Business and Economics Journal

Aljebrin, Bus Eco J 2014, 5:4
http://dx.doi.org/10.4172/2151-6219.1000124

Research Article Open Access

Revisiting Electricity Consumption Function: the Case of Saudi Arabia

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Received date: November 05, 2014, **Accepted date:** November 29, 2014, **Published date:** December 07, 2014

Abstract

Total electricity consumption in Saudi Arabia is growing steadily and very rapidly. This study empirically estimates the critical parameters of electricity consumption function in Saudi Arabia for the period 1982-2011 by using ordinary least squares (OLS) and error correction model approach. The empirical results obtained show that, in both long run and short run, there are negative and significant relationship between the electricity consumption and electricity price. On the other hand, there is positive and significant relationship between electricity consumption and real income in the long run but insignificant in the short run. The error correction is correctly negatively signed and highly significant but has a small magnitude (-0.106) suggesting a slow adjustment process, which means that, if electricity consumption is 1 percent out of equilibrium, a 10.6 percent adjustment towards equilibrium will take place within the first year.

The results of the this study will lead to some serious policy implications for decision-makers as electricity conservation policies through demand side management, which aim at declining the wastage of electricity without affecting the end-use benefits especially with no adverse effect on economic growth.

JEL Classification: D12, L94, Q41

Keywords: Electricity consumption function; Error correction model; Saudi Arabia

Introduction

Saudi Arabia was the world's largest producer and exporter of total petroleum liquids in 2010, and the world's second largest crude oil producer behind Russia. Saudi Arabian economy remains heavily dependent on crude oil. Oil export revenues have accounted for 80-90 percent of total Saudi revenues and above 40 percent of the country's gross domestic product (GDP). Saudi Arabia is the largest consumer of petroleum in the Middle East, particularly in the area of transportation fuels and direct burn for power generation. Domestic consumption growth has been spurred by the economic boom due to historically high oil prices and large fuel subsidies. In 2008, Saudi Arabia was the 15th largest consumer of total primary energy, of which almost 60 percent was petroleum-based and the rest natural gas.

Thus, total electricity consumption in Saudi Arabia is growing steadily and very rapidly, at an average growth rate of 7.32 percent/year during 1982-2011. Then, the results of the present study is very important, because it will lead to some serious policy implications for decision-makers as energy conservation policies through demand side management, which aim at declining the wastage of electricity without affecting the end-use benefits especially with no adverse effect on economic growth.

This paper attempts to identify the determinants of electricity consumption which enables policy makers from enhancing electricity consumption efficiency to save electricity, diversifying electricity sources, energetically exploiting renewable energy, drawing out corresponding policies and measures and transforming appropriate development pattern.

The paper will be structured as follows: Introduction of the paper will be introduced in. Introduction part. Stylized Facts about Saudi Economy and the Behavior of Electricity Consumption and production in Saudi Arabia provides some stylized facts about Saudi economy and the behavior of electricity power consumption and production in Saudi Arabia. Literature Review presents the theoretical background on which the models are based and also gives an empirical review of the literature. The Model and the Methods discusses the data, evaluates the specifications of the economic models and describes the econometric methodology that will be adopted. Empirical Results reports on the empirical results and Concluding Remarks summarizes the concluding remarks.

Stylized Facts about Saudi Economy and the Behavior of Electricity Consumption and Production in Saudi Arabia

The Saudi economy recorded high growth in 2012 as global economic recovery lifted up oil prices, and enlarged fiscal spending by the government boosted domestic demand and accelerated the growth in non-oil GDP. On the same line, the actual budget recorded a surplus of SAR 374.09 billion or 14 percent of GDP in 2012 compared by a surplus of SAR 291.09 billion or 11.6 percent of GDP in 2011. The ratio of public debt to GDP decreased from 8.5 percent in 2010 to 3.7 percent in 2012. The persistent increase in the current account of the balance of payments recorded a surplus for last the fourteenth years amounting to SAR 617.8 billion or 22.1 percent of GDP in 2012 [1].

Saudi Arabia generated 292.2 billion kilowatt/hours of electricity in 2013, 7% more than in 2012 and more than double the electricity generated in 2000 (World Bank, World Bank Development Indicator). Like many developing countries in the Middle East and North Africa, Saudi Arabia faces a sharply rising demand for electric power. Demand is driven by population growth, a rapidly expanding industrial sector led by the development of petrochemical cities, high demand for air conditioning during the summer months, and heavily subsidized electricity rates. So, Saudi Arabia has the largest expansion plan in the Middle East for generation, with plans to increase generating capacity to 120 GW by 2032 [2]. All existing generating capacity is powered by oil or natural gas, but Saudi Arabia plans to diversify fuels used for generation, in part to free up oil for export. The Saudi Electricity Company (SEC) has plans to reduce direct crude burn for electricity generation by more than 500,000 barrel/day by switching to natural gas [3]. By 2032, Saudi Arabia plans to add 41 GW of solar power, 18 GW of nuclear power, and 4 GW from other renewable sources to expand electricity supply [2].

In this respect, Saudi Arabia plans to increase electricity generating capacity to 120 gigawatts by 2032 to face the country's rapidly growing demand for electric power. Saudi Electricity Company is the largest provider of electric power in the Saudi Arabia, with total available generating capacity of 58 GW [4]. The state-owned Saline Water Conversion Corporation (SWCC), which provides most of the Saudi Arabia's desalinated water, is considered the second-largest generator of electric power. SWCC plans to rapidly increase its desalination capacity, with an equivalent increase in generation capacity. Privately-owned independent water and power plants also provide electricity to the grid. Saudi Aramco continues to build cogeneration plants to generate power for its own needs at various oil facilities.

Saudi Arabia is moving to create a more competitive power market through a series of physical and regulatory changes. In 2013, the Electricity and Cogeneration Regulatory Authority (ECRA) allowed Saudi Aramco to sell any excess electricity it produced through the intermediary of SEC [5]. According to ECRA, Saudi Arabia has to invest about $140 billion through 2020 to increase SEC generating capacity to 71 GW and to satisfy increasing electricity demand [5].

In an attempt to privatize the electricity market, ECRA hired HSBC Holdings to explore splitting SEC into four separate power generation companies in 2014. Physical improvements will also be needed to allow more companies to sell electric power to the grid. SEC also has planned projects that will link power plants in the western, eastern and southern portions of the country together. In order to face peak demand requirements, Saudi Arabia participates the Gulf Cooperation Council the efforts to link the electric power grids of other the five Gulf Cooperation Council member countries. Saudi Arabia has also discussed a 3 GW cable link with Egypt, whose peak electricity demand hours vary from those of Saudi Arabia. The power link is estimated to cost $1.6 billion and bidding for the project is expected to begin in 2015.46 Expansions to the power grid will allow Saudi Arabia to improve access to back up power generation from renewable sources [6].

In this respect, as it shown in Figure 1, there has been a significant increase in total electricity consumption of 29.18 million megawatts/h in 1982 to 226.57 million megawatts/h in 2011. Thus, the electricity consumption function has been an important subject of empirical and theoretical researches in Saudi Arabia although the increase of electricity production. These researches should highlight the significance of the economic factors that influencing the behavior of electricity consumption, such as gross domestic product (GDP) and electricity consumer prices.

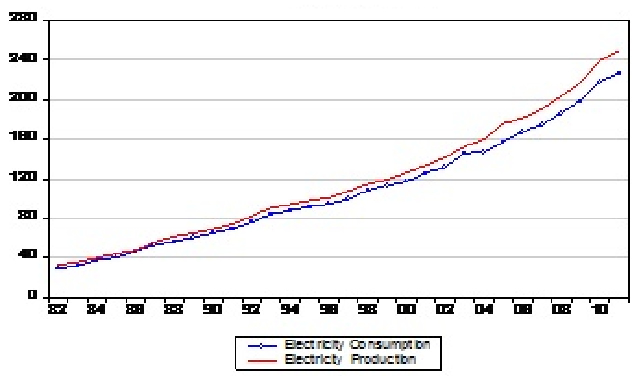

Figure 1: Electricity consumption and production in Saudi Arabia 1983-2011 (million megawatts).

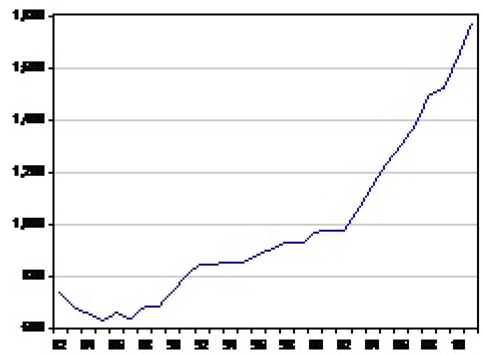

Figure 2: Real gross domestic product in Saudi Arabia 1983-2011 (2005 constant prices only).

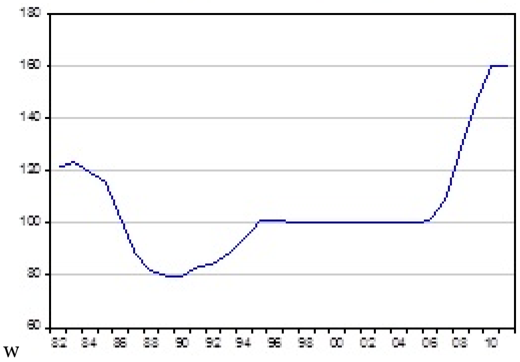

Figure 3: Energy consumer price index in Saudi Arabia (2005-100).

The Figures 1 and 2 indicate that there are similar directions among electricity consumption, electricity production and real gross domestic product with the exception of energy consumer price index in Figure 3, which takes different direction.

Table 1 indicates that electricity consumption growth rate during 1982-1991 was 9.01 percent and it is little more than the growth rate of electricity production which during the same period was 8.44%. This slight difference continued during the next two periods 1992-2001 and 2002-2011. But during the whole period 1982-2011 the difference fell to 0.08% which has increased the need to search for solutions to control electricity consumption, increasing production and decreasing electricity transmission and distribution losses which increased by 6.33% during the period 1982-2011, this also highlights the need to search for new and renewable energy sources.

Electricity Transmission and Distribution Losses (%)	Electricity production (%)	Electricity Consumption (%)	Period
2.7	8.44	9.01	1982-1991
7.58	4.53	5.19	1992-2001
9.11	5.04	5.56	2002-2011
6.33	6.99	7.07	1982-2011

Table 1: Electricity Consumption and Production growth rates in Saudi Arabia (1982-2011).

Figure 4 indicate that during the period (1982-2011) electricity production from natural gas increased from 49% to 55% on the expense of electricity production from oil which decreased from 41% to 33%, that is considered more desirable because the production of electricity from natural gas is less harmful to the environment.

1982 2011

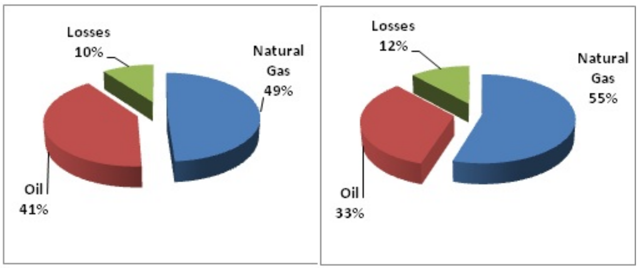

Figure 4: The Structure of Electricity Production 1982-2011.

Literature Review

Energy consumption has been analyzed extensively on a national and international basis since the early 1980s, electricity consumption as one of the types of energy consumption has been analyzed within the most studies that undertaken of energy consumption. The primary exercise in most electricity use analysis is to determine income and price elasticities of electricity consumption, so that meaningful forecasts or policy simulations can be performed. These studies typically analyze the long-term and short-term impact of energy prices and GDP on aggregate consumption or consumption per capita of one or more fuels, in individual sectors or over the whole economy.

There is an impressive body of literature on the relationship between energy or electricity consumption and economic variables. Research on this issue has primarily been aimed at providing significant policy guideline in designing efficient electricity use conservation policies. Labandeira et al. [7] use high-quality micro data on electricity consumption to propose a method to calculate price elasticity of demand when information on other economic variables is incomplete or missing, even though, again, the discrete decision on the purchase of durables is not contemplated. Ibrahim [8] presented an empirical analysis of the interactions among energy consumption, real income and energy price in Saudi Arabia using annual data from 1982 to 2007, the paper analyzed the dynamic interaction by applying widely used time series analysis techniques such as unit root tests, Vector Autoregressive model, Granger causality tests, impulse response functions and the forecast error variance decompositions, results show that real income and energy consumption are clearly Granger causal for energy price, and there is bidirectional causality between energy consumption and income. The paper also found that energy price isn't a Granger causal for either energy consumption or real income. Thus, real income can play an important role in policy that targeting to enhance the energy efficiency to save energy in Saudi Arabia.

Adom [9] found evidence of uni-directional causality running from economic growth to electricity consumption, thus supporting the growth-led energy hypothesis in Ghana. The nexus between energy consumption and economic growth in Vietnam examined by Binh [10], he found a cointegrated relationship between energy consumption and economic growth. He also found evidence of uni-directional causality running from electricity consumption to economic growth. Lean and Smyth [11] investigated the causal relationship between aggregate output, electricity consumption, exports, labor and capital in a multivariate model for Malaysia. They found evidence in support of bi-directional causality between aggregate output and electricity consumption and export- led growth hypothesis in Malaysia.

Francis et al. [12] found a long run relationship between electricity consumption and economic growth in Barbados. Yoo and Kwak [13] found long run relationship between electricity consumption and economic growth in Venezuela and Columbia. Payne [14] surveyed the literature on causal relationship between electricity consumption and economic growth and concluded the evidence on causal relationship between electricity consumption and economic growth is mixed. His analysis showed that 31.15% of studies supported the neutrality hypothesis, 27.87% of the studies supported conservation hypothesis; 22.95% supported the growth hypothesis; and 18.03% supported the feedback hypothesis Chandran et al. [15] investigated the relationship between electricity consumption and growth in Malaysia, including price. They found a long run relationship between the variables. Lean and Smyth [16] applied Johansen Fisher panel cointegration test and found a long run relationship between carbon dioxide emission, electricity consumption and output in ASEAN countries. Ciarreta and Zarraga [17] applied panel data methodology to examine the long run relationship between economic growth and electricity consumption in 12 European countries. Their study included energy prices as an additional variable and found evidence that three series move together in the long run. Smyth and Lean [16] used time series data from 1970-2008 to study the causal relationship between economic growth, electricity generation, prices and exports. They found a uni-directional causality running from economic growth to electricity consumption.

Akinlo [18] found evidence of long run relationship between electricity consumption and economic growth. Yoo [19] did not find any evidence of cointegration between electricity consumption and economic growth in ASEAN countries. Tang [20] investigated the relationship between electricity consumption and economic growth in Malaysia and also did not find any evidence of cointegration. Narayan and Smyth [21] found positive effects of electricity consumption and exports on output in a panel of six Middle Eastern Countries. Abosedra et al. [22] found long run relationship between electricity consumption and real GDP. Odhiambo [23] found that electricity, employment and economic growth in South Africa.

Narayan and Singh [24] found that electricity consumption, employment and real GDP are cointegrated in Fiji. Ho and Siu [25] found a long run relationship between electricity consumption and GDP for Hongkong. Mozumder and Marathe [26] found that there is unidirectional causality from per capita GDP to per capita electricity consumption in Bangladesh. Mozumder and Marathe [26] investigated electricity consumption and GDP from 1971-1999 in Bangladesh; Mehrara [27] investigated the energy consumption and economic growth data of 11 oil exporting countries from 1971-2002; and so on the Contrary to the above, some studies found that there is unidirectional causal relationship that runs from energy consumption to output. Erdogdu [28] investigated short and long run price and income elasticities of electricity demand in Turkey. The estimated elasticities indicated that the price and income elasticities of electricity demand in Turkey are quite low, meaning that there is definitely a need for economic regulation in Turkish electricity market. Otherwise, since consumers do not react much especially to price increases, the firms with monopoly power (or those in oligopolistic market structure) may abuse their power to extract “monopoly rent”.

Squalli [29] found a long run relationship between electricity consumption and economic growth for all Organization of Petroleum Exporting Countries using bound tests. The author also found evidence of importance of electricity consumption for economic growth in Indonesia, Iran, Qatar, Venezuela and Nigeria.

Chen et al. [30] use GDP and electric power consumption data of Asia’s 10 newly industrialized countries (NICs) over the period from 1971 to 2001. Yuan et al. finds that electricity consumption and economic growth are cointegrated. Wolde-Rufael [31] finds mixed evidence on causal relationship between electricity consumption and real GDP per capita.

Altinay and Karagol [32] found a uni-directional causality running from electricity consumption to GDP for Turkey. Narayan and Smyth found that electricity consumption, employment and real income are cointegrated. Lee and Chang [33] found similar evidence for Taiwan. Other studies have found evidence of unidirectional running from economic growth to electricity consumption. These included Ghosh [34] for India, Hatemi and Irandoust [35] for Sweden. Other studies have found evidence of uni-directional causality running from electricity consumption. Shiu and Lam [36] found that electricity consumption and economic growth in china are cointegrated.

Wolde-Rufael [37] found that over the period from 1952 to 1999 energy consumption in Shanghai Granger causes GDP. Morimoto and Hope [38] came up with the same outcome on Sri Lankan data from 1960 to1998 that electricity production causes economic growth. Soytas and Sari [39] investigated G-7 and 10 emerging economy’s data except China and find bi-directional causal relationship between per capita GDP and energy consumption in Argentina over the period from 1950 to 1990. However, in the same study they found two different results for other countries. In case of Italy, from 1950 to 1992 and Korea, from 1953 to 1991 they found that causality runs from GDP to energy consumption, whereas the opposite was found in case of Turkey, Germany, France and Japan over the period from 1950 to 1992. Other studies that also came up with same conclusions are Asafu-Adjaye [40] and Wolde-Rufael [31]. Masih and Masih [41] investigated causal link between energy and output for Korea and Taiwan over the period from 1955 to 1991 and 1952 to 1992 respectively and concluded that there is bi-directional causal relationship between these variables.

From the above discussion some important conclusions can be drawn. First, the relationship between energy or electricity consumption and economic growth or energy or electricity price is not unique. Second, different studies use different measures of energy. Third, in most of these studies time series property of underlying variables has not been considered properly. Fourth, studies identifying both short- and long-run causality between energy consumption or electricity consumption and income or price are limited. The present article is an attempt to overcome some of these deficiencies in the earlier studies. It differs from previous studies on the following ground: to the author's knowledge this is a paper considering electricity consumption function in a largest producer and exporter country of oil.

The Model and the Methods

This paper employs Ordinary Least Squares (OLS) technique for estimating electricity consumption determinants in Saudi Arabian economy during the period 1982-2011.

The representation of OLS with respect to our variables is as given:

$$Log(EL_t) = C_0 + C_1 Log(RGDP_t) + C_2 Log(EP_t) + \xi_t \quad (1)$$

Where:

(EL) electricity consumption.

(RGDP) real income.

(EP) electricity price (represented by energy price consumer index)

We sourced data for the study from World Development Indicators and Saudi Arabian Monetary Agency (SAMA) [1]. All variables were transformed into natural logarithm in order to avoid the problem of heteroscedasticity and obtain elasticities.

If the three variables are cointegrated, they can be represented equivalently in terms of a short run OLS framework. The most common procedure to test for cointegration is the Engle-Granger two-step estimation technique (EG). The first step in this method implies fitting the long-run relationship in levels by OLS and using the resulted residuals to test the hypothesis of cointegration by applying the ADF test. If the hypothesis of cointegration is accepted, then there exists an error correction representation [42]. Then, the next step is to construct the Error Correction Model, which represents the short-run dynamics.

$$\Delta Log(EL_t) = C_0 + C_1 \Delta Log(RGDP_t) + C_2 \Delta Log(EP_t) + C_3 ECT_{t-1} \quad (2)$$

Johansen and Julesius [43] developed Another procedure to test cointegration which is known as the maximum likelihood (ML) approach. According to this method we estimate and test for multiple

Citation: Aljebrin M (2014) Revisiting Electricity Consumption Function: the Case of Saudi Arabia. Bus Eco J 5: 124. doi: 10.4172/2151-6219.1000124

cointegrating vectors (multivariate cointegration). It applies the analysis of the vector auto-regressive (VAR) model where all variables are treated as endogenous variables.

The existence of short run relationship can be known by the sign and significance of the coefficient of error correction term ECTt-1. Its sign and value tell us about the speed and divergence or convergence from or to the long run equilibrium. The negative value indicates about the convergence whereas the positive value indicates about the divergence. A significant coefficient of error correction with negative sign is considered as a further proof of the existence of stable long run relationship.

Empirical Results

Providing evidence as to whether the variables are stationary and integrated of the same order, Augmented Dickey- Fuller (ADF) test is calculated for individual series. The results for each variable appear in Table 2. To eliminate the serial correlation in residual, the lag parameter in ADF test is selected by Akaike information criterion (AIC). Table 2 indicates that, the null hypothesis of a unit root can't be rejected for levels of all variables but the null hypothesis is rejected for the first differences of all variables. Then, we conclude that the series are integrated of order one.

		ADF
Log(EL)	Level	-0.70579
	First Diff.	-4.261286a
Log(RGDP)	Level	2.304373
	First Diff.	-3.524070b
Log(P)	Level	-1.90058
	First Diff.	-2.708517b

Table 2: Unit root test. Notes: ADF-Dickey DA, Fuller WA [44] unit root test with the Ho: Variables are I (1); a, and b indicate significance at the 1% and 5% levels respectively.

Cointegration analysis refers to the process of getting equilibrium or long-run relationships among non-stationary variables. The idea is that although the variables are non-stationary, a linear combination of them may be stationary, given that all variables are integrated of the same order [42]. The vector that links the variables in the long-run relationship is called the cointegrating vector.

The estimated OLS Model is:

$$Log(EL_t) = 15.14 + 2.18 * Log(RGDP_t) - 1.03 * Log(EP_t) + \xi_t \quad (3)$$

Table 3 illustrates the ADF test result for residual which indicates that the residual is integrated at 5% level, so the hypothesis of cointegration is accepted, then there exists an error correction representation.

	Level
ECT	-3.031936b

Table 3: ADF unit root test for residual. b indicates significance at 5% level.

Tables 4 and 5 illustrate the Likelihood Ratio tests results which based on the Maximum Eigen value and the Trace of the stochastic matrix respectively. The results of both tests confirm the existence of two cointegrating vectors between the variables, which means that there is a long-run relationship between them.

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.606627	50.94503	29.79707	0.0001
At most 1 *	0.518288	22.95515	15.49471	0.0031
At most 4 *	0.034165	1.042857	3.841466	0.3072

Table 4: Cointegration test based on Trace of the Stochastic Matrix. Trace test indicates 2 cointegrating eqn (s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level.

Hypothesized No. of CE(s)	Eigen value	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.606627	27.98987	21.13162	0.0046
At most 1 *	0.518288	21.91229	14.26460	0.0026
At most 4 *	0.034165	1.042857	3.841466	0.3072

Table 5: Cointegration test based on Maximal Eigen value of the Stochastic Matrix. Max-eigen value test indicates 2 cointegrating eqn(s) at the 0.05 level.* denotes rejection of the hypothesis at the 0.05 level.

Since the three variables are cointegrated, they can be represented equivalently in terms of a short run OLS framework. Then, the next step is to construct the Error Correction Model, which represents the short-run dynamics.

$$\Delta Log(EL_t) = 0.074 + 0.006 * \Delta Log(RGDP_t) + -0.307 * \Delta Log(EP_t) - 0.106 * ECT \quad (4)$$

The robustness of the model has been definite by several diagnostic tests such as Breusch- Godfrey serial correlation LM test, ARCH test, White Heteroskedasticity Test and Jacque-Bera normality test. All the tests disclosed that the model has the aspiration econometric properties, it has a correct functional form and the model's residuals are serially uncorrelated, normally distributed and homoskedastic. Therefore, the outcomes reported are serially uncorrelated, normally distributed and homoskedastic. Hence, the results reported are valid for reliable interpretation.

The stability of the long-run coefficient is tested by the short-run dynamics. Once the ECM model given by equation (4) has been estimated, the cumulative sum of recursive residuals (CUSUM) and the CUSUM of square (CUSUMSQ) tests are applied to assess the parameter stability [45]. Figure 5 plot the results for CUSUM and CUSUMSQ tests. The results indicate the absence of any instability of the coefficients because the plot of the CUSUM and CUSUMSQ statistic fall inside the critical bands of the 5% confidence interval of parameter stability.

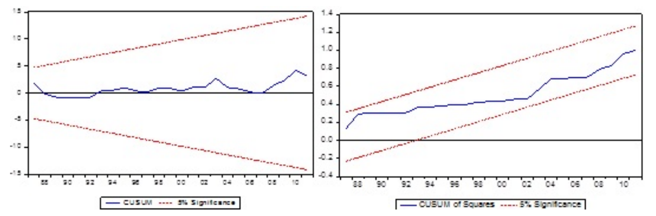

Figure 5: Parameters Stability Tests of Short-run Model.

The error correction is correctly negatively signed and highly significant but has a small magnitude (-0.106) suggesting a slow adjustment process, which means that, if electricity consumption is 1 percent out of equilibrium, a 10.6 percent adjustment towards equilibrium will take place within the first year.

Table 6 summarizes the empirical results of the long run and short run OLS estimates, these results obtained show that, in both short run and long run, there are negative and significant relationship between the electricity consumption and electricity prices. On the other hand, there is positive and significant relationship between electricity consumption and real income in the long run but insignificant in the short run. The short and long run elastic price relationship of electricity demand indicates that use of price increases will be effective tool for electricity conservation. The long run income elasticity indicate that any potential future income increases will result in significant increases in the demand for electricity.

Variable	Coefficient	
	Long Run	Short Run
C	15.13738a	0.073654a
log(RGDP)	2.175312a	0.005527
log(EP)	-1.026081a	-0.306821a
ECT(-1)	-	-0.105975b

Table 6: OLS estimates for the long run and short run (1982-2011).

- a and b denotes significance level at 1% and 5% respectively.

Concluding Remarks

Total electricity consumption in Saudi Arabia is growing steadily and very rapidly, at an average growth rate of 7.32 percent/year during 1982-2011. So, this study is very important to know the electricity consumption determinants in Saudi Arabian economy. This study empirically estimates the critical parameters of electricity consumption function in Saudi Arabia for the period 1982-2011 by using ordinary least squares (OLS) and error correction model approach [46-52]. The empirical results obtained show that, in both long run and short run, there are negative and significant relationship between the electricity consumption and electricity prices. On the other hand, there is positive and significant relationship between electricity consumption and income in the long run but insignificant in the short run. The error correction is correctly negatively signed and highly significant but has a small magnitude (-0.106) suggesting a slow adjustment process, which means that, if electricity consumption is 1 percent out of equilibrium, a 10.6 percent adjustment towards equilibrium will take place within the first year.

The results of the this study will lead to some serious policy implications for decision-makers as electricity conservation policies through demand side management, which aim at declining the wastage of electricity without affecting the end-use benefits especially with no adverse effect on economic growth. Saudi Arabia should speed moving to create a more competitive power market through a series of physical and regulatory changes, privatizing the electricity market, increasing electricity generating capacity, enhancing electricity consumption efficiency to save electricity, diversifying electricity sources by exploiting renewable energy, drawing out corresponding policies and measures and transforming appropriate development pattern.

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