Alshami, Mohamed

**Article**

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# A VAR Based Study on Energy Consumption and Economic Growth

**Mohamed AlShami***

Alqasimia University, Sharjah, UAE. *Email: malshami@alqasimia.ac.ae

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**ABSTRACT**

Economic growth and energy consumption are interrelated for an economy and these variables are expected to indicate a positive correlation. This relationship has been probed in the study in the context of the United Arab Emirates for the time period 1996-2020. The study uses basic regression and Vector Auto Regression techniques for analysis. The study found that energy consumption and non-renewable energy consumption are positively correlated, are dependent on the country's economic growth and this relationship is optimum at a lag of 7 years.

**Keywords:** Energy; UAE; VAR; Economic Growth
**JEL Classifications:** Q2; Q3; Q4

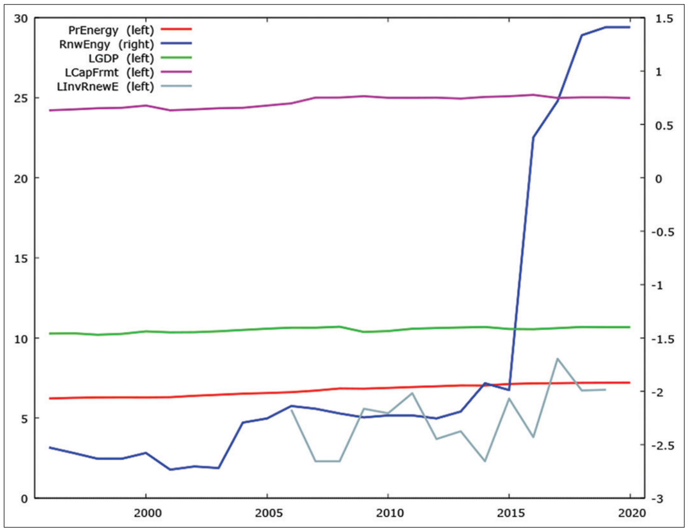
## 1. INTRODUCTION

Over the last few decades many emerging and developing economies have experienced rapid increases in trade, income and energy consumption (Payne, 2010). Energy economics defines the tools and methods which can be used to analyze contemporary energy issues (Subes, 2019). Energy is considered as the most important element in development of a country and the quality of life of its residents (Laila et al., 2021).

The activity in the energy sector (renewable and non-renewable) is directly proportional to the level of economic activity. Non-renewable energy is limited. This source will eventually end. Energy is an important ingredient for an economy and its people. The global energy crisis of 1973 made the world realized its importance (Ghadiryanfar et al., 2016). An energy paradox is that the energy conservation reduces the greenhouse gas emissions which results in slow economic growth. Also there is EKC (Environment Kuznets Curve) which indicates that pollution emissions initially increase with economic growth and then gradually decrease. The EKC, in a seminal paper (Kuznets, 1955), was introduced to explain income inequality and economic growth.

The rapidly growing investments in renewable energy in the Gulf Cooperation Council (GCC) region may be divided into two broad categories: investments in (1) renewable energy projects, and (2) the renewable energy value chain. A considerable share of investment is driven by individual, large projects, implying considerable year-on-year fluctuations in investment volumes. So far, investments are concentrated in the United Arab Emirates (UAE). As deployment picks up, annual investment flows will likely become more consistent, and increase across all countries. Investment trends in renewable energy projects in the GCC between 2006 and 2018 are shown in Figure 1. As a result of increasing government interest and falling technology costs, investment in new projects rose in 2015, and included USD 326 million in the UAE's 200 Mega Watt Mohammed bin Rashid Al Maktoum Solar Park Phase II, USD 400 million in the Shagaya project in Kuwait and USD 600 million in Oman's 1 Miraah Solar project. After a lean year in 2016, investments again picked up in 2017, mainly in three large-scale solar projects in the UAE.

**Figure 1:** Graphical Representation of time Series




Source: Author's illustration

In Dubai's Mohammed Bin Rashid Al Maktoum solar Park, the 800 Mega Watt solar (Phase III) plant and the 700 Mega Watt (Phase IV) plant received investments of USD 940 million and USD 3870 million, respectively. In Abu Dhabi, about USD 870 million was invested in the 1177 Mega Watt Noor Abu Dhabi solar plant in the Sweihan region. While data on investment in small-scale solar projects in 2017 is not available, IRENA's conservative estimates are USD 40 million in the UAE, USD 30 million in Saudi Arabia and USD 12 million in Oman is invested in such projects. So far, the UAE has received the lion's share of investment in the region and the country is expected to retain its leadership in future.

## 2. REVIEW OF LITERATURE

Energy economics has been extensively studied in previous literature (Sadorsky, 2011; Laila et al., 2021) and few studies have been conducted in the context of the Middle Eastern economy (Salim et al., 2014). Kenny et al. (2010) focused on the economic shocks in the energy sector and found that energy consumption is stationary around a broken trend. Sadorsky (2011) studied the relationship between trade and energy and found that only 30% of total global energy demand is accounted. They conclude that Middle East as a region is a good example for the world in terms of impressive increases in economic growth, energy demand and trade. They also found that causality runs from energy to income and has a direct implications for energy conservation. Laila et al. (2021) did a qualitative research based on 22 research papers and found that country, renewable energy, $CO_2$ emissions are few of the common keywords in these researches. Salim et al. (2014) found that the high level of economic growth leads to a high level of consumption in non- renewable energy and government should make the policies to renewable energy for sustainable growth.

Bhattacharyya (2019) highlight the growing importance of academic and research focus on energy and the required attention from people from different fields including engineers, scientists, geologists, environmentalists, bankers, investors, policy makers and politicians. Kassim and Isik(2010) along with Edenhofer(2013) focussed on renewable energy (RE) where Edenhofer(2013) observe that there are remaining white areas on the knowledge map concerning consistent and socially optimal RE policies. Oliveira and Moutinho, did a bibliometric analysis on RE and economic growth and found 'Sustainability' as the journal which has published maximum on the theme. Sakmar(2008) studied the impact of energy as a commodity in global trade.

Arouri et al. (2011) evaluated the relationship between carbon emissions, income, energy and total employment in five selected OPEC countries. They found that the income elasticity in the long run is smaller than the short run. The empirical analysis revealed that for individual countries, in the long run, carbon dioxide emissions have fallen as national income increases. About 1% increase in Gross Domestic Product (GDP) generated an increase of 0.68% in emissions. Additionally, they found that carbon dioxide emissions are stabilizing in rich countries and that in the Middle East and North African (MENA) region water pollution, soil pollution and air pollution should be focused upon apart from the carbon dioxide emissions. The results also showed that EKC (Environment Kuznets Curve) is not verified for the sample countries, except for Jordon.

Nematollahi et al. (2016) found that the energy resources are the main drivers of a country's agriculture and industry. The focus was on the interrelationship between income, energy and trade for eight Middle East countries. Considering the geography of Yemen, Saudi Arabia and Egypt, it was recommended that they should explore more locations for solar energy. Iran, Turkey, Iraq, Egypt, Yemen and Oman were observed as the top countries with high wind energy potentials. Matsuo et al. (2013) studied demand forecasting models for the year 2035 and observed that the Asian countries are decreasing their energy dependency on the Middle East region and making arrangements with other countries such as Australia and the African region to fulfill their energy needs. They forecast that the Middle East's share of Asia's total imports will decline from 77% in 2010 to 65% in 2035 for oil. They comment that for the energy policies the future costs, benefits and technologies should be considered along with the economic impacts of these policies in long run.

Energy consumption and economic growth is expected to move in the same direction and both of these variables are dependent on investments. The primary problem and the research question being addressed in the study is that whether energy consumption and economic growth explain each other. Additionally, the relationship between energy consumption and investments is also studied. The secondary problem statement is to suggest an action plan for the future course of the energy sector, particularly for the UAE's economy.

Middle East is a region which traditionally has been dependent on fossil fuels but recently is making efforts to diversify into other industrial sectors. The main source of income is global oil and gas market (Ghadiryanfar et al., 2016). Thus, energy is an imperative sector to study for the Middle East region. The interrelationship of the energy variables with other macroeconomic variables is expected to reveal relevant findings for effective policy making. This study is aimed in this direction and is focused on the UAE's energy sector.

## 3. RESEARCH METHODOLOGY

The primary objective of the research is to understand the relationship between energy consumption and economic growth, particularly in the context of the United Arab Emirates. Kenny et al. (2010) studied consumption, production and economic shocks in the energy sector. Sadorsky (2011) studied the relationship between energy consumption and GDP. The secondary research objective to explore the interrelationships between renewable energy consumption and renewable energy investments. For the purpose, selected time series variables have been used to probe and draw inferences about the research objective. The variables and the research design has been used as in Kenny et al. (2010) and Sadorsky (2011). The data variables used are explained in Table 1. The country of UAE has been taken as a sample considering the country's importance to the global energy demand and considering the UAE economy's high dependence on non-renewable energy sources. Published data from secondary sources (World Bank, Irena) has been used for the six variables for the time period 1996-2019. The time period used in the study is for the year 1996-2019. The study uses basic regression and Vector Auto Regression techniques for analysis. SPSS 20.0 and Gretl software have been used for data processing and the subsequent analysis.

Accordingly three null hypothesis were proposed for evaluation,

H01: Economic growth does not causes primary energy consumption.
H02: Economic growth does not causes renewable energy consumption.
H03: Investment in renewable energy does not causes renewable energy consumption.

## 4. ANALYSIS

The Table 1 indicates average values and coefficient of variation (CV) values for the data variables. Here, "L" indicates natural logarithm. The highest standardized volatility (CV = 85%) was observed for renewable energy while the lowest was observed for capital formation (1.4%).

Analyzing Table 2, a high correlation was observed for the primary energy consumption with renewable energy consumption (0.73), low with GDP (0.17), high with capital formation (0.58) and with the investments in renewable energy (0.41). A high positive correlation was found between renewable energy consumption and investment in renewable energy (0.52). A negative correlation was found for GDP with capital formation (–0.29) and renewable energy investments (–0.22).

Analyzing regression equations, based on the research objective, primary energy consumption was found to be positively and significantly related (R-squared is 64%, P = 0) with economic growth (equation 1). Also, renewable energy consumption was found to be positively and significantly related (R-squared is 29%, P = 0.005) with economic growth (equation 2). Additionally, renewable energy consumption was found to be positively and significantly related (R-squared is 27%, P = 0.05) with the investments in renewable energy (equation 3).

*Primary energy consumption= -12.33+1.81 * Economic growth* (1)

**Table 1: Descriptive data about the study variables**

| Variable | Mean | CV (%) | Time period | Definition |
|---|---|---|---|---|
| LPEngCons | 6.741 | 5.31 | 1996-2020 | Primary energy consumption (Tera watt hours) measures the total energy consumption of a country. It covers consumption of the energy sector itself, losses during transformation and distribution of energy, and the final consumption by end users. |
| LRnWperPE | -1.6779 | 84.84 | 1996-2020 | Renewable energy consumption as a percentage of primary energy consumption. |
| LGDP | 10.509 | 1.50 | 1996-2020 | Gross Domestic Product (GDP) per capita (current US$) for the country. |
| LCapFrmt | 24.738 | 1.41 | 1996-2020 | Capital Formation is defined as that part of country's current output and imports which is not consumed or exported during the accounting period, but is set aside as an addition to its stock of capital goods. |
| LMrchTrperGDP | 4.805 | 5.43 | 1996-2020 | Merchandise trade as a percentage of GDP for the country. |
| LInvRnewE | 4.9952 | 39.27 | 2006-2019 | Country's investments in renewable energy (Million US Dollar). |

Source: Author's calculation

**Table 2: Correlation coefficients for the study variables**

| | LPEngCons | LRnWperPE | LGDP | LCapFrmt | LMrchTrperGDP | LInvRnewE |
|---|---|---|---|---|---|---|
| LPEngCons | 1 | 0.73 | 0.17 | 0.58 | 0.83 | 0.41 |
| LRnWperPE | | 1 | 0.26 | 0.24 | 0.31 | 0.52 |
| LGDP | | | 1 | -0.29 | 0.06 | -0.22 |
| LCapFrmt | | | | 1 | 0.68 | -0.11 |
| LMrchTrperGDP | | | | | 1 | 0.13 |
| LInvRnewE | | | | | | 1 |

Source: Author's calculation

*Renewable energy consumption = -53 + 4.8 * Economic growth* (2)

*Renewable energy consumption = -3.23 + 0.39 * Renewable energy investments* (3)

The time series for economic growth and primary energy were found NOT to be co-integrated and hence unrestricted Vector Auto Regression (Sims, 1980) was used (Table 3) with lag selection based on the Akaike Information Criteria (AIC) as in Akaike (1981). Primary energy and the economic growth was used as the two endogenous variables in the VAR system at an optimum lag of 7. The VAR system with primary energy as the dependent variable (Table 3) was found statistically significant (P = 0) with an R-squared value of 99.80%. Considering the variance decomposition in the forecast of primary energy consumption for a ten year period, the decompositions was observed as 50% each for primary energy and economic growth at a lag of 7 years. The maximum effect of the economic growth on the variance decomposition was observed after 8 years (57%). The impulse response of primary energy to a one standard error shock of economic growth was observed maximum (−0.01) at a lag of 7 years (Table 4).

**Table 3: VAR results (dependent variable: Primary energy**

| | Coefficient | P-value |
|---|---|---|
| Constant | 5.65 | 0.21 |
| PrEnergy_1 | −0.34 | 0.46 |
| PrEnergy_2 | 0.86 | 0.08 |
| PrEnergy_3 | 0.50 | 0.11 |
| PrEnergy_4 | 0.48 | 0.11 |
| PrEnergy_5 | 0.33 | 0.25 |
| PrEnergy_6 | 0.34 | 0.32 |
| PrEnergy_7 | −1.14 | 0.03 |
| LGDP_1 | 0.17 | 0.22 |
| LGDP_2 | −0.13 | 0.30 |
| LGDP_3 | 0.03 | 0.77 |
| LGDP_4 | −0.006 | 0.96 |
| LGDP_5 | −0.058 | 0.65 |
| LGDP_6 | −0.45 | 0.02 |
| LGDP_7 | −0.13 | 0.28 |

Source: Author's calculation

**Table 4: VAR results (dependent variable: Renewable energy**

| | Coefficient | P-value |
|---|---|---|
| Constant | 33.41 | 0.05 |
| RnwEngy_1 | 0.48 | 0.02 |
| RnwEngy_2 | 0.58 | 0.02 |
| RnwEngy_3 | 0.13 | 0.47 |
| RnwEngy_4 | −0.2 | 0.31 |
| RnwEngy_5 | −0.09 | 0.88 |
| RnwEngy_6 | −1.75 | 0.21 |
| RnwEngy_7 | 5.87 | 0.01 |
| LGDP_1 | −2.48 | 0.11 |
| LGDP_2 | 5.13 | 0.01 |
| LGDP_3 | −1.25 | 0.23 |
| LGDP_4 | 2.88 | 0.03 |
| LGDP_5 | −0.49 | 0.49 |
| LGDP_6 | −0.03 | 0.96 |
| LGDP_7 | −5.99 | 0.00 |

Source: Author's calculation

The same VAR process was repeated to study the impact of economic growth on renewable energy and a lag effect of 7 years was observed based on the AIC criteria. The R-squared value was observed as 99.75% and statistically significant (P = 0.001). The decomposition in variance was observed as 55% for economic growth for the second year forecast which reduced to 30% till the 10th year. The impulse response of renewable energy to a one standard error shock of economic growth was observed maximum (0.08) at a lag of 7 years. The VAR process was repeated to study the impact of investment in renewable energy on the renewable energy consumption and a lag effect of 4 years was observed based on the AIC criteria. The R-squared value was observed as 98.86% and statistically insignificant (P = 0.22). The decomposition in variance and the impulse responses did not indicated meaningful results and hence were ignored in analysis.

The primary energy consumption, capital formation and the economic growth indicated a stable and rising trend across the time period (Figure 1). Here, renewable energy consumption indicated a steep increase along with a volatile but increasing trend in renewable energy investments, after the year 2015. A high volatility (85%) was observed for renewable energy consumption indicating a fluctuating demand for this energy source where as a low volatility was observed for capital formation, indicating a stability in this variable. A positive correlation of primary energy consumption with renewable energy consumption (0.73), GDP (0.17), capital formation (0.58) and with investment in renewable energy (0.41) indicates that an increase in these variables will result in an increase in primary energy consumption. A negative correlation was found for economic growth with capital formation (-0.29) and renewable energy investments (-0.22). This indicates that capital formation is due to non GDP factors.

All the three null hypothesis were rejected. This implies that primary energy consumption and renewable energy consumption is dependent on economic growth of a country (H01 and H02). A high positive correlation was found between renewable energy consumption and investment in renewable energy (0.52) indicating that relevant investment in renewable energy is yielding results. This was validated by rejection of null hypothesis (H03). Economic growth explained 64% of the variance in primary energy consumption and 29% in renewable energy consumption. Renewable energy investments explained 27% of the variance in renewable energy consumption.

Subsequently, Vector Auto Regression technique was used to probe more and understand the lag effects in the focused relationships. Here, the primary energy as the dependent variable was found as statistically significant (P = 0) with an R-squared value of 99.80% at a lag of seven years with the economic growth. Similarly, the renewable energy was found statistically significant (P = 0.001) with an R-squared value of 99.75% (lag 7 time years) and the economic growth being the independent variable.

Some of the significant findings from the analysis are listed below.

- The primary energy consumption, capital formation and the economic growth indicated a stable and rising trend across the time period.
- The renewable energy consumption indicated a steep increase along with a volatile but increasing trend in renewable energy investments, after the year 2015.

- A high volatility was observed for renewable energy consumption where as a low volatility was observed for capital formation.
- A positive correlation of primary energy consumption with renewable energy consumption, GDP, capital formation and with investment in renewable energy was observed.
- A negative correlation was found for economic growth with capital formation and renewable energy investments.
- Economic growth was able to explain the variance in primary energy consumption and in renewable energy consumption.
- Renewable energy investments was able to explain the variance in renewable energy consumption.
- In VAR the primary energy as the dependent variable was found as statistically significant at a lag of seven years with the economic growth.

## 5. CONCLUSION

The objective of the research was to understand more about the dynamics of energy variables with economic growth and the research was able to achieve the objective. Primary energy consumption and non-renewable energy consumption were found to be positively correlated and dependent on economic growth. This was validated by linear regressions and Vector Auto Regressions. A lag effect of 7 years was observed for both types of energy. Additionally, renewable energy consumption was found to be dependent on investment in renewable energy. Renewable energy consumption is increasing in UAE but there is lack of consistency in renewable energy investments. The policy makers should push primary energy and non-renewable energy consumption for economic growth and vice versa. More consistent investment in renewable energy is needed in UAE to support the growth in renewable energy consumption. The effects of this policy measure are expected to be realized after 7 years. VAR is additionally validated as a forecasting technique for energy variables and economic growth variables.

### 5.1. Limitations of the Study

The study is constrained by data from a single country and for a specific time period. The data reliability depends on the source.

### 5.2. Scope for Further Research

Another study on similar variables but on a multiple country sample is expected to give more robust results. Forecast efficiency of model 1,2 and 3 may be validated on a different data to assess the accuracy and reliability of the models.

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