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The relationship between electricity consumption, peak load and GDP in Saudi Arabia: A VAR analysis

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Abstract: This study aims to investigate the dynamic relationship between electricity consumption (EC), peak load (PL) and gross domestic product (GDP) in the Kingdom of Saudi Arabia by employing a vector auto-regression (VAR) analysis using time series data from 1990–2015. We also employ Granger causality testing, the impulse response function and forecast error variance decompositions. The forecasts for the total EC, PL and GDP using the VAR model with a ten-year horizon show positive growth rates of around 7.21%, 6.87% and 14.14%, respectively. We find bidirectional Granger causal relationships between the PL and the EC and GDP. The results also show that 29% of the PL is explained by its own innovative shocks. The contributions of the EC and GDP to the PL are 10% and 34%, respectively. This study demonstrates PL to be a significant variable that relates to growth.

Keywords: *Electricity consumption, peak load, GDP, Granger causality, VAR model*

1. INTRODUCTION

The relationship between energy consumption and economic growth has been the subject of investigation in numerous prior studies, which have applied both bivariate and multivariate models to different countries and time periods as well as employed a variety of econometric methodologies. The study of the associations and linear relationships between energy consumption and economic growth began with the seminal work of Kraft and Kraft [23], who applied an empirical test to investigate that causality along with the presence of a causal linkage between energy consumption and the gross national product (GNP). Interestingly, their study found causality to run from the GNP to energy consumption in the United States, but not from energy consumption to the GNP. After the results of their study were published, many authors joined in the debate, some opposing and empirically challenging Kraft and Kraft's initial findings, and others supporting their views [12, 21, 28, 30, 31, 35, 38, 39, 42, 46, 48, 49, 50].

In general, the divergence in the findings of such studies could be summarized based on four categories. The first category of study finds bidirectional causality between energy consumption and economic growth [7, 13, 19, 32]. The second category finds unidirectional causality from economic growth to energy consumption [14, 23, 26, 27, 29, 33, 36, 43, 44], which implies that the adoption of energy conservation policies will impede economic growth, while for sustainable economic growth, energy exploration policies should be encouraged. The third category finds unidirectional causality running from energy consumption to economic growth [4, 16, 24]. The fourth category finds no causal relationship between energy consumption and economic growth [10, 25, 34], which suggests that energy does not play a role in enhancing economic growth and, hence, the implementation of energy conservation policies would not prove harmful to economic growth.

In many emerging economies, there exists a mismatch between the electricity supply and the increasing demand for energy, which causes issues such as energy shortages and peak demand deficits. Technically, the demand placed on the system is affected by numerous factors, for example, the load changes with different frequencies ranging from hourly to an annual basis. The system's load is mainly determined by the "usage" pattern of electricity consumers [37]. Such rising usage patterns have been noted in South Australia, especially during the hot summer days, which might be a result of the increased use of air conditioners, for example. The Australian Energy Market Operator (AEMO), in consultation with the Government of South Australia, managed this mismatch across the national electricity grid. The surging trends led to higher energy consumption, which may translate into a higher gross domestic product. It is the prime responsibility of the energy regulators to mitigate this gap between the peak load and the energy supply in order to avoid energy crises. Similar crises have also been observed in some developing economies, for example, Pakistan.

Therefore, energy analysts and government organisations alike require guidelines to help them examine the relationships between electricity consumption (EC), peak load (PL) and gross domestic product (GDP). The aim of this paper is thus to study the nature of the inter-relationships between EC, PL and GDP in the Kingdom of Saudi Arabia (KSA) over the period 1990 to 2015. This paper examines the relationships between EC, PL and GDP using a time series analysis by means of a vector auto-regression (VAR) analysis, which includes Granger causality (GC) testing, the impulse response function (IRF) and forecast error variance decomposition (FEVD).

The present study makes three key contributions to the literature. First, it is the only study thus far to examine the relationship between EC, PL, and GDP. The existence of a Granger causal relationship between the variables may have significant policy implications with regard to the electricity supply, the increasing demand for electricity, and hence,

sustainable development in the KSA. Second, this study develops VAR models to predict the EC, PL, and GDP over the next ten years, with historical data being used in a multivariate manner to understand the variables' behaviour in terms of trends. Advanced planning is required on the part of generators with respect to capacity generation (i.e., peak and off-peak generators have different input needs for production). Therefore, when the EC and PL are efficiently forecasted, more accurate planning can take place in relation to supplies. Third, this study investigates the impulse response so as to trace the effect of a shock on both the current and future values of the endogenous variables, while the variance decomposition technique is used to compare the magnitude of influence between the various variables.

The remainder of the paper is organized as follows. Section 2 presents an overview of EC, PL and GDP in the KSA. Section 3 reviews the relevant literature. Section 4 explains the time series methodology, while section 5 describes the data and the model specification. Section 6 outlines the empirical results. Finally, section 7 offers the concluding remarks.

2. OVERVIEW OF EC, PL AND GDP IN THE KSA

Over the last few decades, the KSA has experienced large economic and demographic surges fuelled by its sizeable oil revenues. The KSA's real GDP increased from around 1.26 trillion Saudi Arabian Riyals (SAR) in 2010 to 2.52 trillion SAR in 2015 [40], while the country's total primary energy consumption increased from about 22.5 million tonnes of oil equivalent (Mtoe) to roughly 200 Mtoe during the same period [22]. With respect to the key macro-economic indicators, the KSA's GDP was 646 billion United States Dollars (USD) in 2015, representing 1.04% of the global economy [47].

Economic development in the KSA has been accompanied by a large increase in electricity consumption. Indeed, Saudi Arabian EC grew annually at a rate of 12–25% during the 1970s and 1980s, while it increased at a rate of 6% during the 1990s and 2000s [3]. These high levels of electricity consumption in the KSA may be due to several factors. First, Saudi Arabia has experienced significant population growth. Between 1979 and 2014, the population grew from 9.3 million to 31.5 million [47].

Second, electricity tariffs are highly subsidised in the KSA and thus represent only a fraction of the actual (market) cost. The International Energy Agency (IEA) [22] estimated that in 2014, the implicit subsidies for electricity and fossil fuels in the KSA amounted to over 70 billion USD.

Third, the KSA has witnessed the rapid development of its industries as well as the modernisation of its cities [21]. As part of its process of industrialisation, Saudi Arabia has opted to promote energy-intensive industries such as aluminium, cement, petrochemicals and steel.

The Saudi Electricity Company's (SEC's) [41] annual report for 2015 shows the proportion of electrical energy consumed by various sectors in Saudi Arabia (Fig. 1). As can be seen in the figure, household demand accounts for around half the total electricity used in Saudi Arabia. This is followed by industrial and commercial use (16%) and the governmental segment (14%). The KSA's electricity demand and consumption patterns are unique, since it is the residential sector that drives consumption rather than the industrial sector, which is the case in other developed and developing countries worldwide.

[INSERT FIGURE 1 HERE]

The peak load of an installation or system is simply the algebraic sum of the maximum load of power plants during a given period of time [8]. Between 2000 and 2014, the PL in the

KSA grew by around 7.1% annually [41]. The government has therefore taken steps to decrease consumption through the introduction of energy efficiency measures on the demand side as well as adding new capacity to the existing fleet on the supply side. Fig. 2 presents the monthly PL (MW) for 2014. The figure shows that the PL increases substantially during the summer months (June–September).

[INSERT FIGURE 2 HERE]

3. LITERATURE REVIEW

Numerous studies have analysed the electricity-growth nexus for different countries and regions around the world using different econometric techniques (e.g., ECM, ARDL, VAR, OLS-EG, DOLS, FMOLS, etc.). For example, O' and Lee [45] reinvestigated the causal relationship between energy consumption and economic growth using Korean data from 1970 to 1999. Their study applied a multivariate model, including capital, labour, energy consumption and GDP. To test the Granger causality, the study applied a vector error correction model rather than a vector autoregressive model, since there was co-integration between the variables of interest. The study reported a long-run bidirectional causal relationship between energy consumption and GDP.

In the absence of co-integration between the variables, a VAR model has been used to analyse the causal relationship between energy consumption and GDP. For example, Stern [11] tested for Granger causality in a multivariate setting using a VAR model comprising GDP, capital and labour input, as well as a Divisia index of energy use in place of energy use as measured in heat units. When both the multivariate approach and the quality-adjusted energy index were employed, Stern found that energy consumption Granger caused the GDP.

Causality studies begin by examining the extent of energy consumption, which is then narrowed into its subcomponents, such as energy, electricity and oil consumption. The relations

between these subcomponents and GDP and/or economic growth are then investigated. For example, Kayıkçı and Bildirici [15] estimated the causal relationship between oil rents, electricity consumption and economic growth at aggregate levels using annual data from 1972 to 2011 for the Arab Gulf states and some Middle Eastern and North African countries. Initially, this study reported co-integration between the variables. Finally, the Granger causality tests indicated that the direction of causality between the variables varied from country to country depending on the nature of the domestic natural resource levels.

Alshehry and Belloumi [3] used a Johansen multivariate co-integration approach to examine the dynamic causal relationships between energy consumption, energy prices and economic growth, employing carbon emissions as a control variable. Their results showed unidirectional causality in the long- and short-term between energy consumption and economic growth in Saudi Arabia. The authors also conducted a variance decomposition analysis, which showed the effect of energy consumption on economic growth to be minimal.

Mezghani and Haddad [20] applied a time-varying parameter vector autoregressive (TVP-VAR) model with stochastic volatility to examine the inter-temporal dynamics between Saudi Arabia's real GDP (oil, non-oil), electricity consumption and CO₂ emission levels for 1971–2010. The key focus of their study was the high- and low-level regimes. The authors also conducted time-varying impulse responses, which showed that the responses depended on the magnitude of the structural volatilities of the real GDP (oil, non-oil), electricity consumption and CO₂ emission shocks.

An earlier version of this paper was presented at MODSIM 2017, the 22nd International Congress on Modelling and Simulation, which was held in Tasmania, Australia [17]. The preliminary results revealed significant Granger causality from the PL to the EC and from the PL to the CO₂. Here, we seek to capitalize on the results of the pilot study and hence perform further in-depth analyses.

The existing empirical literature has failed to reach a consensus regarding the direction of causality between energy consumption and GDP, while none of the above-mentioned studies have clearly explained how the PL related to the EC affects the latter variable. Hence, there is little evidence concerning the nature of the associations between EC, PL and GDP in the KSA. The present study attempts to fill this gap in the literature.

Using a time series analysis, this study models and explores EC, PL and GDP time series data for the KSA. VAR modelling was used to examine the nature of the inter-relationships. Moreover, GC tests were applied to investigate the GC linkages between EC, PL and GDP. Additionally, the IRF allowed for the measurement of both the duration and speed of the interactions that exist between EC, PL and GDP. Further, FEVD was used to determine the extent to which the forecast error variances of EC, PL and GDP are influenced by one another.

To address these issues and achieve the aims of this study, the following hypotheses are empirically tested:

H1. There are positive linkages among EC, PL, and GDP.

H2. There are Granger causal effects among each of the EC, PL, and GDP variables.

4. METHODOLOGY

4.1 Multivariate analysis/ Vector auto-regression analysis

VAR models were first developed by Sims [5] as a better alternative to traditional dynamic simultaneous equation models in terms of examining the dynamic interactions that exist among interrelated time series data. Such models include an equation for each variable explaining its evolution with its own lags and the lags of other variables, so that all the variables are symmetrically treated as endogenous. In comparison to the “incredible identification

restrictions” seen in other structural models, a VAR model represents a theory-free method for detecting economic relationships [6]. This feature has been applied to study the interaction between energy consumption and economic growth [1, 23].

The VAR model used in the present study can be described as follows:

Step 1: The augmented Dickey–Fuller (ADF) test is used to individually check the stationarity of all the influential factors’ historical data. If the ADF t-statistic is lower than the Mackinnon critical value at a significance level of 5%, then the series is supposed to be stationary.

Step 2: The optimal lag length (h) for the model is determined based on the Schwarz Bayesian information criterion (SBIC) test results. Selecting the optimal lag prior to constructing the VAR model is important because a trade-off is always involved in the selection of the number of lags. More specifically, too low a number of lags may lead to poor model specification, while too high a number may lead to the loss of too many degrees of freedom.

Step 3: The VAR model is estimated based on the optimal lag order. A VAR analysis is performed to determine which variables are significantly linked.

Step 4: The VAR model obtained in Step 3 is validated and tested on the residuals. The residual tests that focus on the VAR portmanteau test and residual serial correlation Lagrange multiplier (LM) test for autocorrelations are examples of the null hypothesis that no serial correlation exists in the residuals for the lag order (h).

Step 5: The short-term relationships are investigated, including the forecasting performance, Granger causality testing, impulse response function, and forecast error variance decompositions.

[INSERT FIGURE 3 HERE]

A first-order lag VAR model of EC, PL and GDP can be given as follows:

$$\begin{aligned} EC_t &= C_1 + \alpha_{11}EC_{t-1} + \alpha_{12}PL_{t-1} + \alpha_{13}GDP_{t-1} + \varepsilon_{1t} \\ PL_t &= C_2 + \alpha_{21}PL_{t-1} + \alpha_{22}EC_{t-1} + \alpha_{23}GDP_{t-1} + \varepsilon_{2t} \\ GDP_t &= C_3 + \alpha_{31}GDP_{t-1} + \alpha_{32}EC_{t-1} + \alpha_{33}PL_{t-1} + \varepsilon_{3t} \end{aligned} \quad (1)$$

4.2 Granger causality

An additional advantage offered by the VAR model is the ability to perform Granger causality testing in order to examine the direction of causality among the variables [9]. The GC test is used to check the lead lag or Granger causal relationship between the variables. If a variable, for example, X , is found to be helpful in predicting another variable, for example, Y , then X is said to Granger-cause Y . The methodological structure of the model allows Granger causality tests to be conducted so as to indicate whether there is one or two-way Granger causality between each of the three variables, namely electricity consumption, peak load and gross domestic product.

4.3 Impulse response function

The impulse response function provided by VAR models is considered in terms of the standard deviation shocks during the period used. It shows how the variables respond to those shocks as well as how this affects the other variables. It exhibits the current and lagged effects over time of changes in the error terms $(\varepsilon_{1t}, \varepsilon_{2t}, \dots, \varepsilon_{kt})$ on the endogenous variables $(y_{1t}, y_{2t}, \dots, y_{kt})$. When the VAR process of order “ p ” is stable, the error term ε_{1t} has immediate effects, while $\varepsilon_{2t}, \varepsilon_{3t}, \dots, \varepsilon_{kt}$ all have lagged effects on y_{1t} .

If any covariance stationary VAR(p) process has a Wald representation of the form

$$Y_t = \mu + \varepsilon_t + \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + \dots \quad (2)$$

where the ϕ_s are $(n \times n)$ moving average matrices and the impulse response $\phi_{ij}^s, (i, j)^{th}$ elements of the ϕ_s are defined by

$$\frac{\partial Y_{i,t+s}}{\partial \varepsilon_{j,t}} = \frac{\partial Y_{i,t}}{\partial \varepsilon_{j,t-s}} = \phi_{ij}^s \quad i, j = 1, 2, \dots, n \quad (3)$$

then it is only possible if $var(\varepsilon_t) = \Sigma$ is a diagonal matrix in which the ε_t are uncorrelated.

4.4 Forecast error variance decomposition

A variance decomposition analysis is also typically performed by VAR models, which supplements the impulse response function analysis [2]. Variance decomposition concerns the decomposition of the variance within a given dataset in order to show the changes in a variable that are brought about by its own innovation or due to some other variable. To examine how the EC, PL and GDP variables affect other variables, a variance decomposition analysis within the context of a vector autoregression will be conducted. In general, considering a k -dimension vector autoregressive model denoted as VAR (p):

$$Y_t = \sum_{i=1}^p \theta_i Y_{t-i} + \varepsilon_t \quad (4)$$

where ε_t is an independent and identically distributed error term with zero mean and covariance matrix Σ . If we assume weak stationarity, the value Y_t will obtain a moving average order represented as:

$$Y_t = \sum_{j=0}^{\infty} \psi_j \varepsilon_{t-j} \quad (5)$$

The suitable restrictions available in this case are such that Σ can be represented as PP, so that $\varepsilon_t = P^{-1}\varepsilon_t$ is the orthogonalized error with the identity covariance matrix.

5. DATA SOURCES

The dataset consists of annual observations, while the sample covers the period from 1990 to 2015. The variables included in the estimations are the EC (Gigawatt hours [GWh]), PL (Gigawatt [GW]) and GDP (billion USD). The choice of study period was constrained by the availability of time series data concerning the PL. Data concerning the EC and PL were extracted from the Electricity and Cogeneration Regulatory Authority (ECRA) database, while

data concerning the real GDP were obtained from the Saudi Arabian Monetary Agency (SAMA). All the variables were converted into natural logarithms. Fig. 3 presents graphs of the level series. The graphs provide evidence that all the series indicate an upward trend.

[INSERT FIGURE 4 HERE]

6. RESULTS

6.1 Analysis based on correlations and unit root test

In Table 1, we conduct a preliminary analysis of the expected correlations amongst the variables. A correlation matrix presents the strength of the relationship(s) between variables. The variables are positively correlated with each other, with the correlation factor ranging between 0.96 and 0.99. The highest correlation is found between PL and EC (0.9954), while the lowest correlation is found between GDP and EC (0.9635). The results of the correlation analysis therefore indicate that EC, PL and GDP are becoming increasingly linked or integrated over the years.

Hence, we conduct a further analysis of the relationship between EC, PL and GDP based on methodologies that are known to be more robust than correlation. It has been well established in the literature that correlations suffer from a number of weaknesses, including the assumption of linearity. We apply VAR, GC, IRF and FEVD analyses as they are known to overcome the problem of misspecification and allow for a simultaneous multi-variable analysis.

[INSERT TABLE 1 HERE]

A number of diagnostic tests are conducted prior to performing the VAR analysis. In order to determine the stationarity of the data, unit root tests based on the augmented Dickey-Fuller (ADF) test are performed first. The optimal lags to be used in the model are also first tested based on Schwarz's Bayesian information criterion. The ADF unit root test is used to examine the stationarity of the series, and the results are presented in Table 2. From the table, it can be seen that all the variables are non-stationary in terms of their levels, although they are stationary with respect to the first differences.

We performed Johansen co-integration tests to determine the number of cointegrating vectors. The results of the Johansen co-integration testing (trace and Max-Eigen statistics) are presented in Table 3. The value of the trace statistic is equal to 23.378, which is less than the 5% critical value of 29.68, so we cannot reject the null hypothesis of Johansen co-integration tests (i.e., there is no co-integration among the variables). The same analysis could be performed for the results of the Max-Eigen test. This means that our three variables, namely EC, PL and GDP, are not co-integrated, and we can thus use an unrestricted VAR model.

[INSERT TABLE 2 HERE]

[INSERT TABLE 3 HERE]

6.2 VAR analysis

Before estimating the VAR, the optimum lag is determined based on the results of the SBIC test. The test results are shown in Table 4, which indicates the VAR models with LR, FPE, AIC and HQ values from 0 to the 4th lag. The results show that a lag of four is statistically significant.

We first perform the VAR analysis to determine which variables are significantly linked. Table 5 presents the results of the VAR analysis. As shown in the table, some variables

used in the VAR framework have significant coefficients. Hence, there is significant interdependence among certain variables, that is, either as a variable influencing another variable or as a variable that is influenced. Thus, there is significant interdependence between EC, PL and GDP, which supports the findings of the correlation analysis. Therefore, in the next three sections, we investigate the degree and manner of the interactions between EC, PL and GDP that are significantly linked based on the GC, IRF and FEVD analyses.

[INSERT TABLE 4 HERE]

[INSERT TABLE 5 HERE]

$$\begin{aligned} ES_t = & 0.544054 + 0.71ES_{t-1} + 0.08ES_{t-2} + 0.28ES_{t-3} - 0.14ES_{t-4} \\ & + 0.07PL_{t-1} + 0.65PL_{t-2} - 0.05PL_{t-3} + 0.30PL_{t-4} \\ & - 0.10GDP_{t-1} + 0.09GDP_{t-2} - 0.08GDP_{t-3} - 0.009GDP_{t-4} + u_t \end{aligned} \quad (6)$$

$$\begin{aligned} PL_t = & -6.773212 + 0.21ES_{t-1} + 0.34ES_{t-2} + 0.09ES_{t-3} + 0.09ES_{t-4} \\ & + 0.39PL_{t-1} - 0.15PL_{t-2} - 0.46PL_{t-3} + 0.30PL_{t-4} \\ & + 0.01GDP_{t-1} + 0.00GDP_{t-2} + 0.003GDP_{t-3} + 0.16GDP_{t-4} + u_t \end{aligned} \quad (7)$$

$$\begin{aligned} GDP_t = & 1.575349 - 1.11ES_{t-1} + 2.58ES_{t-2} - 1.07ES_{t-3} + 0.13ES_{t-4} \\ & + 2.67PL_{t-1} - 0.41PL_{t-2} + 1.05PL_{t-3} - 1.84PL_{t-4} \\ & + 0.56GDP_{t-1} - 0.32GDP_{t-2} + 0.25GDP_{t-3} - 0.57GDP_{t-4} + u_t \end{aligned} \quad (8)$$

As shown in Table 4, the lag selection criterion suggested lag 4 for the KSA time series. VAR (4) was used to assess the interaction between the EC, PL, and GDP variables. In other words, it was used to determine how the EC, PL, and GDP variables may influence each other. The VAR results showed that the PL has a significant impact on the EC in the KSA (Table 5). The independent variable, namely the PL (lags 2, 3, and 4), is significant (less than 10% and

5%) in terms of explaining the dependent variable, the EC. Further, the GDP (lags 1, 2, and 3) variable is statistically significant at the 5% significance level, and hence, it may be able to explain EC in the KSA.

The VAR results further showed that the GDP has a significant impact on the PL. The independent variable, that is, the GDP (lags 2 and 4), is significant (less than 5%) in terms of explaining the dependent variable, which is the PL. However, the independent variable, the EC, is not significant with regard to explaining the dependent variable, the PL, because the probability value of all the coefficients is more than 5%.

The VAR results also showed that the PL (lags 1 and 4) affects the GDP, with the effect being statistically significant at less than 10% and 5%, respectively. In addition, the independent variable, namely the EC (lags 1 and 2), exerts an impact on the dependent variable, the GDP, which is statistically significant at less than 10% for lag 1 and 5% for lag 2.

Moreover, the results suggest that the future levels of the EC, PL, and GDP in the KSA can be predicted using Equations 6, 7, and 8, as developed using the VAR.

This study also forecasts the total EC, PL and GDP using the VAR model with a ten-year horizon (i.e., 2016–2025). The forecast results for the EC, PL and GDP (Fig. 4) show positive growth rates of around 7.21%, 6.87% and 14.14%, respectively.

[INSERT FIGURE 4 HERE]

6.3 Granger causality

Granger causality tests were conducted to test the VAR model and determine the causal flow between the variables. The results of the short-run Granger causality tests are presented in Table 6. The Granger causality tests show that there is a significant Granger causality effect from PL to EC and GDP at less than 5%. In other words, there is bidirectional causality from PL to EC and GDP in Saudi Arabia. This means that the maximum of the electrical power

demand (PL) Granger-causes EC and GDP and, similarly, that EC and GDP Granger-cause PL. It is evident that PL has contributed to the progress and development of major needs, namely transportation, communication and manufacturing. Economists strive to identify new determinants (variables) of economic growth. PL is one such variable. Further, the testing reveals a unidirectional causal flow from GDP to EC.

[INSERT TABLE 6 HERE]

6.4 Impulse response function

[INSERT FIGURE 5 HERE]

In this part of our examination of the relationship between EC, PL and GDP, we determine the shocks that arise in one variable and consider whether or not those shocks are transmitted to other variables. As discussed in the methodology section, this is achieved based on the impulse response analysis within the context of the VAR system. Fig. 5 shows the impulse response analyses of the three variables. The results of the ten-year analysis reveal that one positive standard deviation shock in EC will cause the PL to rise positively by about 0.21. Further, the EC impulse responds to a positive GDP shock after one step for each point of the sample.

Yet, the results analysis reveals that one positive standard deviation shock in the PL will cause the GDP to rise positively by about 2.6, while the responses of EC to the PL decrease during the sample period. The response of the PL first increases then decreases and becomes negative due to shocks stemming in GDP, whereas the response of EC to the GDP decreases over time.

6.5 Forecast error variance decomposition

The results of the variance decomposition of the three variables are presented in Table 7. This test is used to determine the extent of the variation, in percentage terms, caused by a variable itself as well as whether or not other variables have contributed to it. The variance decomposition of EC reveals that the major changes in EC are attributable to its own innovation. Further, the contribution of GDP is 27%, while that of PL is 68% over the ten-year period. The results also show that 29% of the PL is explained by its own innovative shocks. The contributions of EC and GDP to PL are 10% and 24%, respectively. The variance decomposition of the GDP shows that the main change in this variable emerges from its own innovation. The contribution from EC is 15%, while that from PL is 38%.

[INSERT TABLE 7 HERE]

7. DISCUSSION AND CONCLUSION

The aim of this study was to examine the nature of the relationships that exist between EC, PL and GDP. To do this, we applied a VAR model from which we could obtain the GC, IRF and FEVD results for interpretation. The VAR model revealed bidirectional Granger causal relationships from PL to EC and GDP in Saudi Arabia using GC. We further find a unidirectional Granger causal relationship from economic growth to electricity consumption in the short term. Our results similar to those of certain prior studies [26, 29, 33]. Since granger causality is shown to run from GDP to electricity consumption, it is suggested that energy conservation policies may be initiated and designed in the KSA to reduce energy consumption growth without much need to be concerned about negative effects on economic growth. On the

contrary, energy conservation is expected to increase the efficient use of electricity and, therefore, enhance economic growth in Saudi Arabia.

According to the results of the variance decomposition, it appears that GDP is the most important variable in terms of explaining PL. The results of the FEVD analysis also show that in the case of EC, the major changes arise from its own innovations as well as from the contribution of PL. This highlights the intensity of energy-related economic activities in Saudi Arabia, which is explained by the overuse of energy and the low local prices of fossil fuels.

The PL process may be the main driver of both GDP and EC. In order to obtain a high level of production and services, it is important to ensure the timely availability of primary energy sources without interruptions to the peak supply. This is crucially important in terms of ensuring stable economic production and consumption. As economic growth and environmental protection are considered national objectives of the KSA, alternative renewable energy sources, such as solar power and wind power, may prove useful, especially with regard to ensuring a sufficient supply of electricity to cover PL periods. In addition, reforms to energy sources and supply, including any subsequent lowering of prices, may constitute an important policy aspect in relation to both the conservation of energy and the encouragement of initiatives intended to explore and promote alternative energy sources. Such alternatives tend to be more cost effective and environmentally friendly.

In terms of future research, there has been some interest in the KSA in exploring the different potential categories of electricity consumption. One limitation of the present study is that it does not differentiate between renewable and non-renewable electricity consumption. Doing so could represent a valuable direction for future research examining this issue in relation to the situation in the KSA.

Another limitation of this study concerns the fact that the analysis is conducted at an aggregate level. Future studies could examine the relationship between EC, PL, and GDP at a disaggregate level in the KSA (e.g., the industrial, transport, commercial, and agricultural sectors), which would serve to extend the present analysis.

A third potential avenue for future research could involve conducting similar studies in other regions of the world. The most obvious candidates here would be the other countries that form the Gulf Cooperation Council (GCC), namely Kuwait, the United Arab Emirates, Qatar, Bahrain, and Oman, either individually or as part of a panel study. The findings of such studies could have important policy implications, particularly if carbon dioxide emissions were to be added as another variable within the VAR framework.

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Fig. 1. Saudi Arabia’s EC by sector for 2015 [41].

Fig. 2. Saudi Arabia’s monthly PL (MW) during 2014 [41].

Fig. 3. Flow Chart of VAR Analysis.

Fig. 4(a). EC for 1990–2015 (level series).

Fig. 4(b). PL for 1990–2015 (level series).

Fig. 4(C). GDP for 1990-2015 (level series).

Fig. 5. Forecast VAR model.

Figure 6. Impulse response graphs.

Table 1. Correlation matrix

	EC	PL	GDP
EC	1.0000		
PL	0.9954	1.0000	
GDP	0.9653	0.9751	1.0000

Table 2. The ADF unit root test

Variable	Level		First Difference	
	ADF	p-value	ADF	p-value
EC	-0.461	0.8994	-5.777	0.0000
PL	0.905	0.9932	-5.446	0.0000
GDP	-0.301	0.9254	-4.120	0.0009

Table 3. Johansen co-integration test results

Trace Test					
Maximum rank	Parms	LL	Eigenvalue	Trace statistic	Critical value 5%
0	12	128.286	.	23.3728*	29.68
1	17	137.234	0.52560	5.4758	15.41
2	20	139.972	0.00400	0.0000	3.76
Max-Eigen Test					
Maximum rank	Parms	LL	Eigenvalue	Max statistic	Critical value 5%
0	12	128.286	.	17.8970	20.97
1	17	137.234	0.52560	5.4758	14.07
2	20	139.972	0.00400	0.0000	3.76

Table 4. Results of the criteria for EC, PL and GDP

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	44.351				4.7e-06	-3.75921	-3.72417	-3.61044
1	122.71	156.73	9	0.000	8.6e-09	-10.065	-9.92484	-9.4699*
2	128.41	11.408	9	0.249	1.2e-08	-9.76538	-9.57005	-8.72393
3	141.35	25.861	9	0.002	1.0e-08	-10.1227	-9.77223	-8.63492
4	159.63	36.57*	9	0.000	5.9e-09*	-10.966*	-10.511*	-9.03268

Table 5. VAR coefficients

ES	Lags	Coef.	P-value
ES	L1.	0.7164568	0.000
	L2.	0.0882025	0.568
	L3.	0.289617	0.081
	L4.	-0.1469793	0.240
PL	L1.	0.0739687	0.595
	L2.	0.6536065	0.000
	L3.	-0.8569441	0.000
	L4.	0.3087758	0.002
GDP	L1.	-0.1010144	0.001
	L2.	0.0967463	0.005
	L3.	-0.0863894	0.016
	L4.	0.0095836	0.774
	Cons	0.544054	0.581
PL	Lags	Coef.	P-value
ES	L1.	0.216532	0.287
	L2.	0.3403006	0.098
	L3.	0.098611	0.555
	L4.	0.0997514	0.549
PL	L1.	0.3920062	0.034
	L2.	-0.1332099	0.530
	L3.	-0.163699	0.011
	L4.	0.1152704	0.382
GDP	L1.	0.0182602	0.653
	L2.	0.095019	0.035
	L3.	0.0030981	0.948
	L4.	0.1615083	0.001
	Cons	-6.773212	0.000
GDP	Lags	Coef.	P-value
ES	L1.	-1.710491	0.070
	L2.	2.585234	0.007
	L3.	-1.077228	0.294
	L4.	0.1347616	0.862
PL	L1.	2.678214	0.002
	L2.	-0.4107752	0.677
	L3.	1.052311	0.215
	L4.	-1.84632	0.003
GDP	L1.	0.5916357	0.002
	L2.	-0.3252723	0.125
	L3.	0.2515178	0.256
	L4.	-0.5724697	0.012
	Cons	1.575349	0.796

Table 6. Granger causality tests for EC, PL and GDP

Equation	Excluded	chi2	df	P-value
EC	PL	49.631	4	0.000
EC	GDP	15.407	4	0.004
PL	EC	29.836	4	0.000
PL	GDP	22.227	4	0.000
GDP	EC	7.7986	4	0.009
GDP	PL	20.68	4	0.000

Table 7. Variance decomposition

Horizon	VDA (EC)			VDA (PL)			VDA (GDP)		
	EC	PL	GDP	EC	PL	GDP	EC	PL	GDP
1	1	0.1333	0.1221	0	0.8666	0.1451	0	0	0.7327
2	0.8070	0.1927	0.0764	0.0134	0.8031	0.2909	0.1795	0.0041	0.5326
3	0.7876	0.3283	0.1301	0.0969	0.5951	0.4256	0.1153	0.0765	0.4442
4	0.7387	0.3949	0.1946	0.1295	0.5150	0.4001	0.1316	0.0899	0.4051
5	0.7180	0.4701	0.2195	0.1404	0.3705	0.3869	0.1415	0.1593	0.3934
6	0.7143	0.4839	0.2582	0.1389	0.3759	0.3871	0.1467	0.1400	0.3546
7	0.7403	0.5406	0.2825	0.1319	0.3428	0.3795	0.1277	0.1164	0.3378
8	0.7352	0.5777	0.2931	0.1219	0.3048	0.3643	0.1427	0.1173	0.3425
9	0.7391	0.5840	0.3006	0.1096	0.2914	0.3485	0.1512	0.1244	0.3507
10	0.7391	0.5818	0.2738	0.1070	0.2920	0.3402	0.1537	0.1261	0.3858