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Renewable Energy and Economic Growth in Saudi Arabia: Evidence from ARDL model

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Abstract

This study examines the nexus between energy consumption, financial development, urbanization, and growth in Saudi Arabia, employing an Autoregressive Distributed Lag (ARDL) model with an Error Correction Model (ECM).

Our findings reveal a long-run co integrating relationship among the variables, with industry value added, power consumption, renewable energy, and financial development having positive long-run impacts on economic growth. The results underscore the crucial role of renewable energy consumption in driving economic growth, highlighting its importance as a proxy for technological progress in the energy sector.

The study's findings provide a comprehensive framework for sustainable economic growth, emphasizing the need for policymakers to prioritize investments in renewable energy and financial development to promote economic growth. The results have significant policy implications for resource-rich countries like Saudi Arabia, informing energy transition strategies and economic reforms efforts.

Keywords: economic growth, energy consumption, renewable energy, financial development, urbanization, ARDL model, ECM, cointegration, sustainable development, Saudi Arabia.

دراسة العلاقة بين استهلاك الطاقة، التطور المالي، التحضر، والنمو الاقتصادي في المملكة العربية السعودية باستخدام نموذج الانحدار الذاتي الموزع مع نموذج تصحيح الخطأ

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ملخـــــــص

تبحث هذه الدراسة في العلاقة بين استهلاك الطاقة، التطور المالي، التحضر، والنمو في المملكة العربية السعودية، باستخدام نموذج الانحدار الذاتي الموزع (ARDL) مع نموذج تصحيح الخطأ.(ECM)

تكشف نتائجنا عن علاقة تكاملية طويلة الأمد بين المتغيرات، حيث أن القيمة المضافة الصناعية، استهلاك الطاقة، الطاقة المتجددة، والتطور المالي لها تأثيرات إيجابية طويلة الأمد على النمو الاقتصادي. تؤكد النتائج على الدور الحيوي لاستهلاك الطاقة المتجددة في دفع النمو الاقتصادي، مما يبرز أهميتها كمؤشر للتقدم التكنولوجي في قطاع الطاقة.

توفر نتائج الدراسة إطار عمل شامل للنمو الاقتصادي المستدام، مشددة على ضرورة أن يعطى صناع السياسات الأولوية للاستثمارات في الطاقة المتجددة والتطور المالي لتعزيز النمو الاقتصادي. تحمل النتائج دلالات سياسة هامة للدول الغنية بالموارد مثل المملكة العربية السعودية، حيث تساهم في توجيه استراتيجيات الانتقال الطاقي وجهود الإصلاح الاقتصادي.

الكلمات المفتاحية: النمو الاقتصادي، استهلاك الطاقة، الطاقة المتجددة، التطور المالي، التحضر، نموذج ARDL، ECM، التكامل المشترك، التنمية المستدامة، المملكة العربية السعودية

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Introduction:

Saudi Arabia, heavily reliant on fossil fuels, is undergoing a significant energy transition, aiming to diversify its energy mix and promote sustainable economic growth through substantial investments in renewable energy sources, primarily solar and wind. This review analyzes the existing research on the link existing between renewable energy development and growth in Saudi Arabia, exploring its potential, challenges, and the existing research landscape.

While Saudi Arabia possesses vast renewable energy resources, especially solar, its current installed renewable capacity remains relatively modest. By the end of 2021, the total installed capacity was around 0.8 GW, primarily from solar photovoltaic (PV) projects (IRENA, 2023). However, ambitious targets and large-scale projects are underway, reflecting the Kingdom's commitment to transitioning towards a sustainable energy future.

The Kingdom's Vision 2030 outlines a strategic framework for economic diversification and sustainability, setting a target of achieving 58.7 GW of renewable energy capacity by 2030 (Ministry of Energy, 2023). To achieve this goal, major initiatives like the National Renewable Energy Program (NREP) have been launched, attracting significant investments and fostering public-private partnerships. Notable projects include the Sakaka Solar PV Plant (300 MW) and the Dumat Al Jandal Wind Farm (400 MW), representing significant milestones in the country's renewable energy development.

Policy support mechanisms are crucial for attracting investments and facilitating renewable energy deployment. The Saudi government has implemented various initiatives, including feed-in tariffs, competitive auctions, and net metering schemes, to incentivize renewable energy projects and create a favorable investment climate (IRENA, 2022). Additionally, the establishment of the Renewable Energy Project Development Office (REPDO) streamlines project development processes and fosters collaboration between stakeholders.

The transition towards renewable energy in Saudi Arabia offers substantial opportunities for economic advancement and diversification. The development and implementation of renewable energy projects have the potential to create a significant number of jobs across various skill levels, ranging from highly skilled engineers and technicians to construction and administrative personnel. Projections indicate that the renewable energy sector could generate tens of thousands of new jobs in Saudi Arabia by 2030 (IRENA, 2020).

Moreover, as a major oil exporter, Saudi Arabia's domestic energy consumption heavily relies on fossil fuels, leading to opportunity costs associated with exporting oil instead of utilizing it domestically. The expansion of renewable energy sources can mitigate this dependence on fossil fuels, freeing up resources for export and generating additional revenue. Additionally, the burgeoning renewable energy sector presents opportunities for developing domestic manufacturing capabilities for essential components such as solar panels and wind turbine blades, contributing to economic diversification, reducing import dependence, and fostering the creation of high-skilled jobs.

Ultimately, by fostering a new energy industry, Saudi Arabia can diversify its economy beyond oil and gas, mitigating its vulnerability to oil price fluctuations and establishing a more resilient and sustainable economic foundation.

The widespread adoption of renewable energy in Saudi Arabia faces several challenges and barriers despite its significant potential. Integrating large-scale variable renewable energy sources into the existing grid infrastructure presents technical challenges, necessitating substantial investments in grid modernization and expansion to ensure stability and reliability.

Financial barriers also pose a significant hurdle, as the high upfront capital costs associated with renewable energy projects require innovative financing mechanisms and risk mitigation strategies to attract private sector investment. Streamlining permitting processes and ensuring regulatory certainty are crucial for encouraging private sector participation and accelerating project development, highlighting the importance of a supportive regulatory framework.

Additionally, public awareness and acceptance of renewable energy technologies are essential for successful deployment, requiring community engagement and transparent communication to address potential social and environmental concerns associated with large-scale projects.

Literature review:

The link existing between renewable energy consumption (REC) and growth has garnered significant attention from researchers due to its implications for sustainable development and climate change mitigation. A multitude of studies, employing diverse methodologies and focusing on various countries and regions, have explored this complex association.

A dominant theme across the literature is the positive impact of REC on economic growth. Studies like Bhattacharya et al. (2016) and Apergis and Payne (2012) utilized production function models and panel data techniques to demonstrate this positive effect, particularly in developing and emerging economies. They advocate for increased investment in renewables to foster low-carbon growth and economic development. This positive association is further supported by research employing the ARDL bounds testing approach, such as Gozgor et al. (2018), who found a positive long-run link existing between both REC and NREC and economic growth in OECD countries, with a stronger impact observed in countries with higher growth levels.

Several studies have delved into the nuances of the REC-growth relationship. Wang and Wang (2020) and Cho et al. (2015) addressed potential non-linearities, highlighting the importance of contextual factors. Wang and Wang (2020) revealed that the positive impact of REC on growth is contingent on the level of financial development, suggesting that policies promoting renewables might require adjustments based on specific economic circumstances. Similarly, Cho et al. (2015) observed differing causal relationships between REC and growth in developed and less-developed countries, attributed to variations in financial development and technological progress.

Environmental benefits of REC are another key focus in the literature. Both studies by Alola et al. (2019) investigated the role of REC in achieving environmental sustainability targets. They found a negative impact of REC on both the ecological footprint and carbon emissions, indicating its contribution to environmental quality and highlighting the importance of promoting REC as part of a comprehensive sustainability strategy.

Additional factors influencing the link existing between REC and growth have also been explored. Gozgor (2018) examined the mediating role of economic complexity, finding that REC positively affects economic growth directly and indirectly through enhanced productive capabilities and innovation. Balcilar et al. (2018) highlighted the importance of demand-side factors and oil price shocks in driving REC, suggesting that policies fostering economic growth and energy price stability are crucial.

Furthermore, Magnani and Vaona (2013) demonstrated positive regional spillover effects from renewable energy production, indicating its potential to stimulate economic activity in neighboring regions. Meanwhile, Lazkano et al. (2017) emphasized the critical role of electricity storage in addressing the intermittency challenges of renewables and facilitating their integration into the power grid.

Empirical researches on Renewable Energy and Growth

The intricate link existing between renewable energy consumption and growth has captivated researchers seeking sustainable solutions to the world's energy challenges. A multitude of studies, employing diverse methodologies and spanning different countries and regions, have painted a complex yet predominantly optimistic picture of this association.

One of the most compelling findings across the literature is the positive impact of REC on economic growth. This positive effect has been demonstrated in various contexts, particularly in developing and emerging economies, using production function models and panel data techniques. Studies like Bhattacharya et al. (2016) and Apergis and Payne (2012) highlight the role of REC in fostering low-carbon growth and economic development, advocating for increased investment in renewable energy technologies and infrastructure.

The positive association between REC and growth is further corroborated by research employing the ARDL bounds testing approach. For instance, Gozgor et al. (2018) identified a positive long-run link existing between both REC and non-renewable energy consumption (NREC) and economic growth in OECD countries, with a particularly strong impact observed in nations with higher growth levels.

However, the link existing between REC and growth is not without its nuances and complexities. Studies like Wang and Wang (2020) and Cho et al. (2015) have revealed non-linear relationships, suggesting that the impact of REC on growth may be contingent on various contextual factors. Wang and Wang (2020) found that the positive effect of REC is dependent on the level of financial development, implying that policies promoting renewables may require tailoring to specific economic circumstances.

Similarly, Cho et al. (2015) demonstrated differing causal relationships between REC and growth in developed and less-developed countries, highlighting the influence of varying stages of economic development and financial systems.

Adding to the complexity, researchers have also investigated the role of various mediating factors in the REC-growth nexus. Gozgor (2018) explored the impact of economic complexity, finding that REC not only directly promotes economic growth but also indirectly enhances it by fostering innovation and diversifying productive capabilities. Balcilar et al. (2018) emphasized the importance of demand-side factors and oil price shocks as key drivers of REC, suggesting that policies promoting economic growth and energy price stability can indirectly encourage renewable energy adoption.

Beyond economic benefits, numerous studies have underscored the significant environmental advantages of renewable energy. Both studies by Alola et al. (2019) demonstrated the positive impact of REC on environmental sustainability, with a focus on reducing ecological footprint and carbon emissions. These findings highlight the crucial role of REC in achieving environmental goals and transitioning towards a more sustainable future.

Furthermore, regional and spatial dynamics play a crucial role in understanding the REC-growth relationship. Magnani and Vaona (2013) provided evidence of positive regional spillover effects from renewable energy production in Italy, suggesting that the development of renewables in one region can stimulate economic activity in neighboring areas through knowledge spillovers, technology transfer, and increased demand for goods and services. This underscores the potential of regional cooperation and coordinated efforts in promoting renewable energy development and maximizing its economic benefits.

Empirical study:

This study is an attempt to empirically investigate the effect of renewable energy on growth in KSA using data from the World Development Indicators 2024. The analysis employs the econometric method of Autoregressive Distributed Lag (ARDL) model, which allows for the examination of both short-term and long-term relationships between the variables. Additionally, a bounds test is conducted to determine whether a cointegrating relationship exists between renewable energy and economic growth.

The ARDL approach is well-suited for this analysis as it can accommodate variables that exhibit different orders of integration, i.e., I(0) and I(1), within a single framework. This methodological flexibility is particularly advantageous in the context of Saudi Arabia, where the dynamics between renewable energy and growth may exhibit complex interactions.

By investigation the existence of links between the use of renewable energy and stimulation of economic growth in Saudi Arabia, the present study attempts to contribute in the growing body of literature regarding the economic implications of renewable energy transitions in resource-rich developing economies. The findings are expected to provide valuable insights for policymakers and stakeholders as they navigate Saudi Arabia's energy transformation and sustainable development strategies.

Variables of the model:

The dependent variable in this study is economic growth, measured by the logarithm of GDP per capita.

The explanatory variables include renewable energy, power consumption, industry value added, manufacturing sector value, trade openness, and financial development. The consumption of renewable energy is measured in kilowatt-hours, power consumption is measured in kilowatt-hours, industry value added is measured as a percentage of

GDP, manufacturing sector value is measured as a percentage of GDP, trade openness is measured as the sum of exports and imports as a percentage of GDP, and financial development is measured by domestic credit to the private sector as a percentage of GDP.

The study covers the period from 1995 to 2020, and all data are collected from the World Development Indicators (WDI) 2024. This empirical investigation aims to determine the impact of these renewable energy and other macroeconomic factors on economic growth in Saudi Arabia using an Autoregressive Distributed Lag (ARDL) model and a bounds test to assess the existence of a cointegrating relationship.

Unit roots tests:

The unit root tests conducted on the variables in the study indicate that all the variables are integrated of first order I(1). This means that the variables of the model are non-stationary in their levels but become stationary after taking the first difference.

The presence of variables integrated of order one allows for the use of the Autoregressive Distributed Lag (ARDL) modeling approach, which is well-suited for analyzing relationships between variables with mixed orders of integration, i.e., I(0) and I(1).

The ARDL model provides a flexible framework to examine both the short-run and long-run dynamics between the dependent variable (economic growth) and the explanatory variables, such as renewable energy consumption, power consumption, industry value added, manufacturing sector value, trade openness, financial development, and urbanization.

This approach is particularly advantageous in the context of the current analysis, as it can accommodate the different order of integration exhibited by the variables in the model.

Findings:

Table (1)

results of ARDL model

Dependent Variable: LGDP_PER_CAPITA				
Method: ARDL				
Selected Model: ARDL (2, 2, 1, 0, 1, 2, 0, 2)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LGDP_PER_CAPITA(-1)	1.367623	0.081482	16.78439	0.0000
LGDP_PER_CAPITA(-2)	-0.381974	0.081362	-4.694731	0.0000
LINDUSTRY	1.120992	0.074290	15.08941	0.0000
LINDUSTRY(-1)	-1.510883	0.156765	-9.637897	0.0000
LINDUSTRY(-2)	0.520461	0.107898	4.823659	0.0000
LMANUFACTURING	-0.230073	0.076813	-2.995236	0.0036
LMANUFACTURING(-1)	0.382083	0.081906	4.664868	0.0000
LOPENESS	-0.001324	0.028223	-0.046926	0.9627
LPOWER_CONS	0.379738	0.075388	5.037130	0.0000
LPOWER_CONS(-1)	-0.325377	0.078049	-4.168905	0.0001
LREN_CONS	0.034656	0.013816	2.508346	0.0141
LREN_CONS(-1)	-0.043720	0.022794	-1.918065	0.0586
LREN_CONS(-2)	0.023182	0.012212	1.898311	0.0612
LURBANIZ	-1.073361	0.543273	-1.975731	0.0516
LFINAN_DEV	0.124520	0.051321	2.426292	0.0175
LFINAN_DEV(-1)	-0.205521	0.088007	-2.335296	0.0220
LFINAN_DEV(-2)	0.088865	0.049669	1.789126	0.0773
C	3.551059	2.142205	1.657666	0.1013
R-squared	0.999924	Mean dependent var		9.575827
Adjusted R-squared	0.999908	S.D. dependent var		0.436024
S.E. of regression	0.004176	Akaike info criterion		-7.956130
Sum squared resid	0.001412	Schwarz criterion		-7.484290
Log likelihood	411.8284	Hannan-Quinn criter.		-7.765222
F-statistic	62851.90	Durbin-Watson stat		1.755782
Prob(F-statistic)	0.000000			

From Table 1, we can denote the following conclusions:

- Industry value added (LINDUSTRY) has a positive long-run impact on economic growth, with a coefficient of 1.120992.
- Manufacturing sector value (LMANUFACTURING) has a negative long-run impact on economic growth, with a coefficient of -0.230073.
- Power consumption (LPOWER_CONS) has a positive long-run impact on economic growth, with a coefficient of 0.379738.
- Renewable energy consumption (LREN_CONS) has a positive long-run impact on economic growth, with a coefficient of 0.034656.
- Financial development (LFINAN_DEV) has a positive long-run impact on economic growth, with a coefficient of 0.124520.
- Trade openness (LOPENESS) does not have a statistically significant long-run impact on economic growth.
- Urbanization (LURBANIZ) has a negative long-run impact on economic growth, with a coefficient of -1.073361.

Model Diagnostics:

- The high R-squared (0.99) and adjusted R-squared (0.99) values indicate an excellent fit of the model to the data.
- The F-statistic (62851.90) and its associated probability (0.00) suggest that the overall model is statistically significant.
- The Durbin-Watson statistic (1.75) indicates that the model does not suffer from severe autocorrelation issues.

Table (2)
F-Bounds test.

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	6.390246	10%	1.92	2.89
k	7	5%	2.17	3.21
		2.5%	2.43	3.51
		1%	2.73	3.9
Actual Sample Size	99		Finite Sample: n=80	
		10%	2.017	3.052
		5%	2.336	3.458
		1%	3.021	4.35

The F-Bounds Test results presented in the table provide information on the existence of a long-run cointegrating link existing between the variables in the ARDL model.

The null hypothesis of the F-Bounds Test is "No levels relationship", which means that there is no long-run cointegrating relationship among the variables.

The calculated F-statistic value is 6.390246, which is compared to the critical value bounds provided in the table.

Interpretation:

1- Asymptotic Critical Values (n=1000):

- The F-statistic value of 6.390246 is greater than the upper bound critical value of 3.90 at the 1% significance level.
- This suggests that the null hypothesis of "No levels relationship" can be rejected, indicating the presence of a long-run cointegrating relationship among the variables.

1- Finite Sample Critical Values (n=80):

- The F-statistic value of 6.390246 is also greater than the upper bound critical value of 4.35 at the 1% significance level.
- This further confirms the rejection of the null hypothesis and the existence of a long-run cointegrating relationship.

The results of the F-Bounds Test, therefore, provide strong evidence that a long-run cointegrating relationship exists among the variables in the ARDL model.

This implies that the variables, including renewable energy consumption, power consumption, industry value added, manufacturing sector value, trade openness, financial development, and urbanization, are all related in the long run and have a stable equilibrium relationship with the dependent variable, economic growth (GDP per capita).

The existence of this cointegrating relationship justifies the use of the ARDL modeling approach, as it allows for the estimation of both short-run and long-run dynamics between the variables.

Short run relationship:

Table (3)
short run relationship

ARDL Error Correction Regression				
Dependent Variable: D(LGDP_PER_CAPITA)				
Selected Model: ARDL(2, 2, 1, 0, 1, 2, 0, 2)				
ECM Regression				
Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LGDP_PER_CAPITA(-1)	0.381974	0.071259	5.360350	0.0000
D(LINDUSTRY)	1.120992	0.048122	23.29492	0.0000
D(LINDUSTRY(-1)	-0.520461	0.094479	-5.508736	0.0000
D(LMANUFACTURING)	-0.230073	0.054805	-4.198051	0.0001
D(LPOWER_CONS)	0.379738	0.060643	6.261886	0.0000
D(LREN_CONS)	0.034656	0.011084	3.126610	0.0025
D(LREN_CONS(-1)	-0.023182	0.010473	-2.213491	0.0297
D(LFINAN_DEV)	0.124520	0.039358	3.163794	0.0022
D(LFINAN_DEV(-1)	-0.088865	0.040463	-2.196220	0.0309
CointEq(-1)*	-0.014351	0.001805	-7.949367	0.0000
R-squared	0.983742	Mean dependent var		0.009800
Adjusted R-squared	0.982098	S.D. dependent var		0.029773
S.E. of regression	0.003984	Akaike info criterion		-8.117746
Sum squared resid	0.001412	Schwarz criterion		-7.855612
Log likelihood	411.8284	Hannan-Quinn criter.		-8.011686
Durbin-Watson stat	1.755782			

Table 3 provides the results of applying the Error Correction Model (ECM) regression, it provides insights into the short-run dynamics and the adjustment process towards the long-run equilibrium.

2- Interpretation of the Error Correction Term (CointEq(-1)):

- The coefficient of the error correction term (CointEq(-1)) is -0.014351, and it is statistically significant at the 1% level.
- The negative sign of the error correction term indicates that there is a long-run cointegrating relationship among the variables, and the system will adjust towards the long-run equilibrium.
- The magnitude of the error correction term (-0.014351) suggests that the speed of adjustment towards the long-run equilibrium is relatively slow, with about 1.44% of the disequilibrium in the previous period being corrected in the current period.

3- Interpretation of the Short-Run Dynamics:

- The coefficients of the differenced variables represent the short-run elasticities of the corresponding variables.
- The lagged dependent variable, D(LGDP_PER_CAPITA(-1)), has a positive and significant coefficient of 0.381974, indicating that past changes in economic growth have a positive impact on the current changes in economic growth.
- Industry value added, D(LINDUSTRY), has a positive and significant coefficient of 1.120992, implying that a risee in industry value added has a positive short-run effect on growth.
- The lagged change in industry value added, D(LINDUSTRY(-1), has a negative and significant coefficient of -0.520461, suggesting that the impact of industry value added on economic growth is not immediate and may be reversed in the subsequent period.

- Manufacturing sector value, D(LMANUFACTURING), has a negative and significant coefficient of -0.230073, indicating a negative short-run impact on economic growth.
- Power consumption, D(LPOWER_CONS), has a positive and significant coefficient of 0.379738, implying that an increase in power consumption positively affects economic growth in the short run.
- Renewable energy consumption, D(LREN_CONS), has a positive and significant coefficient of 0.034656, suggesting that a rise in the consumption of renewable energy has a positive short-run effect on growth. The lagged change in renewable energy consumption, D(LREN_CONS(-1)), has a negative and significant coefficient of -0.023182, indicating a reversal of the positive impact in the subsequent period.
- Financial development, D(LFINAN_DEV), has a positive and significant coefficient of 0.124520, implying that an increase in financial development positively affects economic growth in the short run. The lagged change in financial development, D(LFINAN_DEV(-1)), has a negative and significant coefficient of -0.088865, suggesting a reversal of the positive impact in the subsequent period.

Table (4)
Heteroskedasticity test

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
Null hypothesis: Homoskedasticity			
F-statistic	1.348168	Prob. F(17,81)	0.1855
Obs*R-squared	21.83403	Prob. Chi-Square(17)	0.1912
Scaled explained SS	25.90743	Prob. Chi-Square(17)	0.0762

From table4, since all the p-values associated with the test statistics are greater than the typical significance levels (e.g., 0.05 or 0.10), we fail to reject the null hypothesis of homoskedasticity.

This means that the residuals of the ARDL model exhibit constant variance, and there is no evidence of heteroskedasticity in the model. In other words, the assumption of homoskedasticity, which is important for the validity of the model's inferences, is not violated.

The results of this Breusch-Pagan-Godfrey Heteroskedasticity Test suggest that the ARDL model is well-specified, and the standard errors and statistical inferences derived from the model are reliable and valid.

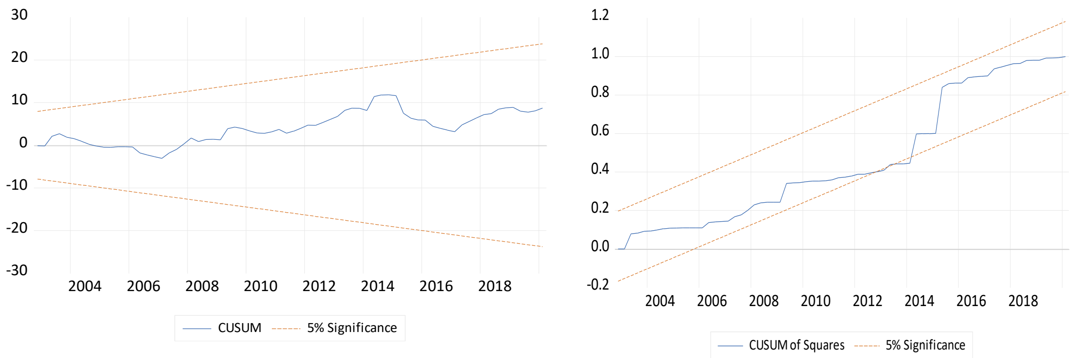

Figure (1)

CUSUM and CUSUMQ of errors of the model.

- The CUSUM and CUSUM of Squares plots suggest that the model is well-specified and stable over the sample period. There is no evidence of parameter instability or structural breaks in the model.
- The results indicate that the estimated model is reliable and can be used for valid statistical inferences and forecasting purposes.
- The stability of the model parameters implies that the underlying relationships between the variables in the model have remained consistent over time, without any significant changes or shifts.

- Overall, the CUSUM and CUSUM of Squares plots provide evidence of the model's stability and the appropriateness of the specified model for the given data and context.

Discussions and Conclusion:

The empirical analysis reveals that industry value added, power consumption, renewable energy consumption, and financial development have positive long-run impacts on economic growth, while manufacturing sector value and urbanization have negative long-run impacts. The Error Correction Model (ECM) regression results show that there is a long-run cointegrating relationship among the variables, and the system adjusts towards the long-run equilibrium at a relatively slow pace. The short-run dynamics suggest that industry value added, power consumption, renewable energy consumption, and financial development have positive short-run impacts on economic growth.

The study's findings contribute to the existing literature on the energy-growth nexus by highlighting the importance of renewable energy consumption and financial development in promoting sustainable economic growth. The results imply that policymakers should prioritize investments in renewable energy and financial development to drive economic growth.

The study's findings highlight the crucial roles of renewable energy consumption, financial development, and urbanization in driving economic growth. By integrating these factors, a comprehensive framework for sustainable economic growth emerges. Renewable energy consumption, a proxy for technological progress in the energy sector, drives economic growth by increasing productivity and reducing energy costs, which in turn fuels further technological progress. Financial development enables access to credit, facilitating the adoption of clean energy technologies and driving economic growth.

However, urbanization, which is often associated with environmental degradation, can hinder economic growth in the long run if environmental costs are not mitigated. Therefore, policymakers must balance the benefits of urbanization with environmental sustainability to ensure sustainable economic growth. By integrating these interconnected components, a framework for sustainable economic growth can be established, driven by technological progress, enabled by financial development, and balanced with environmental sustainability.

This framework provides a comprehensive understanding of sustainable economic growth, highlighting the need for policymakers to adopt a holistic approach that considers the interplay between renewable energy, financial development, and urbanization.

The study's findings have significant policy implications for resource-rich countries like Saudi Arabia. Policymakers can use the results to inform their energy transition strategies and diversify their economic base. Specifically, the study suggests that policymakers should:

- Optimize the utilization of renewable energy to positively affect the economic growth
- Enhance the role of the industrial and manufacturing sectors in driving economic expansion
- Implement measures to improve financial development and its impact on growth
- Address the challenges posed by urbanization

Limitations and Future Research Directions:

The study has some limitations, including the use of a single-country dataset and the omission of institutional quality and governance factors. Future research can address these limitations by:

- Examining the dynamic interactions between the variables using more advanced time series techniques
- Investigating the potential non-linear relationships or threshold effects between the variables
- Analyzing the spillover effects of renewable energy and other macroeconomic factors across different sectors or regions
- Exploring the role of institutional quality, governance, or other contextual factors in moderating the relationships

This study contributes to the debate regarding the impact of renewable energy in stimulating the economic development. The findings advance our understanding of the association between renewable energy, macroeconomic factors, and economic growth, providing valuable insights for policymakers and stakeholders.

References

- Al-Mulali, U., Ozturk, I., & Lean, H. H. (2015). The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. Natural Hazards, 79(1), 629-646.
- Alola, A. A., Bekun, F. V., & Sarkodie, S. A. (2019). Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe. Science of The Total Environment, 685, 702–709.
- Alola, A. A., Yalçiner, K., Alola, U. V., & Saint Akadiri, S. (2019). The role of renewable energy, immigration and real income in environmental sustainability target: Evidence from Europe largest states. Science of The Total Environment, 674, 307–315.
- Apergis, N., & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. Energy Economics, 34(3), 733–738.
- Balcilar, M., Ozdemir, Z. A., Ozdemir, H., & Shahbaz, M. (2018). The renewable energy consumption and growth in the G-7 countries: Evidence from historical decomposition method. Renewable Energy, 126, 594-604.
- Bhattacharya, M., Paramati, S. R., Ozturk, I., & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. Applied Energy, 162, 733–741.
- Chen, Y., Wang, Z., & Zhong, Z. (2019). CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renewable Energy, 131, 208-216.

- Cho, S., Heo, E., & Kim, J. (2015). Causal relationship between renewable energy consumption and economic growth: Comparison between developed and less-developed countries. Geosystem Engineering, 18(6), 284–291.
- Gozgor, G. (2018). A new approach to the renewable energy-growth nexus: evidence from the USA. Environmental Science and Pollution Research, 25(17), 16590-16600.
- Gozgor, G., Lau, C. K. M., & Lu, Z. (2018). Energy consumption and economic growth: New evidence from the OECD countries. Energy, 153, 27-34.
- Greiner, A., Gruene, L., & Semmler, W. (2013). Economic growth and the transition from non-renewable to renewable energy. Environment and Development Economics, 34 p.
- International Renewable Energy Agency (IRENA). (2020). Renewable Energy Market Analysis: GCC 2020.
- International Renewable Energy Agency (IRENA). (2022). Renewable Energy Policies in a Time of Transition: Insights from the IEA-IRENA Renewables Policies Database.
- International Renewable Energy Agency (IRENA). (2023). Renewable Capacity Statistics 2023.
- Ivanovski, K., Hailemariam, A., & Smyth, R. (2020). The effect of renewable and non-renewable energy consumption on economic growth: Non-parametric evidence.
- Ministry of Energy, Saudi Arabia. (2023). National Renewable Energy Program.

- Omri, A., & Nguyen, D. K. (2014). On the determinants of renewable energy consumption: International evidence. Energy, 72, 554-560.
- Salim, R. A., & Rafiq, S. (2012), Why do some emerging economies proactively accelerate the adoption of renewable energy?. *Energy Economics*, Vol34, Issue 4.

Annex: Unit roots tests: ADF (Augmented Dickey and Fuller)

UNIT ROOT TEST RESULTS TABLE (ADF)						
Null Hypothesis: the variable has a unit root						
	At Level	LGDP_PER_CAPITA	LINDUSTRY	LFINAN_DEV	LMANUFACTURING	LOPENESS
With Constant	t-Statistic	-1.3832	-1.6641	-0.6073	-1.6973	-0.9164
	Prob.	0.5876	0.4463	0.8631	0.4295	0.7793
		n0	n0	n0	n0	n0
With Constant & Trend	t-Statistic	-1.8848	-1.7140	-3.2104	-3.0451	-0.6671
	Prob.	0.6549	0.7379	0.0884	0.1256	0.9723
		n0	n0	*	n0	n0
Without Constant & Trend	t-Statistic	0.7897	-0.6454	2.2456	0.5599	-0.7573
	Prob.	0.8819	0.4353	0.9940	0.8355	0.3859
		n0	n0	n0	n0	n0
	At First Difference					
		d(LGDP_PER_CAPITA)	d(LINDUSTRY)	d(LFINAN_DEV)	d(LMANUFACTURING)	d(LOPENESS)
With Constant	t-Statistic	-3.3696	-3.3271	-3.3063	-3.7139	-2.6342
	Prob.	0.0144	0.0162	0.0172	0.0052	0.0896
		**	**	**	***	*
With Constant & Trend	t-Statistic	-3.4408	-3.5125	-3.2904	-3.7100	-3.0368
	Prob.	0.0519	0.0435	0.0739	0.0262	0.1277
		*	**	*	**	n0
Without Constant & Trend	t-Statistic	-3.2750	-3.3044	-2.2247	-3.6684	-2.5783
	Prob.	0.0013	0.0012	0.0258	0.0003	0.0103
		***	***	**	***	**

Table (5)
Unit Roots tests.

	At Level				
		LPOWER_CONS	LREN_CONS		
With Constant	t-Statistic	-1.9988	-0.7		
	Prob.	0.2870	0.83		
		n0	n0		
With Constant & Trend	t-Statistic	-1.7742	-1		
	Prob.	0.7096	0.99		
		n0	n0		
Without Constant & Trend	t-Statistic	0.3241	-0.46		
	Prob.	0.7771	0.51		
		n0	n0		
	At First Difference				
		d(LPOWER_CONS)	D(LREN_CONS)		
With Constant	t-Statistic	-2.1746	-3.32		
	Prob.	0.06	0.016		
		*	**		
With Constant & Trend	t-Statistic	-2.7	-3.6		
	Prob.	0.04	0.0316		
		**	**		
Without Constant & Trend	t-Statistic	-2.6	-3		
	Prob.	0.04	0.001		
		**	***		

Notes:

a) (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant

b) Lag Length based on SIC

c) Probability based on MacKinnon (1996) one-sided p-values.