainty. During periods of high EPU, Gulf governments may respond by intervening in energy markets. For instance, they may increase or maintain energy subsidies to keep domestic fuel and electricity prices stable, which can encourage higher energy consumption (Tsai et al . 2020). Finally, in recent years, Gulf countries have recognized the importance of diversifying their energy mix by investing in renewable energy sources like solar and wind. While these initiatives aim to reduce dependency on oil and mitigate the impact of EPU in the long run, they might not have an immediate impact during times of economic uncertainty (Alqahtani et al .2021). In these countries, it is important to acknowledge the unique economic features that differentiate them from other regions. In addition, policies that result in a reduction of EPU are likely to hold promise in addressing environmental challenges linked to their substantial energy dependency. When factoring in the higher levels of development these nations have achieved, it becomes obvious that EPU could stimulate energy consumption.

Investigating government effectiveness as an institutional factor impacting energy consumption in column (1), our findings align with established research, showing the dynamic connection between GOVE and energy consumption noted in previous studies (Apergis et al. 2015; Barrera-Santana et al. 2022). Our study, as a contribution to the limited literature exploring this nexus, reveals a positive significant relationship only in the long run, indicating a phase of adjustment. This aligns with the findings of Al-Tal et al. (2021), emphasizing that an effective government tends to prioritize economic development and to implement policies fostering industrial growth and infrastructure development. Such efforts stimulate energy-intensive economic activities, contributing to an increased energy consumption over time. These results resonate with earlier studies (Bellakhal et al. 2018; Li et al. 2022). The initial lack of significance in the short run of the relationship between government effectiveness and energy consumption can be attributed to the time needed for policies to take effect and industries to adjust. In the long run, as industries adapt and optimize energy-efficient practices, the significance and the positive impact of government effectiveness become more pronounced. This gradual shift underscores the importance of considering the adaptation and adjustment processes over time (Mehmood 2022).

Similarly, when integrating regulatory quality as an institutional proxy in column (2), we found the same results showing a positive link with energy consumption, particularly in the long run. This outcome aligns with expectations, as high regulatory quality implies a stable environment, attracting investments in energy-related industries. Such investments promote the expansion of energy-intensive sectors, resulting in an increased energy consumption (Khan and Ulucak, 2020; Halkos and Tzeremes, 2013). Additionally, improved regulatory quality facilitates long-term energy infrastructure projects, attracting financing and promoting successful completion, leading to increased energy consumption (Ibrahim et al. 2022). Integration of REGQ in the model has unconventional short-term effects on the GDP-energy consumption nexus. This may have resulted from their distinct roles within the regulatory and governance framework. In summary, the short-term significance of the GDP-energy consumption link when REGQ is included in the model likely reflects the immediate impact of regulatory quality on economic behavior, investments, and energy demand. Over time, the effect of REGQ may diminish as its effects are integrated into the economy, potentially leading to a less pronounced association between GDP and energy consumption in the long run.

The results of all our models indicate that CO2 emissions impacted positively and significantly energy consumption, in both the short and long run, by 5%, and 1% significance levels, respectively. In fact, this result holds regardless of whether the institutional factor is measured by government effectiveness or regulatory quality. In practical terms, this suggests that when there is more economic activity, industrial production, or energy-intensive processes that generate CO2 emissions, it leads to higher energy consumption. Our findings align with previous research. (Magazzino 2016; Alam et al. 2011). This finding was explained by Zhang et al. (2019) by the fact that policies and practices aimed at reducing carbon dioxide emissions have a notable effect on altering energy consumption patterns. In other words, when governments or businesses implement strategies to decrease their CO2 emissions, they often lead to changes in the way energy is used.

As expected, economic growth (GDP) is positively associated with energy consumption. A 1% increase in GDP leads to 2.66% increase in energy use at all significance levels in both the short and long run. This finding is obvious, the connection between GDP growth and increased energy consumption is straightforward. As the economy expands and prospers, demand for energy rises. This happens because of more industries, bigger cities, improved living standards, and greater business activities. With growing economic opportunities, people use more energy for everything from powering factories to cooling homes and running businesses. This connection between economic growth and energy demand is a natural outcome of development and progress in the Gulf nations. This finding aligns with the existing literature (Soyta et al. 2003; Mohiuddin et al. 2016)

To consider the net effect of using institutional factors to shape the relationship between EPU and energy use, Columns (3) and (4) prove that the unconditional effect of economic policy uncertainty is positive (1.453), (1.161) respectively, while the marginal effect of the interaction of governance effectiveness, and regulatory quality with the EPU variable is negative (-0.901), (-0.481), and all are statistically significant at the 5% level.

Take, for example, Column (3) of Table 7, where we calculated the net effect of economic policy uncertainty when factoring of government effectiveness as an institutional factor using Eq (2)

$$\frac{dL\_PEC_{it}}{dEPU_{it}} = 1.453 - 0.901 GOVE_{it} \quad (5)$$

Then, we found that the net effect of EPU on energy consumption is (1.1058) at average GOVE level (The calculations are presented in the appendices). First, the results indicate that the interaction effect between economic policy uncertainty and government effectiveness is more pronounced in the long run than in the short run. The negative coefficient for the interaction term indicates that when both economic policy uncertainty and government effectiveness are high, their combined effect leads to a reduction in energy consumption. In other words, in Gulf countries, a strong and effective governance structure can help mitigate energy consumption increase that would otherwise result from high levels of economic policy uncertainty. The net effect of EPU on energy consumption, when considering this interaction and with an average GOVE level, is positive but reduced. This implies that while EPU tends to increase energy consumption, the presence of effective governance limits this effect to some extent. Our results are consistent with theoretical and empirical expectations (Ali et al. 2023; Jiang et al. 2023). For instance, in Gulf countries, where energy resources play a vital role in the economy, high levels of EPU can create uncertainty in energy-related policies and decisions. For energy consumption, strong governance can result in consistent and well-regulated energy policies, which may discourage excessive energy consumption and promote more efficient energy use (Radwan et al. 2021). Therefore, the negative interaction term suggests that in Gulf countries, strong and effective governance plays a crucial role in mitigating the potential increase in energy consumption associated with high levels of EPU. While EPU tends to stimulate energy consumption due to uncertainty, effective governance structures work to counteract this effect to some extent by providing stability and regulatory consistency in the energy sector. Then, strong governance can help regulate and manage energy consumption, ensuring more efficient use of energy resources. It can also promote the development and adoption of sustainable energy practices (Radwan et al.2021).

When we examined the interaction effect between economic policy uncertainty and regulatory quality, we found similar results but they differ only over time. Specifically, we found that the interaction effect is more pronounced in the short run than in the long run. In the short run, regulatory bodies and businesses in GCC countries may be more responsive to changes in economic policy uncertainty. Regulatory quality reveals the government's ability to establish and implement comprehensive policies that favor private sector development. (Al Abri et al. 2022). When EPU increases, it introduces uncertainty into the business environment. In such situations, regulatory quality becomes crucial because it defines how well businesses can adapt to changing circumstances. In the short run, businesses may rely on clear and favorable regulations to navigate uncertainties quickly. Therefore, regulatory quality reflects how agile and responsive regulatory bodies are in GCC countries. When EPU rises, regulatory authorities may enact or modify regulations rapidly to stabilize the economic environment. Then, well-enforced regulations can help keep energy consumption in check even when economic policies are uncertain (Radwan et al. 2021).

Table 7: Panel ARDL estimation results

Variables	(1)	(2)	(3)	(4)
Long Run				
EPU	0.648** (0.011)	0.675*** (0.007)	1.453*** (0.000)	1.161*** (0.006)
GOVE	0.141** (0.059)		0.206*** (0.000)	
REGQ		0.263*** (0.004)		0.239*** (0.010)
EPU*GOVE			-0.901** (0.011)	
EPU*REGQ				-0.798 (0.166)
CO2	0.029*** (0.000)	0.035*** (0.000)	0.029*** (0.000)	0.029*** (0.000)
Ln_GDP	0.266** (0.018)	0.063 (0.688)	0.313*** (0.000)	0.163 (0.147)
ECT	-0.200*** (0.000)	-0.190*** (0.000)	-0.262*** (0.007)	-0.233*** (0.000)

Short Run				
EPU	0.036 (0.510)	-0.014 (0.841)	0.064 (0.624)	0.104 (0.249)
GOVE	-0.083 (0.309)		-0.0004 (0.967)	
REGQ		0.004 (0.812)		0.027 (0.425)
EPU*GOVE			-0.584 (0.169)	
EPU*REGQ				-0.481*** (0.006)
CO2	0.026*** (0.000)	0.024** (0.084)	0.020** (0.020)	0.019** (0.024)
Ln_GDP	0.255*** (0.003)	0.269*** (0.000)	0.361** (0.043)	0.324 (0.145)

***, **, and * indicates 1%, 5%, and 10% significance levels, respectively

Source: Authors

The error correction term (ECT) determines adjustment speed. The ECM findings show that, as expected, ECT is highly significant and negative at all significance levels. This study suggests that all our variables have a consistent long-run relationship.

5.4. Dumitrescu and Hurlin panel causality

The panel causality results presented in Table (8) by Dumitrescu and Hurlin (2012) suggest a unidirectional causality relationship running from:(1) CO_2 emissions to economic growth; (2)CO_2 emissions to EPU; (3) energy consumption to government effectiveness (4) energy consumption to regulatory quality; and (5) energy consumption to CO_2 emissions. Some researchers have already investigated the relationship between EPU and CO_2 emissions. Nevertheless, the findings are very inconclusive. According to the first research stream, EPU causes CO_2 emissions. EPU affects the economy, causing industry to prefer traditional cheaper energy sources (such as coal and oil) for production, increasing CO_2 emissions (Jiang et al. 2019; Pirgaip et al.2020; Adams et al. 2020). On the other hand, a lot of studies have found unidirectional causality link running from CO_2 to EPU. (Mardani et al. 2019; Ozturk et al. 2021 ; Kivyiro et al. 2014). The economic consequences of environmental problems caused by CO_2 emissions can trigger EPU. The second causality link runs from CO_2 to economic growth. Pirgaip et al. (2020) indicate that economic growth is an outcome of energy consumption, proven by the causality link running from energy use to GDP, especially in high-income countries. Our results therefore support the *''growth hypothesis''*, considering the GCC's unique economic landscape, it becomes an evident result. In fact, given the context of our study, this is expected for many reasons. First, GCC countries often use a substantial portion of their energy production for domestic consumption. As CO_2 emissions are closely tied to energy consumption, any increase in emissions can indicate higher energy use to support economic activities (Babonneau et al. 2023). The final causality relationship found is that energy consumption causes CO_2 emissions. This pronounced relationship in GCC countries is totally apparent because of their substantial reliance on non-renewable energy sources. For a long time, Arab Gulf governments have failed to make genuine commitments to cut carbon emissions. (Bekhet et al. 2017; Salahuddin et al. 2014).

Table 8: Dumitrescu and Hurlin panel causality Results

Variables	W-Stat.	P-Value	Causality Direction
Ln_PEC➔ EPU	1.3583	0.5711	≠
EPU➔ Ln_PEC	0.3291	0.2888	≠
EPU➔CO2	1.3657	0.5632	≠
CO2➔ EPU	4.4795	0.0000***	➔
GOVE➔Ln_PEC	1.8785	0.1648	≠
Ln_PEC➔GOVE	2.6517	0.0090***	➔
REGQ➔Ln_PEC	3.4487	0.0001***	≠
Ln_PEC➔REGQ	0.6432	0.5727	➔
CO2➔Ln_PEC	1.3911	0.5363	≠
Ln_PEC➔CO2	3.2844	0.0003***	➔
Ln_GDP➔Ln_PEC	1.5245	0.4069	≠
Ln_PEC➔Ln_GDP	3.8282	0.0000***	➔
Ln_GDP➔CO2	1.8386	0.1849	≠
CO2 ➔Ln_GDP	3.5992	0.0000***	➔

***, **, and * indicates 1%, 5%, and 10% significance levels, respectively
≠,➔ indicates no causality and unidirectional causality , respectively

Source: Authors

6. Conclusion and Policy Implications

A significant number of studies have been conducted in order to determine the factors that influence energy consumption. Previous research, however, has overlooked the significance of economic policy uncertainty, and the role of institutional factors in shaping the relationship between EPU and energy consumption, notably in the Gulf countries. This study used the PMG-ARDL for 5 of the Gulf Cooperation Council (GCC) countries, using annual data spanning the

1996 to 2021 period. Our findings showed the significance of the EPU-energy consumption nexus. It was observed that, in the long run, an increase in EPU has the potential to drive up energy consumption in GCC countries. This finding, contrary to conventional expectations, can be attributed to several factors. The GCC's heavy reliance on energy resources, coupled with their economic and political contexts, creates an environment where EPU-induced policy responses tend to stimulate, rather than decrease, energy consumption. Moreover, we found that both institutional factors have a positive and significant relationship with energy consumption in the long run only. Government Effectiveness emerged as a significant determinant of energy consumption, indicating that efficiency and autonomy of public services can impact energy use patterns. Meanwhile, Regulatory Quality showed a pronounced effect, shedding light on the role of well-structured regulations in energy governance. This study also highlighted the pivotal role of institutional factors in mediating and moderating the EPU-energy consumption nexus. When EPU levels increased, both GOVE and REGQ intervened as crucial stabilizing factors. While GOVE exhibited its moderating effect in the long run, REGQ played a pivotal role in the short run, showcasing the distinctive temporal dynamics of these institutional factors. Additionally, our analysis uncovered unidirectional causal relationships running from energy consumption to GOVE, REGQ, and CO2 emissions. This finding highlights the deep impact of energy use on governance and environmental policy. Moreover, we identified causal links from CO2 emissions to EPU and GDP, indicating the intricate interplay between environmental quality and economic indicators. Finally, our study gives new insights into the complex connections that drive energy consumption trends in GCC countries. Our study offers valuable insights into three interconnected energy policy challenges, drawing implications from policy-induced uncertainty, institutional factors, and the line of energy innovation. From a policy standpoint, it is worth highlighting that policies aimed at reducing Economic Policy Uncertainty (EPU) hold a potential for addressing environmental concerns stemming from substantial energy reliance. EPU might lead to increased energy consumption despite potentially dampening economic growth, especially when considering the developmental levels of our countries. Furthermore, the role of EPU in influencing energy use or CO2 emissions could be evident in industries turning to conventional production methods to maintain economic activity, instead of investing in contemporary energy-saving technologies. This scenario suggests that achieving complete decarbonisation, as aimed by the Gulf countries, might be limited by increased EPU disrupting the necessary massive investments. In line with these considerations, energy conservation policies in the countries under examination should be designed to account for the interplay between EPU, economic growth, and energy consumption. Recognizing the potential rise in energy use or CO2 emissions during uncertain economic periods due to inherent causal connections with growth, policy frameworks should be flexible enough to adapt to changing circumstances while aiming for sustainable energy use and environmental objectives. Another decision for policymakers is to acknowledge the role of uncertainty in shaping the energy consumption pattern. Ignoring EPU may lead to misinformed decisions and investments. Quick measures that only focus on EPU might harm the environment and the economy in the long run. By adopting a forward-thinking policy framework, governments can create a strong energy sector that withstands uncertainties caused by EPU and guides the nation toward environmentally friendly practices. In essence, the call is for policymakers to overcome the appeal of immediate remedies and embrace policies that are guided by a vision of sustainable prosperity as the EPU's impact results in the long term. Moreover, policymakers in the Gulf region should prioritize efforts to enhance institutional quality. Strengthening the institutional dimensions not only reinforces energy security but also fosters an environment conducive to energy innovation and diversification.

Additionally, sustainable development is not just a global issue but an imperative for Gulf Cooperation Council countries. GCC nations, while enjoying substantial wealth from their abundant energy resources, face unique challenges that underscore the urgent need for sustainable development. As global efforts to combat climate change intensify, reliance on fossil fuels becomes a vulnerability. Rapid population growth and urbanization in the GCC have strained resources and infrastructure, leading to increased energy demand, water scarcity, and environmental degradation. Moreover, GCC countries have realized that diversifying their economies is crucial for long-term stability, as oil prices are subject to volatile fluctuations. Sustainable development, which encompasses economic diversification, renewable energy adoption, environmental conservation, and social progress, offers a path to address these challenges. Not only does it ensure a resilient future in the face of evolving global dynamics but also enhances the well-being and quality of life for the region's inhabitants. Thus, pursuit of sustainable development is not a choice but a necessity for GCC nations to secure their future prosperity and resilience on both regional and global fronts. Finally, an important implication is to consider setting energy efficiency standards and promoting technologies that enhance energy efficiency. Enhanced energy efficiency reduces greenhouse gas emissions and other pollutants associated with energy production and consumption. This contributes to mitigating climate change and improving air quality.

The final category of implications is the path of energy innovation. The first important aspect is investment in Research and Development (R&D). Governments should prioritize investments in R&D for clean and sustainable energy technologies. Funding should be allocated to universities, research institutions, and private enterprises engaged in energy innovation. Establishing dedicated energy innovation funds can encourage private-sector participation in R&D efforts. Tax incentives and grants can also stimulate innovation in the energy sector. Moreover, energy transition strategies that are represented by developing comprehensive energy transition strategies that outline clear goals and milestones for transitioning to cleaner energy sources. These strategies can serve as roadmaps for innovation in the energy sector. Targets for increasing the share of renewables, reducing greenhouse gas emissions, and enhancing energy efficiency should be included in national energy plans.

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Appendices

Appendix1: Calculating the net effect of economic policy uncertainty on energy consumption

We took Column (3) of Table 7, and we calculated the net effect of economic policy uncertainty using Eq (2)

$$\frac{dLn\_PEC_{it}}{dEPU_{it}} = 1.453\text{- } 0.901 GOVE_{it} \quad (5)$$

The average level of government effectiveness (GOVE), which is the first proxy for institutional factors in this study, is found to be 38.54% (i.e., 0.3854 in units ranging from about 2.5 to 2.5) based on the descriptive statistics in Table 2.

As a result, we calculate the net effect by plugging the average value of GOVE into Eq. (2) as follows:

$$\frac{dLn\_PEC_{it}}{dEP\ _{it}} = 1.453\text{- } 0.901 * (0.3854)$$

$$= 1.1058$$

For the REGQ, we found that its average level is 0. 3469

$$\frac{dLn\_PEC_{it}}{dEPU_{it}} = 1.161\text{- } 0.481 * (0.3469)$$

$$= 0.2359$$