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How Does Energy Consumption Affect Economic Growth in Saudi Arabia? A Cointegration Approach

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ABSTRACT

Energy consumption is considered an important driver of economic growth in recent times due to its positive impacts on all economic activities. However, the Saudi Arabian economy has received very less attention from researchers as far as the energy-growth nexus is concerned. Amid this backdrop, the current paper is interested in assessing the responsiveness of economic growth to increased energy consumption in the presence of control variables. Our analysis of Saudi Arabia is based on date for the period 1971-2021. The recently proposed "Auto Regressive Distributed Lagged (ARDL)" cointegration approach is adopted for the estimation purpose. The estimation results revealed a significant positive short-run and long-run impacts of energy consumption on economic growth. The causality exercise also revealed a one-way causality running from energy consumption towards economic growth. Besides, energy consumption, we found that education and employment level have also a dominant positive role in promoting the economic growth of Saudi Arabia. On the other hand, openness to trade is found to be important for economic growth only in the long run confirming that trade liberalization policies could only be effective in the long run. Our results have important policy implications for the policymakers of Saudi Arabia.

Keywords: Energy Consumption, Economic Growth, Autoregressive Distributed Lag, Saudi Arabia
JEL Classifications: C22, O13, Q40. F43; Q42

1. INTRODUCTION

Energy conumpstion and its influence on the conomic growth of countries has recevied notable attention from researchers and policymkaers since 1990 as pointed out by Gahlot and Garg (2024). However, despite the rich literature, still a comprehensive and explicit relationship between energy consmption and economic growth is yet to be established. The availalbe empirical literature has produced largely contradicting and mixed results. Tang et al. (2016) documented that despite the rich literature, still the direction of relationship between economic growth and energy consumption is not clear. Several factors are responsible for the observed contradictory and inconclusive impact that energy consumption has on economic growth. For instance, the use of different methodologies, different proxies for energy consumpiton, and the heterogeneous natural of countries in sample could explain why a robust and explicit relationship between energy conumpton and economic growth is not established yet. However, it is a fact the increased energy consumption is a vital factor for improved economic performance. Nguyen and Bui (2021b) empirically showed that increased energy consumption flourishes the economic growth process. Similarly, Noh and Masih (2017) also displayed the important role of energy consumption for improving economic growth.

Several important hypothesis on the influence EC on EG are available. The "neutrality hypothesis" assumes the absence of any connection between EC and EG. It implies that policies of economic conservations would have no influence on EG. Similarly, the "conservation hypothesis" generally believes that EG impacts EC in unilateral passion. Likewise, "the growth hypothesis" accepts the notion that EC is an important factor for EG. To put it differently, increased EC flourishes the process of EG and vice versa. Lastly, the "feedback hypothesis" assumes that both EC and EG are causing each other in a bidirectional manner.

In general, a considerable body of applied research attempted to explore the nexus among EC and EG energy consumption and economic (Wei and Chen, 2020; Nguyen and Bui, 2021; Shabaz et al. 2020; Muhammad, 2019; Noh and Masih, 2017, Al-Abdulrazag, 2016). In the Saudi Arabia (KSA) case, (Bechir, 2020; Alrajhi and Al-Abdulrazag, 2019; Hasanov, 2019), have conducted empirical studies to assess the response of EG to increased EC. These studies have employed diverse econometric estimating tools including cointegration and causality testing. The findings of the mentioned studies are significantly different from each other in terms of magnitude, direction and the level of significance. In the case of KSA, research evidence is generally lacking about the relationship between EC and EG.

The KSA economy is also heavily dependent on the use of EC as it is the main driver of improved economic performance. Therefore, the EC-EG nexus is indeed important for the policymakers and government authorities of KSA economy. However, the available empirical literature has not produced consistent results about the magnitude and direction of relationship between EC and EG particularly in the case of KSA economy. The current paper is therefore primarily motivated by lack of research on the growth-energy nexus in the case of Saudi Arabia. To fill the research gap in the empirical literature, we in this paper utilize data long time series data from 1971 to 2021 and employs econometric tools to assess the response of economic growth to increased energy consumption by focusing on Saudi Arabia. Moreover, we are also interested to see whether economic growth causes energy consumption, energy consumption causes economic growth. The policymakers of Saudi Arabia and potential researchers would find the results of our study indeed very useful.

We contribute to the literature on KSA on the EC-EG nexus significantly. First, it tackles a crucial current issue due to the price hikes worldwide, which initiates the need to reduce EC. Second, the study applied a modern estimation approach (ARDL) which has some advantages over traditional method over a longer time horizon from 1971 to 2021. Addition. Third, the current study is interested to figure out the direction of relationship between energy consumption and economic growth which is a new phenomenon in the context of Saudi Arabian economy. Our empirical findings would have enormous significance for the policymakers of Saudi Arabia.

The remaining part is split into several interconnected segments. Section 2 presents the relevant literature review on energy-growth nexus. Section 3 provides information about the model designing and data and further discusses the estimation methods. Section 4 presents estimation results and discussion. The penultimate section addresses the causality issue of energy-growth nexus. Finally, section 6 concludes the paper with some policy implications and limitations.

2. EMPIRICAL LITERATURE

A huge and considerable body of empirical research has focused on the energy-growth nexus on both country-specific and multi-country levels. A wide range of estimation techniques (ARDL, NARDL, Johansen cointegration, VECM, Toda-Yamamoto causality, Granger-Causality, among others) has been applied to different data horizon and type (time series or panel), yet, the empirical results were mixed, ranging from significant to insignificant, and from positive to negative impacts of energy consumption on economic growth. Moreover, since the results do not provide causation, the causality results provide mixed causation, such as no causation, unidirectional, and bidirectional causality. Applied researchers usually indicated that this mixture of results is due to different reasons, among them are the nature of the economy of the country, different data time span, and estimation techniques. The present study, in reviewing the previous literature, mainly concentrates on the most recent empirical literature on the subject matter of the nexus between economic growth and energy consumption.

By analyzing data of Jordan for the period 1980-2012 using ARDL framework, Ajlouni (2015) reported that economic growth responds positively to increased energy use. He also provided evidence that both energy use and growth are connected bidirectionally and hence the feedback hypothesis is confirmed. Similarly, Cosimo (2015) also endorsed the bidirectional causality between energy use and growth by analyzing data of the Italian economy. On the other hand, Alper et al. (2014) displayed a positive impact of increased energy use on growth using quarterly-based data of the US economy. Similarly, in the case of Nigerian economy, Bernard (2014) also showed that increased energy use has played a dominant role in promoting growth. The recent research on Turkish economy also indicated that energy use causes growth (Mushtaq, 2021). Furthermore, Khan et al. (2021) revealed that positive shocks of energy use flourishes growth in asymmetric fashion. Further, using data of Malaysian economy, Mohd et al. (2014) demonstrated a one-way causality from the Gas use towards increased growth. These studies suggest that increased energy use is indeed a vital factor for improved growth. However, it is also a fact that increased use of energy sometime leads to some potential problems including environmental degradation. Therefore, the rational solution is to use the greener and cleaner sources of energy use to accelerate the process of growth flourishing without compromising the quality of the environment.

Instead of focusing on individual economies, some studies have been conducted in literature by focusing on the group of economies to assess the response of growth to increased energy use. In this regard, Kartal (2022b) utilized a sample of 78 economies belonging to different economic groups to see the causality between energy use and growth. The results based on data from 1993 to 2018 using bootstrap tool showed that increased energy use is important for improving growth and further the linkages between the energy use and growth are bidirectional. In contrast, Shahateet (2014) has focused on seventeen Arab economies and showed that energy use and growth have no causal relationship. Moreover, the research of Félix et al. (2022) has focused on CEMAC economies and provided evidence that indeed growth is responsible for increased energy consumption. On the other hand, Azam (2019) analyzed quantitative data of BRICS economies and employed the FMOLS tool of estimation. His findings supported the feedback hypothesis that exists between growth and energy use. Finally, Raghutla and Chittedi (2020) also confirmed the presence of feedback hypothesis between energy use and growth by utilizing data from 1978 to 2018 with the help of several relevant econometric tools.

Moreover, some studies have deviated from the traditional literature and investigated the response of growth to increased energy use in the asymmetric manner. For instance, Wei and Chen (2020) have utilized data for the Chinese economy over the period 1990-2019 to figure out the possibility of asymmetry between energy consumption and growth. Their quantitative analysis showed the presence of an asymmetric relationship between energy use and growth which is an interesting contribution to the literature. Similarly, Kartal (2022a) provided evidence that energy security risk adversely impacts growth asymmetrically in the context of Turkish economy. Moreover, Nguyen and Bui (2021a) also adopted the NARDL technique by using data of Vietnam economy and showed that asymmetries are present in the relationship between energy use and growth. They further indicated that a two-way causality between increased energy use and growth in Vietnam. Further, Hafiz et al. (2022) also used NARDL framework and displayed a long run asymmetrical relationship between the use of gas and growth in Pakistan. Finally, Hung-Ming (2020) also searched for both asymmetric and symmetric influence of EC on EG by analyzing data of the US economy. Their results showed that negative shock of energy use decelerates growth. Ayoub et al. (2020) also employed the NARDL by focusing on China and reported the presence of asymmetric relationship between increased energy use and growth.

Regarding the applied research on Saudi Arabia, the issue of energy-growth nexus has been examined by applied researchers over the last few decades by applying different estimation methods (Toumi & Toumi, 2024; Bechir, 2020; Alrajhi and Al-Abdulrazag, 2019; Hasanov et al., 2017). However, it is still not clear in the case of KSA economy whether increased energy use is responsible for increased growth. Similarly, the direction of causality between energy use and growth is also still not settled due to the diverse empirical findings reported in the literature. Amid all these backdrops, the present study focuses on the KSA economy to assess the role of increased energy use in promoting growth Saudi Arabia. The present study is also interested in settling the issue of causality between energy use and growth by employing proper causality testing. Moreover, our study is also interested in looking for the potential structural breaks that may alter the relationship between energy use and growth. We expect that the findings of our study would contribute to the energy-growth literature in the case of KSA economy. Consequently, policymakers would benefit significantly from the outcome of the current study.

3. MODEL AND METHODOLOGY

3.1. The Econometric Model

Model designing is considered the first step in empirical studies. To achieve the objectives of our study, we propose the following economic model as expressed below.

$$LGDP_t = \beta_0 + \beta_1 LENG_t + \beta_2 LOPEN_t + \beta_3 LEDU_t + \beta_4 LEMP_t + \varepsilon_t \quad (1)$$

In model 1, $LENG_t$ is the logarithm of “total energy consumption (kg of oil equivalent per capita)” is used for the measurement of EC. $LGDP_t$ is the logarithm of “real GDP per capita (constant US$)” which is used for quantifying EG. $LOPEN_t$ is logarithm of “trade openness (the ratio of total trade to GDP). For education ($LEDU_t$), we have used the index developed by the “Penn World Tables” while for employment ($LEMP_t$), we have taken the number of people employment. The required data was obtained from the “World Development Indicator (WDI)” and “Penn World Tables (PWT)* for the period 1971-2021.

3.2. ARDL Bounds Test

The “autoregressive distributed lag model (ARDL)” developed by Pesaran et al. (2001) is adopted for the estimation. Several cointegration tools are proposed in literature for the purpose of identifying both the short-run and long run dynamics among the variables (Engle and Granger, 1987; Johansen and Juselius, 1990; Johansen (1988). They all require that all variables be of the same order of integration. The ARDL approach has some advantages over those traditional approaches. The efficiency of ARDL approach is higher particularly when the observations are limited and the integration order of variables is different (Nguyen and Bui, 2021b; Al-Abdulrazag, 2022, Mehta et al., 2021, Musa and Al-Abdulrazag, 2023). Based on the ARDL model specification, equation 1 can be rewritten as follows:

$$\begin{aligned}\Delta LGDP_t &= \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} \\ &+ \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} \\ &+ \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \\ &\gamma_1 LGDP_{t-1} + \gamma_2 LENG_{t-1} + \gamma_3 LOPEN_{t-1} \\ &+ \gamma_4 LEDU_{t-1} + \gamma_5 LEMP_{t-1} + \varepsilon_t \end{aligned} \quad (2)$$

$$\begin{aligned}\Delta LENG_t &= \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} + \\ &\sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} + \\ &\sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \\ &\gamma_1 LGDP_{t-1} + \gamma_2 LENG_{t-1} + \gamma_3 LOPEN_{t-1} + \\ &\gamma_4 LEDU_{t-1} + \gamma_5 LEMP_{t-1} + \varepsilon_t \end{aligned} \quad (3)$$

$$\begin{aligned}\Delta LOPEN_t &= \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} \\ &+ \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} \\ &+ \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} \\ &+ \gamma_1 LGDP_{t-1} + \gamma_2 LENG_{t-1} + \gamma_3 LOPEN_{t-1} \\ &+ \gamma_4 LEDU_{t-1} + \gamma_5 LEMP_{t-1} + \varepsilon_t \end{aligned} \quad (4)$$

$$\Delta LEDU_t = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} + \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \gamma_1 LGDP_{t-1} + \gamma_2 LENG_{t-1} + \gamma_3 LOPEN_{t-1} + \gamma_4 LEDU_{t-1} + \gamma_5 LEMP_{t-1} + \varepsilon_t \quad (5)$$

$$\Delta LEMP_t = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} + \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \gamma_1 LGDP_{t-1} + \gamma_2 LENG_{t-1} + \gamma_3 LOPEN_{t-1} + \gamma_4 LEDU_{t-1} + \gamma_5 LEMP_{t-1} + \varepsilon_t \quad (6)$$

In model 2-6, the parameters (β_1–β_5) connected with the difference operator (Δ) stands for the short-run impacts of independent variables on dependent variable. Similarly, the parameters (γ_1–γ_5) measures the long-run impacts of independent variables on dependent variable in the ARDL framework. Two main hypotheses are proposed in the literature for testing the possibility of cointegration relationship in the ARDL framework. The null hypothesis generally assumes that variables are not cointegrated (H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5$). The alternative hypothesis (H_a: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5$) generally assumes that variables have long-run relationship. The values of F-test obtained will be compared with those proposed by Narayan (2004). The cointegrating relationship will be concluded among the variables if the F-test value is found to be exceeding the upper critical bound. Similarly, no co-integrating relationship will be assumed if the F-test value falls below the lower critical limit.

In the second step of co-integration, we have designed the "error correction model (ECM)." The ECM modeling serves two main purposes. Firstly, the ECM modeling provides estimates of short run relationships among the variables. Secondly, the ECM modeling further provides significant information about the adjustment of disequilibrium from the short run towards the long run. Keeping in mind the importance of ECM modeling, we have designed the ECM framework as shown below.

$$\Delta LGDP_t = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} + \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \gamma_1 ECT_{t-1} + \varepsilon_t \quad (7)$$

$$\Delta LENG_t = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} + \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \gamma_1 LECT_{t-1} + \varepsilon_t \quad (8)$$

$$\Delta LOPEN = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} + \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \gamma_1 LECT_{t-1} + \varepsilon_t \quad (9)$$

$$\Delta LEDU_t = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} + \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \gamma_1 LECT_{t-1} + \varepsilon_t \quad (10)$$

$$\Delta LEMP_t = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta LGDP_{t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta LENG_{t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta LOPEN_{t-i} + \sum_{i=0}^{n4} \beta_4 \Delta LEDU_{t-i} + \sum_{i=0}^{n5} \beta_5 \Delta LEMP_{t-i} + \gamma_1 LECT_{t-1} + \varepsilon_t \quad (11)$$

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. Descriptive Analysis

Table 1 presents the descriptive statistics. The mean value of energy consumption is 4350.464 "Energy use (kg of oil equivalent per capita)" having a standard deviation of 1707.659.586. The maximum value of EG is 6645.960 while its lowest value is 929.586. The minimum value of EG is recorded in 1972 while the maximum value of EG is witnessed in 2014. Similarly, the mean value of trade openness "(trade as % of GDP)" of KSA is 75.561%. The maximum value of trade openness (120.19%) is witnessed in 1973 while the lowest value of trade openness (49.713%) is seen in 2020. Similarly, the average value of education index is 2.130 while its standard deviation is 0.380. The education index reached its maximum value (2.713) in 2019 while its lowest value was recorded in (1.539) in 1971. It means the performance of Saudi Arabia in advancing its education system has been remarkable over the study period. On the other hand, employment level (in millions) takes an average value of 6.401 having a standard deviation of 3.530. The maximum value of employment (13.744) was recorded in 2019 while the lowest value of employment (1.348) was observed in 1971. The average value of GDP per capita is 21422 "(Constant US $)" having a standard deviation of 6116.761. The maximum value of GDP is recorded for the year 1974 while the lowest value of GDP per capita is seen in the year 2022. It implies that the KSA economy has performed well in improving its GDP. The better performance of KSA in terms of GDP over the years is one of the main reasons behind its improved quality of life.

4.2. Stationarity Test (Unit Root Test)

The non-stationarity is a common feature of macroeconomic variables, as consequent, the estimation results may suffer from spurious problem. Therefore, to avoid this problem, the unit root test is applied to determine the level of integration. The well-known "Augmented Dickey Fuller (ADF)" is carried out and results are displayed in Table 2. According to results, all chosen variables are suffering from the well-known problem of unit root at level except employment. The employment variable is stationary at level as well as at first difference. However, the lower portion of Table 2 shows all variables are stationary by considering the first difference. The order of integration of variables mixed. The observed mixed integration order of variable could explain why we opted for the ARDL framework instead of the Johansen testing.

4.3. ARDL Findings

The results of cointegration extracted using the ARDL framework are depicted in Table 3. The presence of cointegration is accepted for all models except where education is used as a dependent variable. The F-test value exceeds the critical values. Therefore, based on the F-test value, the presence of cointegration among the selected variables is accepted.

4.4. The Long Run Results

The estimation results of the long run are shown in Table 4. The results show that energy consumption is indeed a vital factor for promoting economic growth in the case of KSA economy. The point estimate suggests that a 1% increase in energy consumption increases economic growth by 0.272% which is remarkable. It means that the overall better performance in terms of improved economic growth could be explained by the increased energy consumption. In addition, the long-run positive impact provides evidence supporting the energy-led-growth hypothesis, where energy use is considered as the main drivers factor for improved economic growth. Our results are supported by previous studies on the linkages between energy use and economic growth (Bechir, 2020; Alrajhi and Al-Abdulrazag, 2019; Hasanov et al., 2017). However, it is important to mention that increased energy consumption although improves economic growth, but also degrades the environmental quality owing to increased CO_2 emission. Therefore, the rational policy would be to focus on using the cleaner and environmentally energy sources of energy so that to improve economic growth without damaging the environmental quality.

Similarly, the results provided strong support about the affirmative influence that trade openness has on economic growth in the long run. The positive influence of trade openness on economic growth was expected, because higher trade increases income. The significant positive long-run effect of trade openness (0.126) implements the role of trade openness in economic growth process through exports and imports activities. This may be attributed to the volume of exports (including oil exports), and the imports of capital goods as intermediates goods enter in the productive activities that would increase GDP growth. Prior studies have also consistently shown that trade openness is vital factor for economic growth (Tahir and Azid, 2015; Tahir and Khan, 2014; Frankel and Romer, 1999). Hence, the authorities of KSA are suggested to take some visible steps to ensure the free movement of goods and services to accelerate economic growth.

Further, our results show that education which is the dominant driver of growth in the new growth literature has improved the economic growth of Saudi Arabia enormously. The point estimate suggests that impact of education on growth is highest as compared to other variables included in the model. Therefore, the rational policy implication would be to invest more in the education sector to increase its growth-enhancing benefits. Finally, we found evidence that for improving economic growth, the role of employment level is vital. The coefficient of employment variable is positive as well as statistically significant. The coefficient value of employment level shows that its impact on growth is second highest after education level. Therefore, generating more employment opportunities for the growing population would enhance economic performance of Saudi Arabia.

Table 1: Descriptive statistics

GDPt	ENGt	OPENt	EMPt	EDUt	Description
21422.33	4350.464	75.561	6.401	2.13	Mean
35942.45	6645.96	120.619	13.744	2.713	Maximum
15670.73	929.586	49.713	1.348	1.539	Minimum
6116.761	1707.659	13.667	3.53	0.38	Standard deviation
51	51	51	51	51	n

Table 2: Unit root results (ADF test)

Variables	Level	Difference (First)	Conclusion
LGDPt	−1.7163	−4.28***	I (1)
LOPENt	−2.4749	−9.66***	I (1)
$LENG_t$	−1.6995	−8.24***	I (1)
$LEDU_t$	2.217	−8.623***	I (1)
$LEMP_t$	−3.627**	−5.720***	I (0)

The asterisk (***) stands for the 1% significance level

Table 3: ARDL results

Dependent variables	F-test	Conclusion
F (LGDP/LENG, LOPEN, LEDU, LEMP)	18.870	"Co-integrated"
F (LENG/LGDP, LOPEN, LEDU, LEMP)	4.103	"Co-integrated"
F (LOPEN/LGDP, LENG, LEDU, LEMP)	5.984	"Co-integrated"
F (LEDU/LGDP, LENG, LOPEN, LEMP)	3.026	"Not Co-integrated"
F (LEMP/LGDP, LENG, LOPEN, LEDU)	5.216	"Co-integrated"
Critical values (%)	**Lower bound I (0)**	**Upper bound I (1)**
1	(3.29)	(4.37)
5	(2.56)	(3.49)
10	(2.20)	(3.09)

The null hypothesis assumes no long-run relationship

Table 4: Long run results

Variables	Coefficients	Standard errors
LENGt	0.272***	0.055
$LOPEN_t$	0.126**	0.053
$LEMP_t$	0.326***	0.090
$LEDU_t$	2.878***	0.586
Constant	-0.034	0.008

The dependent variable is economic growth. The asterisk (***, **) shows 1% and 5% significance level

Table 5: Long run results

Variables	Coefficients	Standard errors
$\Delta LENGt$	0.164*	0.085
$\Delta LOPEN_t$	−0.004	0.081
$\Delta LEMP_t$	1.071***	0.172
$\Delta LEDU_t$	6.642***	0.586
ECT (−1)	−0.306	0.114

The dependent variable is economic growth. The asterisk (***, **) shows 1% and 5% significance level

Table 6: Diagnostics examination

Test	Null. H	Value	Conclusion
"LM (Serial correlation)"	"H_O: No serial correlation"	0.719	"H_O Accepted"
"Bresusch-Pagan Godfrey"	"H_O: No heteroskedasticity"	1.495	"H_O Accepted"
"Jarque-Bera"	"H_O: Data is normal"	1.432	"H_O Accepted"
"Ramsey test"	"H_O: Correct functional form"	0.763	"H_O Accepted"

Table 7: Pairwise granger causality tests

"Null hypothesis"	F-test	Prob.
"$LENG_t$ does not granger cause $LGDP_t$"	3.910**	0.027
"$LGDP_t$ does not granger cause $LENG_t$"	0.204	0.805
"$LOPEN_t$ does not granger cause $LGDP_t$"	2.948*	0.062
"$LGDP_t$ does not granger cause $LOPEN_t$"	1.898	0.161
"$LEDU_t$ does not granger cause $LGDP_t$"	1.265	0.292
"$LGDP_t$ does not granger cause $LEDU_t$"	2.972*	0.061
"$LEMP_t$ does not granger cause $LGDP_t$"	0.942	0.397
"$LGDP_t$ does not granger cause $LEMP_t$"	2.103	0.134
"$LOPEN_t$ does not granger cause $LENG_t$"	0.204	0.815
"$LENG_t$ does not granger cause $LOPEN_t$"	2.131	0.130
"$LEDU_t$ does not granger cause $LENG_t$"	3.780**	0.030
"$LENG_t$ does not granger cause $LEDU_t$"	0.560	0.575
"$LEMP_t$ does not granger cause $LENG_t$"	0.991	0.379
"$LENG_t$ does not Granger Cause $LEMP_t$"	0.108	0.897
"$LEDU_t$ does not Granger Cause $LOPEN_t$"	0.993	0.378
"$LOPEN_t$ does not granger cause $LEDU_t$"	0.112	0.893
"$LEMPt_t$does not granger cause $LOPEN_t$"	2.713*	0.077
"$LOPEN_t$ does not granger cause $LEMP_t$"	1.506	0.232
"$LEM0_t$ does not granger cause $LEDU_t$"	0.283	0.754
"$LEDU_t$ does not granger cause $LEMP_t$"	1.321	0.277

The asterisk (**, *) shows 5% and 10% significance level

Figure 1: CUSUM test

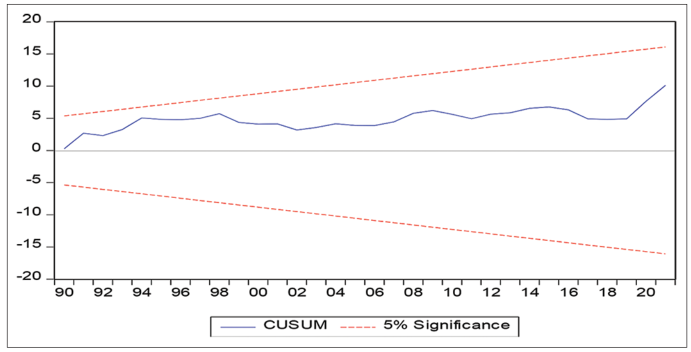
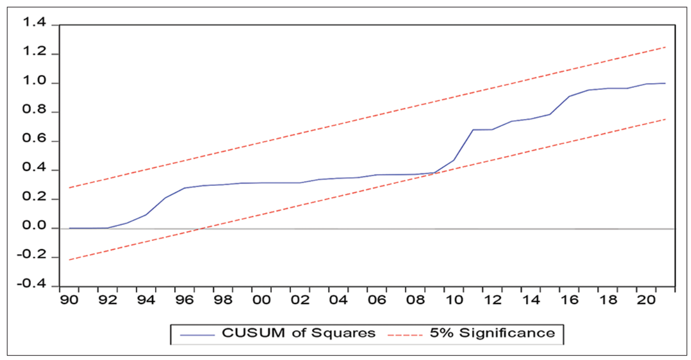


Figure 2: Square of CUSUM test



4.5. Short Run Results

The results based on short-run analysis are shown in Table 5. According to the results, Energy consumption is positively linked with economic growth which is consistent with the earlier result. Similarly, in the short run, employment and education have also maintained their positive impacts on the economic growth of Saudi Arabia. However, in the short run, trade openness has lost both its coefficient sign and significance level. It means that trade openness is the long run remedy for economic growth. In the short run trade openness may not contribute to the growth process in the desirable manner. Finally, the "error correction term" is negative and significant statistically. The coefficient of "error correction term" indicated that the adjustment speed of our model towards the long run is 30%.

4.6. Diagnostic Tests

To assess the reliability and suitability of the results, we have used several tests. These tests include the "normality test of Jarque-Bera" "the heteroskedasticity test of Breusch-Pagan Godfrey" and the "function form test of Ramsey." The diagnostic testing findings are depicted in Table 6. It is revealed that the normality assumption holds correct as confirmed by the "Jarque-Bera" test value. The "LM test" rejected the serial correlation while the "Ramsey test" ensured the correct specification. Lastly, the presence of heteroskedasticity is rejected by the "Breusch-Pagan Godfrey" test. In conclusion, the estimated models are free from any noticeable econometric problem.

4.7. Stability Testing

The stability of estimated model is an integral part of the robust results. For this purpose, the present study carried out the "Cumulative Sum (CUSUM)" and "Cumulative Sum of Square (CUSUMSQ)" testing. Findings of the tests are graphed in Figures 1 and 2. It is found that the residuals are stable as the lines are lying within the critical limits. Therefore, we conclude that residuals are stable.

4.8. Causality Analysis

The causality analysis is conducted using the "pairwise granger causality" framework. According to the findings, as shown in table 7, we have found strong evidence of a one-way relationship between energy consumption and economic growth. On the other hand, openness to trade is found to be connected in a one-way relationship with economic growth. Similarly, education is related unilaterally with education while education is unilaterally linked with energy consumption in the case of Saudi Arabia. Finally, we found that the employment level is causing trade openness.

5. CONCLUSIONS, IMPLICATIONS AND LIMITATIONS

5.1. Concluding Remarks

This study examined the dynamic short-run and long-run impacts of energy consumption on economic growth in the presence of some control variables. The study utilized historical data spanning from 1971 to 2021. The study focused on the Saudi Arabia as sample and the ARDL framework is adopted for the estimation purpose.

Our results show that economic growth has responded positively to increased energy consumption in the case of KSA economy both in the short run as well as in the long run. Further, we found that trade openness, education and employment level have also positively impacted the economic growth of Saudi Arabia. In the short run, our results show that trade openness is not significant. It means that open trade policies are effective for promoting the long run economic growth. All other variables such as energy consumption, education and employment level are positively and significantly connected with economic growth in the short run. In summary our findings support the energy-led growth hypothesis, which implies that energy consumption is a driver of economic growth. This study suggests that Saudi government promotes EC in productive sectors while maintaining energy efficiency.

5.2. Policy Implications

Implications based on the empirical findings are outlined below.

1. The present studies displayed a significant positive linkage between energy consumption and economic growth for the KSA economy both in the long as well as in the short run. However, increased energy consumption is certainly harmful for the environmental quality and the quality of life. But it is also an undeniable fact that higher growth is important for improving the quality of life. Therefore, the present study suggests the authorities of KSA must ensure the use of cleaner and green energy sources to enhance the growth performance without damaging the quality of the environment
2. The policymakers of KSA economy are suggested to encourage the trade liberalization process by giving incentives to importers and exporters and abolish all sort of restrictions. These important steps would ensure the free flow of goods and services, due to which the trade openness degree will be enhanced. Increased trade openness will enhance the EG of KSA economy
3. The policymakers of Saudi Arabia are suggested to invest heavily in education sector as its impacts on economic growth are enormous according to the results. Improved human capital will further boost the growth process of Saudi Arabia
4. Lastly, the policymakers of Saudi Arabia are suggested to create employment opportunities for the growing population. As our results showed that employment level has casted positive impacts on the growth of Saudi Arabia.

5.3. Limitations and Future Research Directions

Following are the unavoidable limitations of the current study.

1. The current study has focused on long historical data in the analysis. However, the presence of non-linearity is not tested. It is therefore suggested that future study could focus on running the NARDL modeling to see the presence of non-linearity in the relationship between EC-EG nexus
2. The present study has only focused on EC and trade openness. However, it is a fact that the higher EG depends on several factors such as investment, research and development and stability. Therefore, we leave these potential research endeavors to future researchers
3. KSA is a unique economy having unique economic structure. Therefore, the generalization of our results may not be possible on a large scale. Therefore, future research is suggested to test the specified model for other economies and see whether our results stay robust or not in other settings.

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