Short-run and Long-run causality between electricity consumption and economic growth in a small open economy

HAMDI, Helmi and SBIA, Rashid

Aix-Marseille University CERGAM (4525), France, DULBEA, Solvay Brussels School of Economics and Management, Belgium

2012

Short-run and Long-run causality between electricity consumption and economic growth in a small open economy

Helmi HAMDI[a]*, Rashid SBIA[b]

[a] Aix-Marseille University CERGAM (4525), France
Corresponding author: helmi_aix@yahoo.fr, Tel +973.36003466
[b] DULBEA, Solvay Brussels School of Economics and Management, Belgium

Abstract

The aim of this paper is to investigate the causal relationship between electricity consumption and GDP growth for the kingdom of Bahrain during the period 1980–2008. By performing an error-correction model, our results reveal that electricity consumption and GDP are cointegrated. The granger causality tests indicate bi-directional relationship between electricity consumption and GDP growth in the long-run while results of the short-run reveal unidirectional causality relationship between the two variables.

Keywords: Electricity consumption, Growth, Bahrain, cointegration, Granger causality
JEL Classification Codes: O13; Q43; C33

1. Introduction

Since the mid-eighties and especially following the second oil shock, there has been a great deal of attention devoted toward the importance of energy in the economy. Hence, several researches have been conducted to study the relationship between energy consumption and economic growth. Some studies have been focused on carbon dioxide emission and its consequences on economic growth while some others have investigated whether electricity consumption increases the output. Studies have analyzed the energy-growth nexus for different countries and regions around the world by the use of different econometric techniques (ECM, ARDL, VAR, OLS-EG, DOLS, FMOLS, etc). The earliest study was conducted by Kraft and Kraft in 1978 in which authors have provided evidence to support unidirectional causality running from income to energy consumption for the United States from 1947-1974 periods. Since this study established, many authors have joined the debate, some who have opposed and empirically challenged Kraft and Kraft's initial findings; and others who have supported their views (Nanthakumar and Subramaniam, 2010).

In general, divergence in findings could be summarized into four different stands. The first range of study finds bidirectional causality between energy consumption and economic growth (Jumbe, 2004; Ghali and El-Sakka, 2004; Wolde-Rufael, 2005). The second range finds unidirectional causality from economic growth to energy consumption (Kraft and Kraft, 1978; Cheng and Lai, 1997; Chang and Wong, 2001; Soytas and Sari, 2003 and Narayan and Smyth, 2008) while the third range finds unidirectional causality from energy consumption to economic growth. Finally the fourth range finds no causal relationship between energy consumption and economic growth (Akarca and Long, 1980; Yu and Choi, 1985; Erol and Yu, 1988; Stern, 1993). The aim of this paper is to test the causal relationship between electricity consumption and economic growth for a small open economy named the kingdom of Bahrain. In fact, during the past decade the government of Bahrain has intensified the structural reforms in order to improve the infrastructure of the kingdom as well as the well being of Bahraini citizens. Bahrain has become an open-ended economy with liberalized trade and capital account. It has also become the hub of international affairs and the preferred destination for investors. Consequently, the economy has known an unprecedented dynamism, population has been grown drastically and projects have been multiplied. Following this performance, energy consumption has increased drastically and electricity is becoming a driver of the local economy. Electricity has been a principal source of the increase in the standard of living of Bahraini citizens and it has played a crucial role in the technological and scientific advancement of the kingdom.

The goal of this paper is to investigate the short-run and long-run causal relationships between energy consumption and economic growth for the case of Bahrain using the time series data and modern econometrics techniques. For this study, the variable electricity consumption (kWh per capita) and per capita real GDP (constant 2000 US $) have been considered as the proxies for energy consumption and economic growth. The testing procedure involves the following steps. At the first step whether each variable contains a unit root will be examined. If the variables contain a unit root, the second step is to test whether there is a long-run cointegration relationship between the variables. If a long-run relationship between the variables is found, the final step is to estimate error correction model in order to infer the Granger causal relationship between the variables. Finally using an appropriate method the long-run and short-run elasticities of economic growth with respect to electricity consumption will be estimated. The reminder of the paper is as follows: section 2 presents an overview on energy supply in Bahrain, section 3 presents the econometric methodology, data and results and section 4 concludes.

2. Electricity in Bahrain

Nowadays the electricity infrastructure is becoming a central component of the economy for many reasons. Firstly, as Bahrain is the center of finance in the Gulf Cooperation Council (GCC) region, electricity is an essential factor for the effectiveness of the banking and financial sector. Secondly, Bahrain is moving toward an industrial based economy to diversify its economy and to shrink its dependency to oil, thus electricity is becoming and important factor for achieving this goal. Thirdly, Bahraini households are among the highest users of information and communication technology (ICT henceforth) in Arab countries (WTI 2011). Bahraini households become dependent on ICT such as Internet and broadband and other technologies such as cell phones, personal computers, digital video recorders, digital music players, etc. Hence; electricity is the first element of the knowledge based society in Bahrain. The role of electricity in the economy of Bahrain seems to be crucial; thus it is worth to investigate whether electricity consumption contribute to economic growth in order to make appropriate energy policies. The kingdom of Bahrain disposes of five electric generation plants namely: Manama power station (Gas Turbine), Muharraq power station (Gas Turbine), Sitra power and water station (Gas Turbine and Steam Turbine), Riffa power station (Gas Turbine), Hidd power and water station (Gas Turbine and Steam Turbine). The total electric generating capacity is around 2.9 Giga watts. To face the growing demand and to avoid recurrent power failure during the peak summer months[1], the kingdom supported independent projects (IPPs) and engaged in privatization process of some state-owned power sector assets. Al Ezzel plant is the first output of this initiative. It has started commercial operation in 2006. Al DDur plant is another example. It is planned to operate in two phases. The first one was finalized in 2011 and the second phase has been launched in the current year. According to the Electricity & Water authority, installed capacity is composed by 4 types:

1- Dual Fuel Gas Turbine with 37.9% of the total capacity;
2- Diesel Fuel Gas Turbine with 1.6%;
3- Steam Turbine with 20%;
4- Gas Fuel Turbine

It is clear that Bahrain rely much more on gas in its power generation. However, gas reserves are systematically declining. Therefore, the issue of gas exhaustion is inevitable. With the present demand and supply patterns of gas consumption, there will be a shortage of gas in the near future.

The government is fully aware of the significance of the gas issue and is pursuing various options to secure sources of gas imports. Currently, none of the import options seems to offer clear scenarios. The major part of electricity generation will continue to be based on natural gas. It is important to mention that The Gulf Cooperation Council (GCC) drew plans for a unified power grid in 2004. The first phase of the project was completed in 2009, linking the grids of Saudi Arabia, Qatar, Bahrain, and Kuwait. The remaining GCC members, United Arab

1 In summer of 2004 a one-day countrywide power failure occurred due to mismanagement of power flow.

Emirates and Oman are expected to be fully integrated into the grid by the mid of 2012. This project aims to secure power supply in GCC countries even in cases of emergencies, while reducing the cost of power generation in member countries. Electricity is becoming a main concern for the kingdom of Bahrain and the GCC region as whole. Does electricity contribute to economic growth of the kingdom?

3. Empirical Results

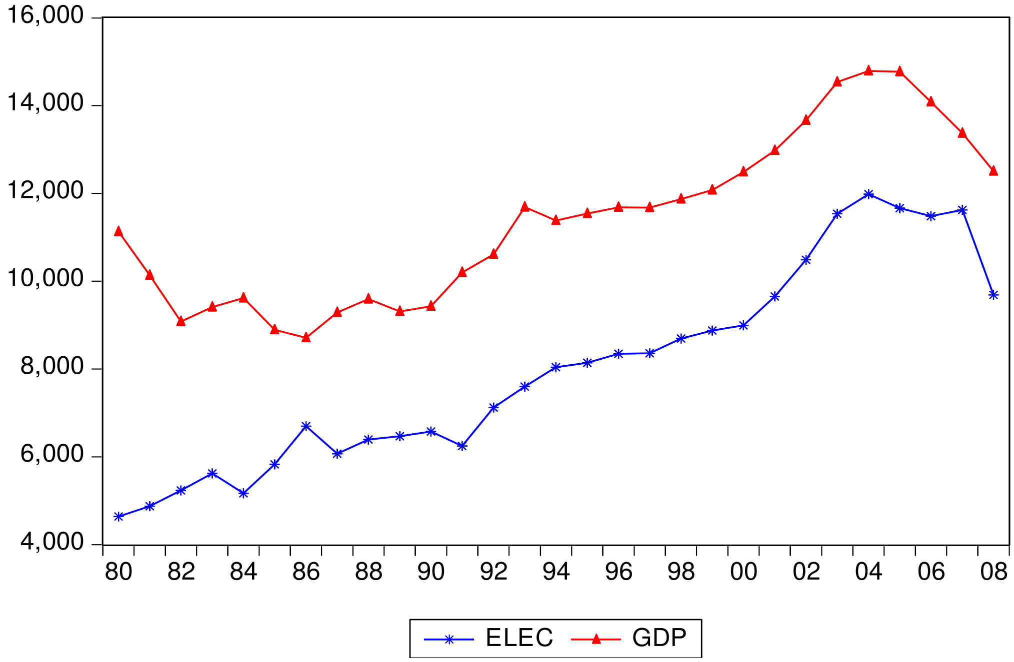
The empirical study is based on annual data from 1980 to 2010 from the World Bank Development Indicators (WDI). Table 1 summarizes the main statistics associated with Electricity consumption per capita (Kwt) and GDP per capita (constant 2000 USS) in the kingdom of Bahrain.

Table 1. Statistical table

	ELEC	GDP
Mean	8003.613	11398.04
Maximum	11984.94	14788.89
Minimum	4637.429	8710.786
Std. Dev.	2274.783	1894.690
Observations	29	29

The average electricity consumption per capita is 8003.61 Kwt with a maximum of 11984.94 Kwt in 2004 and a minimum of 4637.43 Kwt in 1980. In Bahrain, electricity consumption per capita grows at an astonishing rate and statistics show that it has doubled in less than twenty years (from 4637.43 Kwt per capita in 1980 to 8875.75 Kwt per capita in 1999). Regarding, GDP per capita, the mean is 11398.04 dollar, with a maximum of 14788.89 dollar and a minimum of 8710 dollar. The Graph 1 below illustrates the trajectory of the two indicators (before logarithm taking) during the period of our study.

Graph 1. The trajectory of GDP and Electricity Consumption since 1980



Souce: WDI

Our empirical investigation has two dimensions. The first is to examine the long-run relationship between electricity consumption and while the second is to examine the short-run dynamic causal relationship between the 2 variables. The basic testing procedure requires three steps.

1) The first step is to test whether the variables contain a unit root to confirm the stationarity of each variable (Engle and Granger, 1987). This is done by using the Augmented Dickey–Fuller tests (F-ADF) (Choi, 2001) and Philips–Perron (PP) tests (1998).

2) The second step is to test whether there is a long-run cointegrating relationship between the variables. This is done by the use of the Johansen-Fisher methods.

3) Finally, the last step, if all variables are I(1) (integrated of order one) and cointegrated (Masih and Masih, 1996), short-run elasticities can be computed using the vector error correction model (VECM) method suggested by Engle and Granger (1987). In this case, an error correction mechanism exists by which changes in the dependent variables are modeled as a function of the level of the disequilibrium in the cointegrating relationship, captured by the error-correction term (ECT), as well as changes in the other explanatory variables to capture all short-term relations among variables.

3.1 Unit Root test: Augmented Dickey Fuller and Phillips Perron

We use the Augmented Dickey–Fuller (F-ADF) and Philips–Perron (PP, 1998) unit root tests. The results are displayed in Table 2. The test statistics for the log levels of Electricity and GDP are statistically insignificant. When we apply the unit root tests to the first difference of the two variables, both tests reject the joint null hypothesis for each variable at the 1 per cent level. Thus, from all of the tests, the unit roots tests indicate that each variable is integrated of order one.

Table 2: Results of the Unit Roots Tests for Bahrain

	ADF		**PP**		**Order of Integration**
	level	1st diff,	level	1st diff,	
LELECpc	-1.6854	-4.5637***	-1.7294	-4.4874***	I(1)
LGDPpc	-0.6704	-3.5515***	-0.8674	-3.4675***	I(1)

*** Denotes the rejection of the null hypothesis at 1%level of significance

After checking the integration of our four variables at order one, I(1), we selected the optimal lag length of underlying Vector Auto Regression (VAR henceforth) using the conventional model selection criteria. These criteria established that the optimal lag length is one.

The cointegration tests (Trace test and Max-Eigen value) suggest the existence of one cointegrating vectors at 1% of significance.

Table 3. Results for Johansen cointegration tests

Hypothesized	Trace	Max-Eigen
No. of CE(s)	Statistic	Statistic
None *	21.02689***	18.25522**
At most 1	2.771664	2.771664

Trace test and Max-eigen statistics indicate 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

3.2 Long run and short run

Broadly, the existence of cointegration signifies that there is at least one long-run equilibrium relationship among the variables. In this case, Granger causality exists among these variables in at least one way (Engle and Granger, 1987). The VECM is used to correct the disequilibrium in the cointegration relationship, as well as to test for long and short-run causality among cointegrated variables. The correction of the disequilibrium is done by the mean of the Error correction term (ECT).

To test for causality, a VECM is specified as follows:

$$\Delta LELECpc_t = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta LELCpc_{t-i} + \sum_{i=1}^{q} \beta_{1i} \Delta LGDPpc_{t-i} + \lambda_1 ECT_{t-1} + \mu_{1t} \quad (1)$$

$$\Delta LGDPpc_t = \alpha_2 + \sum_{i=1}^{p} \beta_{2i} \Delta LGDPpc_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta LELECpc_{t-i} + \lambda_2 ECT_{t-1} + \mu_{2t} \quad (2)$$

Where ECT is expressed as follows:

$$ECT_t = LELECpc_t - \beta_0 - \beta_1 LGDPpc_t \quad (3)$$

Where *t=1..T,* denotes the time period

The results of the long-run equilibrium relationship are presented in table 4 below. It shows that the coefficient of *LGDPpc* is 1.56 which is positive and significant at the level of 1%. It means that a 1% increase in per capita real GDP will increase electricity consumption by 156% in the long- run.

Table 4. Long-run elasticities

Dependent Variable: ***LELECpc***		
Regressors	coefficients	t-value
LGDPpc	1.56	-12.593***

*** Denotes the rejection of the null hypothesis at 1% level of significance.

Table 5 illustrates the result**s** only in which DLGDPpc is the dependent variable. Since the optimal lag length was one, the short-run results are also presented for only one lag of each variable. These results seem interesting in the sense that all the coefficients are not statistically significant at conventional level of significance This means that in short-run, electricity consumption does not contribute significantly to per capita GDP.

Table 5. ECM results based on Johansen cointegration

Error Correction:	**coef**	**t-value**
Δ (LLEC(1))	0.060016	0.27021
Δ (LGDPCP(1))	0.217832	0.87165
C	0.021903	1.49420
ECT	-0.387020	-3.00268

Table 6 illustrates the results of the tests on causality. We have performed three Granger causality tests: short-run causality, long-run causality and the joint short and long run. The first test indicates the significance of the sum of lagged terms of each explanatory variable by the mean of joint Fisher test; the second test indicates the significance of the error correction term by the mean of the t-test and finally the third test is the short-run adjustment to restore the long-run equilibrium.

Table 5: Results of the causality tests for Bahrain

Variable	*Short run (F-stats)*		***ECT*** *(t-stats)*	*Joint short and long run (F-stats)*	
	ΔLGDPpc	***ΔLELECpc***		***ΔLGDPpc & ECT***	***ΔLELECpc & ECT***
ΔLGDPpc	-	4.077**	0.189**	-	6.275***
ΔLELECpc	0.759	-	-0.387***	4.829***	-

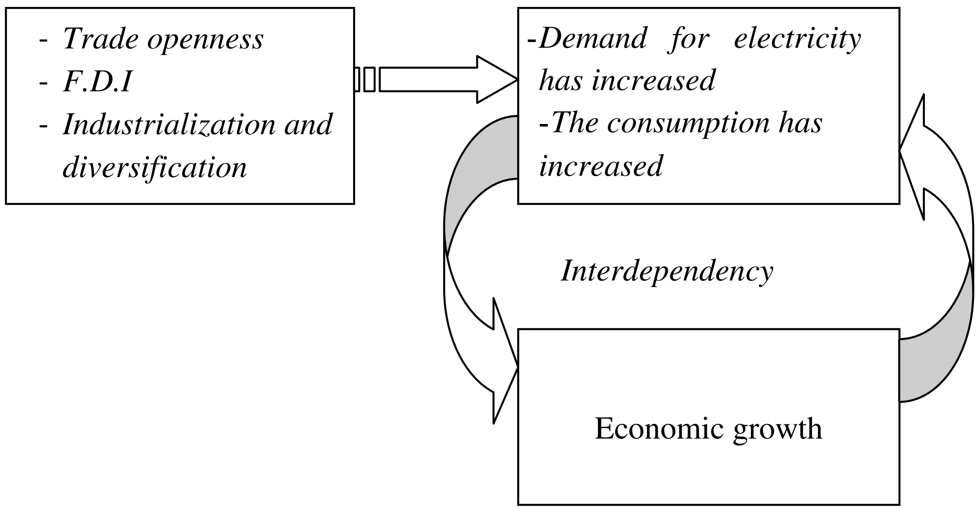
, * Denote the rejection of the null hypothesis at 5%, 1% level of significance, respectively.

Short-run causality is found only from electricity consumption to GDP, but not the reverse. Hence, there is unidirectional Granger causality. The coefficient of the ECT is found to be significant in the real GDP equation and the electricity equation alike. Results of the significance of interactive terms of change in electricity consumption (Δ*LELEC*), along with the ECT in the GDP equation are consistent with the presence of Granger-causality running from electricity consumption to real GDP. These indicate that whenever there is the presence of a shock to the system, electricity consumption would make short-run adjustments to re-establish long-run equilibrium. Moreover, Results of the significance of interactive terms of change in gdp ($\Delta LGDP$), along with the ECT in the electricity equation are consistent with the presence of Granger-causality running from electricity consumption to real GDP. These indicate that whenever there is the presence of a shock to the system, electricity consumption would make short-run adjustments to re-establish long-run equilibrium. Hence, we confirm the presence of bidirectional Granger causality in the long run.

4. Concluding remarks and policy implications

The paper studies the dynamic relationship between electricity consumption and GDP growth in the Kingdom of Bahrain for the period 1980 to 2008. We used a time series analysis based on ECT estimation. First set of tests show the existence of a cointegration relationship and results of the long-run elasticities demonstrate that GDP per capita is positively and significantly linked to per capita electricity consumption. Results of the granger causality tests indicate a bidirectional relationship running from electricity consumption to economic growth in the long-run. This inter-dependency between electricity and GDP means that electricity consumption contributes to economic growth and vice versa in the long-run. In fact, as we discussed earlier in the introduction, the changing in life-styles and the improving living standards of Bahraini citizens during the past decade has driven energy demand growth. As figure below illustrates, the increase in foreign direct investment (FDI) and projects as well as the dynamism of the economy has firstly created employment and secondly has increased the use of electricity for industry as well as for private consumption. Thus, per capita income has increased.

Graph2. Explaining the relationship between electricity consumption and growth



The most demanded energy service in Bahrain is the air-conditioning due to the hard weather conditions during the spring and the summer, where humidity surpasses 100 per cent. In this case, one conclusion to be drawn is that a shortfall in the supply of power supplies will certainly results in slumps in economic activity in the long run. In this case, avoiding shortfall is a most important energy policy to guarantee continuous growth of economic activities. This could be done by building generating capacity to satisfy the different sector of the economy and to develop new sources of energy such as wind energy and green energy.

Turning now to the short-run dynamics; results reveal causality between electricity consumption to GDP, but not the reverse. Hence, there is unidirectional Granger causality. This means that electricity consumption does not contribute to economic growth in the short-run but the inverse is right. Here again, the situation shows that once the GDP per capita increases, Bahraini households increase their demand for energy, especially energy services. After a certain period of time, the consumption of energy impacts positively the level of GDP.

References

Akarca, A. T., Long, T. V., (1980). On the Relationship between Energy and GNP: A Reexamination. *Journal of Energy and Development*, 5, 326-331.

Altinay, G., Karagol, E., (2005). Electricity Consumption and Economic Growth: Evidence from Turkey. *Energy Economics*, 27, 849-856.

Asafu-Adjaye, J., (2000). The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries. *Energy Economics,* 22, 615-625.

Chang, J., Wong, J. F. (2001). Poverty, energy and economic growth in Singapore. Working Paper, Department of Economics, National University of Singapore.

Engle, R., and Granger, C. W. J., (1987). Cointegration and Error- Correction Representation, Estimation and Testing. *Econometric*a, 55, 251-276.

Ghali,-K.H, and El-Sakka,-M.I.T (2004) "Energy use and output growth in Canada: a multivariate cointegration analysis" *Energy Economics,* Vol. 26 (2), pp.225–38.

Granger, C.W.J., (1986). Developments in the study of cointegrated economic variables. *Oxford Bulletin of Economics and Statistics* 48, 213-228.

Granger, C.W.J., (1988). Some recent developments in a concept of causality. *Journal of Econometric*s 39, 199-211.

Hwang, D. B., and Gum, B., (1992). The Causal Relationship between Energy and GNP: The Case of Taiwan. *Journal of Energy and Development*, 16, 219-226.

Jumbe, C. B. L., (2004). Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi. *Energy Economics*, 26, 61-68.

Kraft, J., and Kraft, A., (1978). On the Relationship between Energy and GNP. *Journal of Energy and Development*, 3, 401-403.

Masih, A., and Masih, R., (1996). Energy Consumption, Real Income and Temporal Causality: Results from a Multi-Country Study Based on Cointegration and Error Correction Modeling Techniques. *Energy Economics*, 18, 165-183.

Mazumder, P., and Marathe, A., (2007). Causality Relationship between Electricity Consumption and GDP in Bangladesh. *Energy Policy*, 35, 395-402

Nanthakumar, L.,and Subramaniam, T., (2010). Dynamic Cointegration Link between Energy Consumption and Economic Performance: Empirical Evidence from Malaysia. *International Journal of Trade, Economics and Finance*, Vol.1, No.3.

Narayan, P.K., and Smyth, R., (2008). Energy consumption and real GDP in G7 countries, new evidence from panel cointegration with structural breaks. *Energy Economics* 30, 2331–2341.

Pesaran, M. H., Shin, Y., and Smith, R. J., (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics*, 16, 289-326.

Phillips, P.C.B.and Perron, P., (1988). Testing for a unit root in time series regression. *Biometrika*, 75, 335–346.

Stern, D. I., (2000). A Multivariate Cointegration Analysis of the Role of Energy in the US Macro Economy. *Energy Economics,* 22, 267-283.

Wolde-Rufael, Y., (2005). Electricity Consumption and Economic Growth: A Time Series Experience for 17 African Countries. *Energy Policy,* 34, 1106-1114.

World Bank., (2009). World Development Indicators 2009. Washington: United States.

World Telecommunication Indicators. (2011). ICT Indicators Database 2011. (15th Edition).

Yu, E. S. and Jin, J. C., (1992). Cointegration Test of Energy Consumption, Income and Employment. *Resource and Energy,* 14, 259-66.

Yu, E. S. and Choi, J. Y., (1985). The Causal Relationship between Energy and GNP: An International Comparison. *Journal of Energy and Development*, 10, 249-272.