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RESEARCH ARTICLE

The Relationship Between Energy Consumption And GDP: Saudi Arabia Case Study

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ABSTRACT

This study investigates the intricate relationship between energy consumption and economic growth in Saudi Arabia using the Autoregressive Distributed Lag (ARDL) model for the period from 1980 to 2020. Recognizing energy as a critical input for economic productivity and innovation, the research analyzes the dynamics of total energy consumption from natural gas and oil. The findings reveal a significant long-term relationship, indicating that while increased oil and other liquid consumption positively impacts GDP, higher natural gas consumption correlates with a decrease in GDP. This reflects the dual role of energy sources where oil fuels immediate economic activity, but natural gas, being a cleaner alternative, may inadvertently hamper growth due to associated environmental concerns. Short-term results demonstrate dynamic adjustments, with past GDP variations influencing current economic performance. These findings underscore the challenges of energy dependence and the necessity for economic diversification as outlined in Saudi Arabia's new Vision.

INTRODUCTION

The relationship between energy consumption and GDP is complex and crucial, as energy is the lifeblood of modern economies, driving productivity, innovation and economic growth. Higher levels of energy use are often associated with increased industrial production, transport and overall economic development. Thus, the relationship is a topic of significant interest in economic and environmental research. Citing Stern (2000) and Ozturk (2010) who have shown that energy consumption is not merely a byproduct of economic growth but also a critical input that directly contributes to it. Moreover, Apergis and Payne (2010) suggest that in resource-rich economies there may be a mutual reinforcement between energy consumption and economic growth.

While the question of the relationship between energy and economic growth is not new one and has been the subject of numerous studies, there is still room for further investigation on this important topic. For the economy of Saudi Arabia, one the world's leading oil producers and remains highly dependent on petroleum products for economic growth, this issue is of particular importance. Thus, we'll put the question another way. However, with technological development in global energy markets and the emergence new sources, such as renewable and clean energy, it would be valuable

to examine the robustness of the relationship between non-renewable energy consumption and economic growth in the context of the Saudi economy. For instance, could the increasing use of natural gas contribute positively to long-term economic growth, or might its impact differ from that of traditional oil products? Furthermore, how might short-term fluctuations in energy consumption affect economic performance in a country undergoing structural transformation such as Saudi Arbia?

The aims of this study is to investigate in depth this issue of dynamic interactions between energy consumption and economic growth in Saudi Arabia over the period 1980 to 2020. To do this, we will use the ARDL (Autoregressive Distributed Lag) model, an advanced econometric technique developed by Pesaran and shin (1999). This approach allows a comprehensive examination, in short and long-term, of the interaction between different energy sources, specifically natural gas and oil consumption, and the country's economic performance. Otherwise giving a better understanding of the influence of these crucial energy sources on economic growth.

Focusing on these two energy sources, this study aims to disentangle the specific effects associated with traditional fossil fuels and cleaner energy alternatives. Through this analysis, we hope to provide valuable information that is essential to the formulation of effective energy policies in line with Saudi Arabia's new vision, a strategic framework aimed at reducing the country's dependence on hydrocarbons and fostering sustainable economic development.

The rest of this paper is organised as follows. Section 2 presents a brief literature review. Section 3 details our empirical investigation, including our econometric approach and specific findings. Section 4 is devoted to conclusions and recommendations.

LITERATURE REVIEW

The relationship between energy consumption and economic growth has been extensively studied, with research revealing varied and significant insights across different national contexts. Foundational work by Kraft and Kraft (1978) established the groundwork for two primary perspectives: the "neutrality hypothesis," which suggests that energy has a negligible impact on growth due to its low cost relative to GDP, and the view that energy consumption acts as a crucial constraint on economic growth. This relationship is further influenced by a nation's economic structure and level of development; as economies mature, they often transition to less energy-intensive service sectors. While the importance of energy for economic growth is widely recognized, debates regarding the direction of causality persist.

Recent studies underscore the complexity of this relationship. For example, Zhang and Wang (2022) found a positive impact of energy consumption on growth in countries participating in the Belt and Road Initiative, such as China, Pakistan, and Indonesia. Raza and Shahbaz (2021) identified a bidirectional relationship among BRICS countries (Brazil, Russia, India, China, South Africa), emphasizing the need to prioritize energy access in development policies. Apergis and Payne (2021) highlighted that the energy-growth relationship varies by country, applicable to both advanced and emerging economies. Odhiambo (2020) confirmed a positive effect in South Africa and recommended enhancements in energy efficiency to bolster growth. Moreover, Saeed and Wang (2019) demonstrated that renewable energy contributes to economic growth in South Africa. Collectively, these findings illustrate the critical role of energy consumption in supporting economic growth across varying national contexts.

Additional investigations, including Al-Iriani's (2006) analysis of the Gulf Cooperation Council countries and Mehrara’s (2007) research on 11 oil-exporting nations, suggest that economic activity often Granger-causes energy consumption, indicating that conservation policies should not hinder growth. Notably, these studies frequently overlook essential control variables like fuel prices and CO2 emissions.

Further research highlights the intricate bidirectional relationship between electricity consumption and economic growth. For instance, Squalli (2007) found a long-term relationship for OPEC countries, noting that economic growth influences electricity consumption, while increased electricity usage further drives growth. Similarly, Narayan and Smyth (2009) uncovered long-run bidirectional causality in MENA countries when exports were included as a control variable. Sadorsky's (2011) work also underscored significant relationships through the inclusion of energy prices and trade, elucidating the complexities of these dynamics.

In Saudi Arabia, studies like Khalid's (2012) indicated a unidirectional flow from economic growth to energy consumption over the long term, while Hossein et al. (2012) reinforced the resource curse theory, highlighting challenges faced by resource-rich OPEC nations. Damette and Seghir's (2013) research showed that energy consumption influences economic activity in the short run but reverses in the long term. Mohammadi and Parvaresh (2014) elucidated the significant interdependence between energy consumption and economic output in 14 oil-exporting countries, demonstrating bi-directional causality in both short and long terms.

Overall, these varied findings reveal the complex dynamics between energy consumption and economic growth, emphasizing the significance of using ARDL (Autoregressive Distributed Lag) models. These models facilitate the analysis of both short- and long-term relationships between variables within specific economic contexts. The ARDL approach is particularly valuable for examining the interactions between energy consumption and economic growth, as it effectively handles asymmetries and response delays. Such insights are crucial for policymakers seeking to achieve sustainable economic growth in energy-dependent countries.

DATA AND EMPIRICAL INVESTIGATION

This study employs a comprehensive dataset covering the period from 1980 to 2022, focusing on key indicators to investigate the relationship between energy consumption and economic growth in Saudi Arabia. The analysis includes several critical variables: GDP per capita, which serves as a measure of economic performance; Total Energy Consumption from Natural Gas, reflecting the country's utilization of this resource; and Total Energy Consumption from Petroleum and Other Liquids, indicative of reliance on oil and related energy sources. The examination of these variables aims to capture both long-term trends and short-term fluctuations, shedding light on their interrelationship. The findings are illustrated in Figure 1, which provides a comparative analysis of these metrics throughout the study period

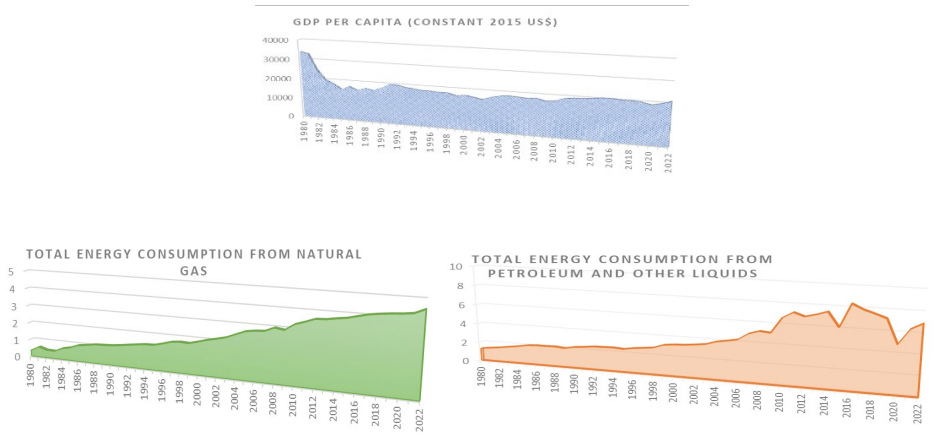

Figure1: Trend Analysis of GDP per capita, the Total energy consumption from natural gas and Total energy consumption from petroleum and other liquids in Saudi Arabia (1980–2022).

To analyze these relationships systematically, the study employs the Autoregressive Distributed Lag (ARDL) model, introduced by Pesaran and Shin (1999) and subsequently extended by Pesaran et al. (2001). This econometric approach synthesizes autoregressive and distributed lag models, allowing for the examination of both short and long-term relationships between the selected variables. The ARDL methodology facilitates the analysis of cointegration and dynamic interactions between dependent and independent variables over various time lags, providing a robust framework for understanding the complexities of the relationships in the context of energy consumption and economic growth in Saudi Arabia.

In developing the ARDL model, the framework of Babatunde (2016) was adapted. Variables such as gross domestic product, energy consumption and natural gas consumption were included in the model.

However, the current model will use the functional form that follows the Equation (1) describing the previous variables as:

$$GDP = f(TCG, TCPL) \quad (1)$$

Where GDP is Gross Domestic Product, dependent variable, TCG is Total Energy Consumption from Natural Gas and TCPL is Total Energy Consumption from Petroleum and other Liquids as independent variables.[1]

The ARDL model will be used to examine the effect of energy consumption on economic growth in Saudi Arabia. The ARDL model based on the functional form presented above in (1) represented as showed in the following equation:

$$\Delta \ln GDP_t = \alpha_0 + \sum_{i=1}^{p} \delta_i \Delta \ln GDP_{t-i} + \sum_{i=0}^{p} \beta_i \Delta \ln TCG_{t-i} + \sum_{i=0}^{p} \gamma_i \Delta \ln TCPL_{t-i} + \lambda_1 \ln GDP_{t-1} + \lambda_2 \ln TCG_{t-1} + \lambda_3 \ln TCPL_{t-1} + \mu_t \quad (2)$$

Where Δ is First difference operator, ln is natural logarithm, p is the optimal lag length, α_0, δ_i, β_i, γ_i, λ_1, λ_2, λ_3 are coefficients to be estimated, μ_t is error term, t is the time period.

Before running our cointegration tests, it is conventionally plausible to first run a unit root test to investigate the order of cointegration of the data series. The rationale behind the unit root test is that it helps to determine the nature of the series in order to avoid spurious regression results.

The ADF test results are presented in table 1. From the table, it is very clearly that all the variables were I(1) and I(0) series.

Table 1: Unit Root test results.

Specification	Variables	ADF	
		t-Statistic	Prob.
Level	Log(GDP)	-4.493187	0.0008***
	Log(TCG)	-2.685579	0.0850*
	Log(TCPL)	-1.366496	0.5894
First difference	Log(TCG)	-10.18896	0.0000***
	Log(TCPL)	-8.108046	0.0000***

*** indicate 1%, ** indicate 5% and * indicate 10%, level of significance.

The ARDL bounds testing approach for cointegration, as proposed by Pesaran et al. (2001), is employed in this empirical study to analyze the short and long-run dynamics of the relationships among the variables.

[1] The data is collected from the WDI.

Using the AIC criterion, the appropriate ARDL model for our analysis is an ARDL(3,4,4). As shown in table 2, the underlying ARDL model satisfies the specified criteria, as tested by all observable diagnostic tests of serial correlation (Durbin-Watson test and Breusch-Godfrey test), and Heteroskedasticity test (Breush-Pagan-Godfrey test) suggesting that the model is free of serial correlation and there is no evidence of heteroskedasticity in the residuals. This suggests that the model is reliable in explaining inflation dynamics.

From the ARDL Bound Test co-integration estimated results, the value of the F-statistic (3.882) exceeds the critical values at the upper bound (3.1 at 5%). Therefore, the empirical findings confirm the existence of the long run relationship among Gross Domestic Product (GDP), Total Energy Consumption from Natural Gas (TCG) and Total Energy Consumption from Petroleum and other Liquids (TCPL).

Having confirmed the existence of co-integration, the conditional ARDL for the long run relationship done by the equation (2) can be estimated. The table 2 summarizes the long and short-run estimates results.

The results show a statistically significant relationship between energy consumption and GDP in the long term. Therefore, an increase of 1% in natural gas consumption (TCG) is associated with a decrease in GDP by 0.0275% ($p < 0.01$). At the same, an increase of 1% in oil and other liquid consumption is associated with a 0.42% increase in GDP ($p < 0.01$). The short-term effects highlight dynamic adjustment in the relationship between energy consumption and GDP. Thus, the results show the past variations in GDP have positive effects on current values, which could reflect economic inertia. The directly effect of change in natural gas consumption is not significant, However, some lags (e.g. -3 periods) show significant coefficients, reflecting a delayed effect. The variation of oil and other liquid consumption have a positive impact on GDP. Thus, an increase by 1% in the consumption of oil and other liquids is associated with a 0.3642% increase in GDP ($p < 0.01$). This could indicate a dependence on this energy source to stimulate immediate economic activity.

Table 2: The long and short run effects

Variables	Coefficient	P-value
Long run effects		
LOG(TCG)	-0.324802	0.0172**
LOG(TCPL)	0.421262	0.0034***
Short run effects		
DLOG(GDP(-1))	0.272176	0.0445**
DLOG(GDP(-2))	0.221914	0.0445**
DLOG(TCG)	0.211440	0.1340
DLOG(TCG)	-0.371125	0.0023***
DLOG(TCG)	0.145207	0.1247
DLOG(TCG(-3))	0.145207	0.1141
DLOG(TCPL)	0.104735	0.0790*
DLOG(TCPL)	0.115891	0.0790*
DLOG(TCPL)	-0.232244	0.0790*
DLOG(TCPL(-3))	-0.231087	0.0790*

CointEq(-1)	-0.231087	0.0790*
Diagnostic Test		
Jarque Bera	0.426	0.808
Breusch-Godfrey Test:	6.355	0.0417
Breusch-Pagan-Godfrey Test	13.074	0.442

The cointegration error coefficient (CointEq(-1)) is -0.2311 with significance at 10% level. This result indicates that 23% of the imbalances are corrected each year. Although moderate, this correction rate reflects a relatively rapid adjustment towards long-term equilibrium.

These results highlight the dual role of different energy sources. In the long term, oil/liquids consumption remains a key driver of economic growth, while the use of natural gas may require improvements to optimise its economic impacts. In the short term, the results indicate economic inertia and a delayed effect of variations in energy consumption.

These findings underline the importance for policy-makers of diversifying energy sources and investing in more efficient technologies, particularly for the exploitation of natural gas. Moreover, dependence on oil raises questions about sustainability and the energy transition in a context of growing environmental concerns.

CONCLUSION

The present study aims to examine the potential relationship between energy consumption and economic growth in Saudi Arabia using the Autoregressive Distributed Lag (ARDL) model over the period 1980 to 2022. In light of our results, it seems reasonable to suggest that there is a notable correlation between energy consumption and economic growth in Saudi Arabia. Thus, the country's economy may be sensitive to changes in energy consumption patterns, potentially experiencing a phenomenon of "energy dependence" where fluctuations in energy consumption may have a persistent impact on economic activity. The results also indicate that there may be a sustainable relationship between Gross Domestic Product (GDP), Total Energy Consumption from Natural Gas (TCG), and Total Energy Consumption from Petroleum and other Liquids (TCPL), implying that changes in energy consumption may have a long-term impact on economic growth.

Furthermore, in the long-term, the results suggest that an increase in natural gas consumption (TCG) is associated with a decrease in GDP, while an increase in oil and other liquid consumption is associated with an increase in GDP. This may be due to the fact that natural gas is a cleaner and more efficient source of energy compared to oil, which can lead to a decrease in economic activity due to environmental concerns. On the other hand, oil and other liquid consumption may have a positive impact on economic growth due to its role as a primary source of energy for industrial and transportation activities.

Moreover, the short-term effects of energy consumption on economic growth also provide valuable insights. The results indicate that there is a dynamic adjustment process between energy consumption and GDP, with past variations in GDP having a positive impact on current values. This may reflect economic inertia, where changes in energy consumption take time to affect economic activity. The results also show that there is a delayed effect of variations in natural gas consumption, while oil and other liquid consumption has an immediate positive impact on GDP.

This dependence underlines the importance of accelerating efforts to diversify the economy, particularly by developing non-energy sectors such as technology, financial services and tourism, in line with Vision 2030. At the same time, it is would be crucial to invest massively in renewable

energies, which could help to reduce this correlation, strengthen economic resilience in the face of oil price fluctuations, and limit the carbon footprint. In addition, initiatives to improve energy efficiency, such as the adoption of innovative technologies and the modernisation of infrastructure, could help to support sustainable economic growth while reducing excessive energy consumption. These actions will create a more balanced economy that is less vulnerable to energy market shocks.

Overall, this study contributes to our understanding of the complex relationships between energy consumption and economic growth in Saudi Arabia. The findings provide valuable insights for policymakers seeking to promote sustainable economic development and reduce dependence on fossil fuels.

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