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Structural Breaks and Causality Relationship between Economic Growth and Energy Consumption in Saudi Arabia

Waheed A. Banafea
Department of Economics & Budget,
Institute of Public Administration, Riyadh 11141, Saudi Arabia.
Email: Banafeaw@ipa.edu.sa

ABSTRACT: The purpose of this paper is to empirically investigate the short and long run causality between economic growth and energy consumption in Saudi Arabia during the period of 1971-2012 using the Gregory and Hansen (1996) cointegration procedure and error-correction models. The results of the unit root tests with structural breaks indicate that total energy and gas consumption are stationary in levels. Thus, we dropped these variables from the cointegration and causality analysis. The stable long run relationship between real GDP and oil consumption is detected by both stability and cointegration tests. The estimated breakpoints correspond with the period of 1974-1985 during the oil boom. The causal relationship is found between real GDP and oil consumption in both the short and long run. We found short run unidirectional Granger causality running from real GDP to oil consumption. However, the long run unidirectional Granger causality is detected from oil consumption to real GDP. Therefore, the energy conservation policy in the long run should be designed with caution, since energy is considered an engine of GDP growth.

Keywords: Energy consumption; Structural breaks; Causality; Saudi Arabia
JEL Classifications: C20; Q43; Q48

1. Introduction

The relationship between economic growth and energy consumption has been extensively investigated in the literature. However, mixed results are found even for the same country under a different time period. Kraft and Kraft (1978) studied the relationship between economic growth and energy consumption for U.S. for the period from 1947 to 1974. They found evidence of a unidirectional causality running from GNP to total energy consumption. In contrast, Yu and Hwang (1984) found no evidence of causality between GNP and total energy consumption when the updated U.S. data for the period 1947-1979 are used. Both papers employed Sims causality methodology.

Moreover, Cheng and Lai (1997) investigated the causality between GDP and total energy consumption for Taiwan during the period of 1955-1993. The results of their study indicated that there is a unidirectional causality that runs from GDP to energy consumption. However, when Lee and Chang (2005) reexamined the causality using both aggregate and disaggregate data categories for energy consumption for the period of 1954-2003 in Taiwan, the results showed evidence of bidirectional causality that runs from GDP to total energy and gas consumption and vice versa. The authors mentioned that structural breaks are important and should be taken into account when examining the relationship between economic growth and energy consumption. They indicated that failure to take into account the influence of structural breaks may lead to a distorted outcome.

The relationship between economic growth and energy consumption is likely to be subject to changes due to economic crises, fluctuations in energy prices, reforms in energy regulation, or changes of energy policy. Therefore, these changes may create structural changes and need to be accounted for when studying the stability and direction of the relationship between economic growth and energy consumption.

Previous works on the causality relationship between economic growth and energy consumption in Saudi Arabia revealed conflicting results. Some studies support the conservation hypothesis, which states that there is a unidirectional causality running from economic growth to energy consumption (Al-Iriani, 2006; Mehrara, 2007a; Chontanawat et al., 2008). In contrast, Mehrara (2007b) found results that support the growth hypothesis, which states that there is a unidirectional causality that runs from energy consumption to economic growth.The feedback hypothesis, which states that there is bidirectional causality between economic growth and energy consumption is supported by Mahadevan and Arafu-Adjaye (2007) and Squalli (2007).

Al-Irian (2006) investigates the relationship between real GDP and total energy consumption for the Gulf Cooperation Council (GCC) for the period of 1971-2002 using Pedroni panel cointegration and based-panel error correction models (ECM). The results support the conservation hypothesis, which denotes that the energy conservation policies in Saudi Arabia can be implemented with little concern about the effects on GDP. Mehrara (2007a) reexamined the causality issue between the real GDP per capita and the commercial energy usage per capita for oil exporting countries including Saudi Arabia for the period of 1971-2002 using Pedroni panel cointegration and panel ECM. The results support the previous findings by Al-Irian (2006).

Mehrara (2007b) applied Johansen's maximum likelihood approach, the causality procedure by Toda and Yamamota (1995), and ECM to test the causality between commercial energy usage per capita and real GDP per capita in Saudi Arabia for 1971-2002 period. This study showed that causality runs from energy consumption to GDP without feedback. Mahadevan and Asafu-Adjaye (2007) utilized panel and time series methods to investigate the causality between real GDP and total energy consumption for Saudi Arabia for the period 1971-2002. They found evidence of bidirectional causality between the two variables.

Using disaggregate data of energy consumption, Squalli (2007) investigated the causal relationship between electricity consumption and GDP in Saudi Arabia for the 1980-2003 period. Using the ARDL-bounds test and Toda and Yamamota's (1995) causality procedure, the results indicated that causality runs from GDP to electricity consumption with no feedback. Chontanawat et al. (2008) found that there is a unidirectional causality running from GDP to total energy consumption for Saudi Arabia for the period 1971-2000 by employing Johansen and Juselius and ECM. A mix of low-income, middle-income, and high-income countries was considered by Huang et al. (2008), who conducted a dynamic panel approach and covered the period of 1972-2002. The results showed a unidirectional causality from GDP to total energy consumption for the high and middle-income panels and no evidence of causality for the low-income panel.

Using data from 11 Middle Eastern and North African countries including Saudi Arabia, Ozturk and Acaravci (2011) examined the short and long run causality issues between electricity consumption and economic growth for the period 1971-2006. They employed the Autoregressive Distributed Lag (ARDL) bound test of cointegration and vector error correction models (VECM). The results showed that there is evidence of unidirectional long and strong Granger causality from electricity consumption to real GDP in Saudi Arabia. Shahateet (2014) utilized ARDL and Granger causality to test the causality relationship between energy consumption and economic growth in 17 Arab countries including Saudi Arabia. The results indicated that there is no causality from economic growth to total energy consumption and the other way around in Saudi Arabia.

The purpose of this paper is to examine the short and long run causality relations between economic growth and energy consumption in Saudi Arabia for the period 1971-2012. The stability tests and cointegration technique are applied to examine the stability of the longrun relationship between real GDP and energy consumption. Next, Granger causality procedure is conducted to establish any causal relationship among the two variables.

What distinguishes this paper from the previous work on Saudi Arabia is that this paper considers evidence from the recent period since it extends the data set to include 1971 to 2012. In addition, since Perron (1989) pointed out that the presence of structural breaks in a series can lead to misleading results; this paper takes into consideration the effect of structural breaks on the relationship between economic growth and energy consumption by using the cointegration test by Gregory and Hansen (1996).

The reminder of this paper is organized as follows. Section 2 discusses methodology and data sources. Section 3 presents empirical results with policy implication. Section 4 concludes the paper.

2. Methodology and Data

Following the literature, the empirical model of the long run relationship between economic growth and energy consumption can be written as follows:

$$y_t = \gamma + \alpha x_t + \epsilon_t \quad (1)$$

where y is the real GDP per capita and x is the energy consumption. This paper uses annual time series data of GDP per capita for the period of 1971-2012, total energy consumption (henceforth, EC) for the period of 1971-2011, and gas and oil consumption for the period of 1971-2012. GDP per capita is expressed in constant 2005 US$, total energy consumption is expressed in terms of kg oil equivalent per capita, and gas consumption is expressed in terms of million tons of oil equivalent. All of the variables in the model are in natural logarithms.The data of gas and oil consumption are obtained from BP Statistical Review of World Energy, while GDP per capita and EC are taken from the World Development Indicators produced by the World Bank.

Three steps will be performed to test for causality between economic growth and energy consumption. First, testing will be performed for unit root in GDP, EC, gas, and oil consumption to determine the order of integration. Second, the long run relationship between the variables in equations will be tested using the cointegration technique, which allows for a one-unknown structural break. Finally, the Granger causality procedure is used to examine the short run and long run causality relations between economic growth and energy consumption.

Saudi Arabia depends heavily on the export of oil and gas, and that may lead to instability of the economic system of the country. It has an oil-based economy, and fluctuations in the prices of oil or gas likely created structural breaks. The use of conventional unit root tests together with cointegration techniques that are not taking into account structural breaks may lead to distorted results. In addition, it is a common problem that macroeconomic series are affected by regime shifts in economic events. Hamilton (2003) showed that an increase in oil prices is more influential than a decrease in oil prices. Therefore, there is a high chance of creating instability of the relationship between economic growth and energy consumption. Hooker (2002) indicated that oil prices have a direct effect on inflation, and taking that in the consideration in the specification of structural breaks provides a better fit on the data.

Figure 1 shows evidence of trend and structural breaks, especially for the GDP. Therefore, if we neglect the structural breaks in our analysis, then we may conclude that the series are not stationary or that the relationship between economic growth and energy consumption is unstable.

2.1. Unit root tests with structural breaks

Two unit root tests are conducted in this paper to determine the order of integration, namely Zivot and Andrews (henceforth, ZA) (1992) and Perron (1997). Both tests deal with a structural break as endogenous. The ZA test is a developed version of the Perron (1989) test. ZA uses three models to test a unit root, shift in the intercept (henceforth, A), shift in the slope (henceforth, B), and shift in both intercept and slope (henceforth, C). Sen (2003) indicated that using model A instead of the model C can lead to a substantial power loss if the break occurs in model C. However, if the break occurs in model A when model C is used, then the power loss is minimal. Thus, model C is conducted to examine the null hypothesis of a unit root against the alternative of trend stationary process with a one-unknown structural break. The regression form can be written as

$$y_t = \gamma + \alpha\, y_{t-1} + \beta\, t + \theta\, DU_t + \mu\, DT_t + \sum_{j=1}^{k} \rho_i\, \Delta\, y_{t-j} + \epsilon_t \qquad (2)$$

where Δ is the first difference operator, DU_t and DT_t are indicator dummy variables for a mean shift and a trend shift, respectively; $DU_t = 1$ and $DT_t = t - TB$ if $t > TB$; 0 otherwise. TB denotes the time at which the structural break occurs. The date of a structural break is determined according to the smallest t-statistics. $t = 1, \ldots, T$ denotes an index of time, and ϵ_t is a white noise disturbance. The lag length is determined using the Akaike Information Criterion (AIC). Asymptotic distribution of the minimum t-statistic and critical values are provided by Zivot and Andrews (1992).

An alternative unit root test is proposed by Perron (1997). Similar to the ZA test, Perron (1997) uses the three models mentioned above to test a unit root against the alternative of a trend stationary process with a one-unknown structural break. This test differs from the ZA test by adding a one-time shock dummy variable. Moreover, the Perron test chooses the breakpoint where the t-statistic for testing $\alpha = 1$ is the minimum or where the t-statistic on the change in slope on the break term is the minimum. The model with shift in both intercept and slope can be written as follows:

$$y_t = \gamma + \alpha\, y_{t-1} + \beta\, t + \theta\, DU_t + \mu_1 DT_t + \mu_2\, DTB_t + \sum_{j=1}^{k} \rho_i\, \Delta\, y_{t-j} + \epsilon_t \qquad (3)$$

where DTB = 1 if t = TB + 1. The lag parameters are determined using AIC.

2.2. Cointegration analysis

The Gregory and Hansen (1996) cointegration tests (henceforth, GH) is an extension of the residual-based tests that take into account the possibility of a one-time unknown structural break in the intercept alone or in both intercept and coefficient vector. The null hypothesis under these tests is that there is no cointegration with a structural break against the alternative that there is cointegration with a structural break. Gregory and Hansen indicate that, when the standard ADF test is used in the cointegration analysis without taking into account the one-time regime shift, it may lead to misleading conclusion that the long run relationship between the dependent variable and its determinants is not exists. They propose three models:

Level shift (C):

$$y_t = \gamma_1 + \gamma_2\, DU_t + \gamma_3\, x_t + \epsilon_t \qquad (4)$$

Level shift with trend (C/T):

$$y_t = \gamma_1 + \gamma_2\, DU_t + \beta t + \gamma_3\, x_t + \epsilon_t \qquad (5)$$

Regime shift (C/S):

$$y_t = \gamma_1 + \gamma_2\, DU_t + \gamma_3\, x_t + \gamma_4 x DU_t + \epsilon_t \qquad (6)$$

They also propose three test statistics, namely $ADF^* = inf_{t\,\epsilon\, T}\, ADF\,(t)$, which is the modified version of the Engle and Granger (1987) cointegration test, and $Z_t^* = inf_{t\,\epsilon\, T}\, Z_t\,(t)$ and $Z_a^* = inf_{t\,\epsilon\, T}\, Z_a(t)$, which are both modified versions of Phillips and Quliaris (1990). The breakpoint is the smallest value of these three test statistics. The modified Mackinnon (1991) critical values are used instead of the critical values which are used in the Engle and Granger method.

2.3. Causality analysis

The two-step procedure from Engle and Granger (1987) are used to examine the short run (weak causality) and long run (weak erogeneity) Granger causality between the economic growth and energy consumption. The first step is to estimate the residuals from the long run relationship. The second step is to add the residual as a variable on the right-hand side in the dynamic ECM. The ECM can be specified as follows:

$$\Delta\, y_t = \gamma_1 + \sum_{i=1} \delta_{1j}\, y_{t-i} + \sum_{j=0} \alpha_{1i}\, x_{t-j} + \theta_1\, ECT_{t-1} + \epsilon_{1t} \qquad (7)$$

$$\Delta\, x_t = \gamma_2 + \sum_{i=0} \delta_{2j}\, y_{t-i} + \sum_{j=1} \alpha_{2i}\, x_{t-j} + \theta_2\, ECT_{t-1} + \epsilon_{2t} \qquad (8)$$

Where ECT is the lagged error term, which is derived from the long run cointegrating relationship. θ is the adjustment coefficient, which shows how fast deviations from the long run equilibrium are eliminated following changes in each variable. The short run causality is examined by testing: H_0: α_{1i} = 0 and H_0: $\delta_{2j} = 0$ for all i and j in equations (7) and (8), respectively, while the longrun causalityis examined by testing: H_0: $\theta_1 = 0$ and H_0: $\theta_2 = 0$ in equations (7) and (8), respectively.

3. Empirical Results

3.1. Unit root test results

Two conventional unit root tests are applied, namely Augmented Dickey-Fuller (1979) (henceforth, ADF), and Phillips and Perron (1988) (henceforth, PP) to test the null hypothesis of a unit root. Both the ADF and PP tests don't take into account the possibility of structural breaks. Therefore, they may lead to a misleading result when accepting the null hypothesis of a unit root.

The plot of the log-level series shows that all the variables have trend (Figure 1). Thus, the unit root tests are run with constant and trend. The selection of the lag length is determined by applying the AIC. The results of the ADF and PP unit root tests are reported in Table 1. The results indicate that GDP, EC, gas, and oil have unit root at levels. However, all variables are stationary in the first difference at the 5% and 1% levels of significance. These results show that GDP, EC, gas, and oil are integrated of order one, I (1).

Figure 1. log values of GDP and energy consumption

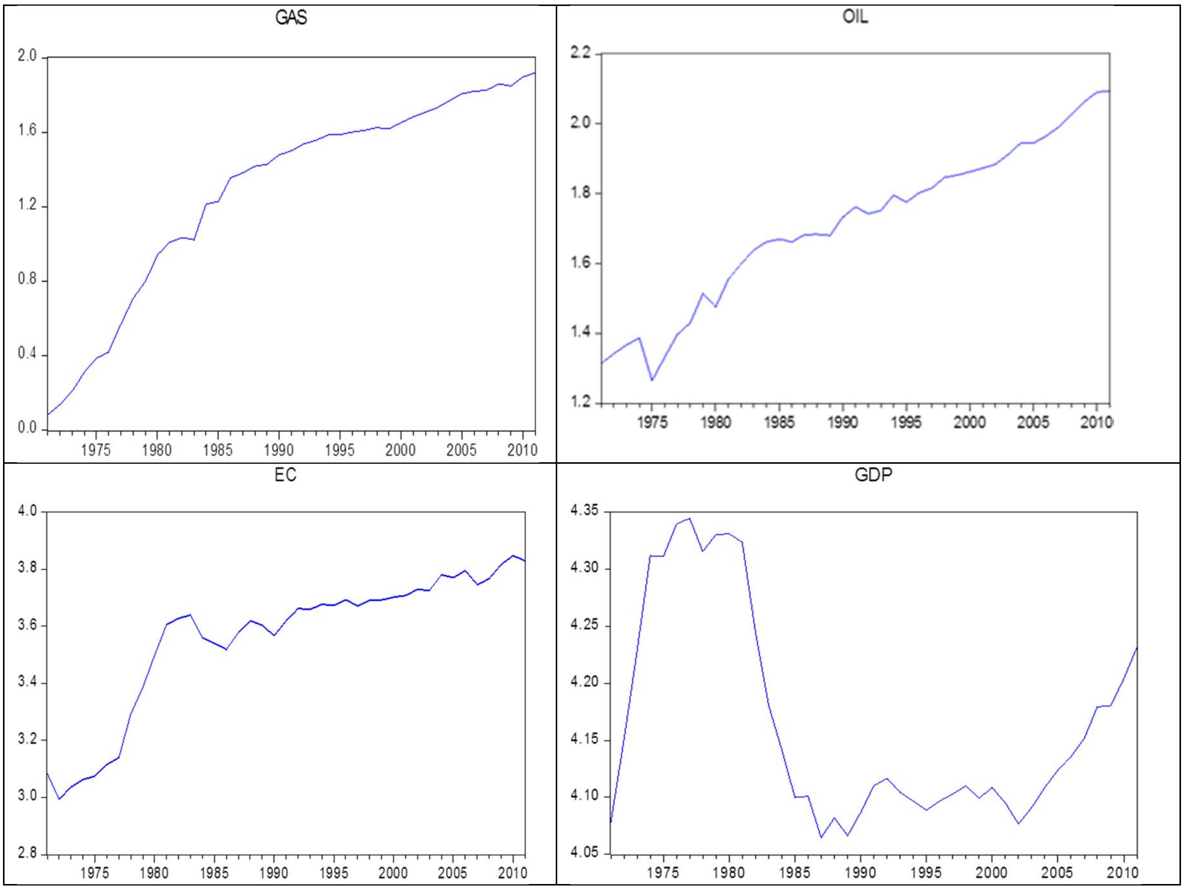


Table 1. Results of unit root tests without structural breaks

Variables	ADF		PP	
	Levels	First difference	Levels	First difference
GDP	-1.848 (2)	-3.556** (0)	-2.096	-3.556**
EC	-2.703 (2)	-5.169*** (0)	-1.545	-5.18***
Gas	-1.736 (0)	-6.953*** (0)	-1.759	-6.948***
Oil	-2.657 (0)	-7.535*** (0)	-2.624	-7.694***

, * denote significance at the 5% and 1% levels, respectively. The number of lag order is shown in parentheses.

Figure 1 shows that GDP, EC, and oil might have structural breaks in the 1970s. Therefore, the ZA and Perron unit root tests are utilized. The lag length is chosen by AIC. The results of the ZA and Perron tests are reported in Tables 2 and 3, respectively. As can be seen from Tables 2 and 3, the results from ZA and Perron tests suggest that GDP and oil series are I (1); however, EC and gas are I(0). The structural breaks which took place in the 1970s and 1980s refer to the period of the oil boom, 1974-1985. Due to the higher oil revenues, the Saudi government made major structural changes in the economy. In the mid 1970s, Saudi Arabia used most of the oil revenues for massive development efforts. They focused mostly on industrialization, airports, schools, roads, and ports. In the 1980s, Saudi Arabia increased its oil and gas resource development through downstream investment in refineries and petrochemical plants. Also, during that period Saudi Arabia started to treat natural gas as a valuable resource instead of wasting it (http://lcweb2.loc.gov/frd/cs/satoc.html).

Table 2. ZA unit root test results

Variables	Levels	Break date	First differences	Break date
GDP	-5.011 (2)	1982	-6.372 (0)***	1986
EC	-5.759 (2)***	1984	-7.419 (0)***	1982
Gas	-5.176 (0)**	1984	-8.467 (0)***	1981
Oil	-4.320 (0)	1977	-8.196 (0)***	1984

, * denote significance at the 5% and 1% levels, respectively. The number of lag order is shown in parentheses.

Table 3. Perron unit root test results

Variables	Levels	Break date	First differences	Break date
GDP	-4.904(0)	1981	-6.726 (0)***	1985
EC	-6.216 (0)**	1977	-7.371 (0)***	1981
Gas	-6.651 (0)***	1983	-8.311 (0)***	1980
Oil	-4.312 (0)	1978	-8.386 (0)***	1977

, * denote significance at the 5% and 1% levels, respectively. The number of lag order is shown in parentheses.

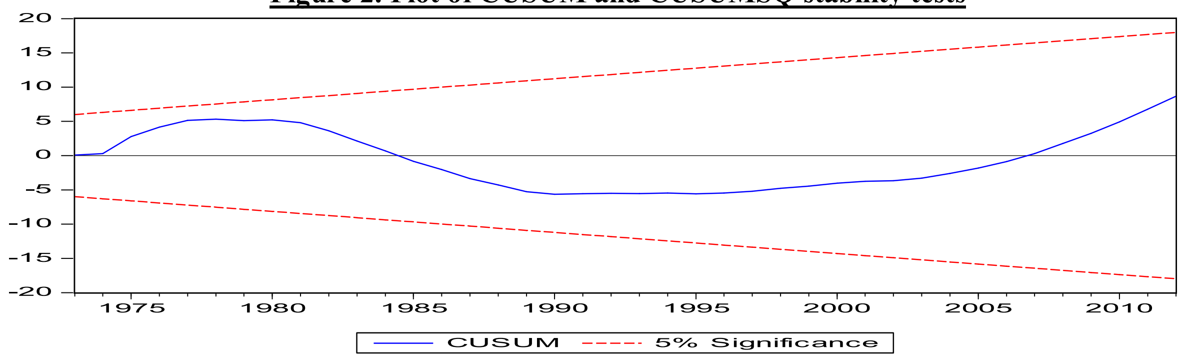
The ZA and Perron unit root tests found different dates of structural breaks. However, this is consistent with some previous empirical results. Lee and Chang (2005) used both ZA and Perron tests to examine the unit root in gas consumption. The results of ZA indicated that there is a significant breakpoint that occurred in 1964 in gas consumption, while the results of Perron test showed that a breakpoint occurred in 1962 for the same series.

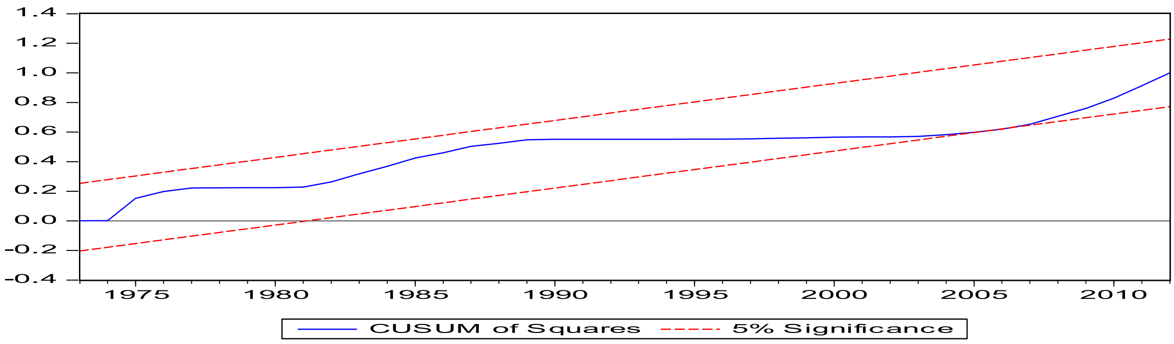
3.2. Cointegration test results

The results of the ZA and Perron unit root tests suggest that we should proceed in our analysis only with variables that are from order one, GDP and oil. Consequently, we should drop total energy and gas consumption from the cointegration and causality analysis. In this section, the long run relationships between GDP and oil consumption are investigated by using both stability and cointegration techniques. Before proceeding with the cointegration analysis, we test the stability of the model by the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests proposed by Brown et al. (1975). Figure 2 shows the plot of CUSUM and CUSUMSQ test statistics for the GDP-Oil model. The results of both tests indicate that the model is stable in the long run, since the test statistics fall inside the critical bounds of 5% significance.

The next step is to investigate the long run relationships between GDP and oil consumption using the cointegration technique, which takes into account a one-time unknown structural break. Perron (1989) indicated that ignoring the presence of potential structural breaks can lead to wrong results not only in the unit root tests but also in the cointegration tests. In addition, Kunitomo (1996) pointed out that the traditional cointegration tests, which don't allow for structural breaks, may lead to spurious cointegration.

Figure 2. Plot of CUSUM and CUSUMSQ stability tests





The results of the GH are reported in Table 4. The results indicate that the null hypothesis of no cointegration is rejected in favor of the existence of one cointegration with a one-time unknown structural break in the GH (C/T) model. The breakpoints are consistent across models. The break date of the year 1975 corresponds with the high oil prices following the Arab oil embargo and the death of King Faisal Al-Saud. In fact, the breakpoint of 1975 could be explained as the full effect of the 1973 oil crisis. If it is possible to determine the exact date of a structural break, the full effect of this structural break would not occur instantly (Enders, p. 106).

Table 4. Gregory and Hansen tests results

	Model	Break date	ADF^*	Break date	Z_t^*	Break date	Z_a^*
	C	1975	-3.865 (0)	1975	-3.88	1975	-22.266
GDP-Oil	C/T	1975	-4.927 (0)*	1975	-4.99*	1975	-31.481
	C/S	1976	-3.932 (0)	1976	-3.899	1976	-21.783

* denotes significance at the 10% level.The number of lag order is shown in parentheses.

3.3. Causality test results

Since there is evidence of cointegration between GDP and oil consumption, we proceed with our analysis by investigating whether there is a causal relationship among both variables. Cointegration implies that causality exists between the GDP and oil consumption, but it does not show the direction of the causal relationship. Granger (1988) indicated that, when there is evidence of cointegration among variables, there should be at least one unidirectional Granger causality among the variables.

The results of short and longrun Granger causalities are presented in Table 5. The ECT is derived from the long run equation (5), which represents the level shift with the trend (C/T) model. A significant ECT with a negative sign suggests that the cointegration relationship established previously is valid as per Granger's representation theorem (Engle and Granger, 1987).

Table 5. Results of Granger causality tests

Null hypothesis	Short-run	Long-run
	F-statistics	t-statistics
$(H_0{:}\alpha_i = 0)$ $\Delta OIL \rightarrow \Delta GDP$	2.22 (0.123)	
$(H_0{:}\ \delta_j = 0)$ $\Delta GDP \rightarrow \Delta OIL$	3.79 (0.032)**	
$(H_0{:}\theta_1 = 0)$ $ECT_{t-1} \rightarrow \Delta GDP$		-1.95* [-0.103]
$(H_0{:}\theta_2 = 0)$ $ECT_{t-1} \rightarrow \Delta OIL$		0.83 [0.065]

*, ** denote the significance at the 10% and 5% levels, respectively. The number of optimal lag is selected by AIC. The numbers in parentheses are probabilities.The numbers in brackets are error-correction coefficients.→ denotes unidirectional causality.

From the GDP equation, the results indicate that there exists one-way long run causality from oil consumption to GDP, as t-test rejects the null of no causality at the 10% significance level. However, no evidence of long run causality is found in the oil equation, as the t-test does not reject the null of no causality. Therefore, there is a unidirectional Granger causality running from oil consumption to GDP, which is consistent with Mehrara (2007b). These results imply that the energy conservation policies in Saudi Arabia may be formulated to conserve energy with much concern about the effects of GDP growth in the long run. Therefore, phasing out the energy subsidies may lead to a negative impact on GDP growth.

The results of the short run Granger causality indicate that causality runs from GDP to oil consumption as the F-test rejects the null of hypothesis of no causality at the 5% significance level in the oil equation. However, there is no evidence of short run causality running from oil consumption to GDP in the GDP equation, since the F-test does not reject the null hypothesis of no causality. Thus, there is a unidirectional short run Granger causality running from GDP to oil consumption, which is consistent with Al-Iriani (2006), Mehrara (2008a), and Chontanawat et al. (2008). These results imply that the energy conservation policies should be formulated to conserve energy without much concern about the effects on GDP growth in the short run.

4. Conclusion

This paper aims to investigate the short and long run causality relations between economic growth and energy consumption for the period of 1971-2012 in Saudi Arabia. Saudi Arabia has an oil-based economy, and fluctuations in the oil prices likely created structural breaks. To take into account the possibility of structural breaks in our analysis, we utilized the unit root tests and the cointegration test that allow for a one-unknown structural break. Also, a dynamic vector error correction models (VECM) are used to examine the causality between economic growth and energy consumption. Different categories of energy were applied as a measure of energy consumption such as total energy, gas, and oil.

The results of the unit root tests, ZA and Perron, indicated that total energy and gas consumption are stationary variables in levels. Both tests showed that the structural breaks occurred in 1977, 1983, and 1984. These breakpoints correspond with the period of the oil boom, 1974-1985. Thus, total energy and gas consumption were dropped from our analysis. The results of the GH (C/T) model showed that the long run relationship exists between real GDP and oil consumption. The GH cointegration tests indicated that the structural break took place in 1975. The breakpoint of the year 1975 corresponds with the high oil prices following the Arab oil embargo andthe death of King Faisal Al-Saud. This breakpoint could be explained as the full effect of the 1973 oil crisis.

This paper finds evidence of one-way long run Granger causality from oil consumption to real GDP. This result implies that an energy conservation policy will hinder the economic growth of Saudi Arabia. Thus, in the long run, the energy conservation policy should be formulated to conserve energy with much concern about the effects on GDP growth. Moreover, one-way short run Granger causality is found from real GDP to oil consumption. This implies that energy conservation may not harm economic growth. Thus, in the short run, the energy conservation policy in Saudi Arabia should be formulated with no caution regarding the effects on GDP.

The future work should be focused on the effect of structural breaks on the relationship between economic growth and energy consumption in GCC countries. Structural breaks are important, and failure to take them into account when analyzing the relationship between economic growth and energy consumption may lead to the wrong results, especially in countries like GCC, which depend heavily on the export of oil and gas.

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