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Causality and Cointegration between Economic Growth and Energy Consumption: Econometric Evidence from Jordan

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Abstract

This paper aims at determining the relationship between economic growth and energy consumption in Jordan within the neo-classical productivity theory framework where capital, labour and energy are treated as separate production factors. It constructs an econometric model using annual time series data covering the period 1970–2011. After estimating the parameters of the model, it uses causality tests to examine the existence and direction of causality between output growth and production factors including energy consumption. Empirical findings suggest that there exists Granger causality running from GDP to energy consumption, but there is no Granger causality running from energy consumption to GDP. The implication being that energy supply constraints could be introduced with little or no impact on economic growth. This unidirectional causality provides empirical evidence that Jordan is a less energy-dependent economy. Such findings undermine the theory of energy conservation policies and support the Government policies that aim at raising the prices of energy and reducing public demand for energy consumption mainly to reduce the deficit of government budget, foreign debt, and its services.

Keywords: unit root, causality, cointegration, energy consumption, economic growth, Jordan

1. Introduction

Jordan is among the highest in the world in its dependency on foreign energy sources. During 2002–2012 more than 95% of the country's energy needs were imported. The meagre resource of energy along with the lack of prospects of oil makes Jordan extremely vulnerable to exogenous energy supply shocks. Furthermore, steadily rising energy demand for expensive crude oil have made it necessary for Jordan to follow a policy of energy conservation to reduce government debt by reducing energy subsidies and direct more inputs to boost economic growth.

Electricity consumption has been growing at a higher pace compared to economic growth due to increasing urbanization, industrialisation, and rural electrification. High prices of oil and the capacity in electric generation with low operating costs have also led to high electricity usage level. From 1970 to 1974, the electricity consumption increased by 15.5% annually. This pattern continued even at higher rates during the 80's and 90's. Figures that are more recent reveal that during 2001–2011 the average annual growth in electricity consumption was almost 7%. In addition, the per capita energy consumption has also followed an overall upward trend, Central Bank of Jordan (2012). More recent years, 2010–2012, had experienced the most difficult times for the energy and electricity sector in Jordan due to the political conditions in the region which in turn contributed to increasing challenges facing this sector since Jordan imports more than 97% of its oil needs and that about 80% of electric power generated in Jordan depends on imported natural gas. In spite of these challenges, energy sector in Jordan has been able to continue its achievements and keep pace with recent and rapid developments by meeting the growing demand for different energy sources in general and electric power in particular. However, it has become urgent to find the appropriate solutions to face this fact in the light of the comprehensive national strategy of energy sector and the future vision derived from it which includes the need to utilize local energy sources depending on oil shale, uranium, use nuclear energy instead of oil to generate electric power, increase renewable energy sources projects, reinforce regional interconnection projects, and create opportunities for the private sector to invest in infrastructure projects of energy sector. This strategy seeks to increase reliance on local and renewable energy from 4% in the current year to 13% in 2016, then to 39% in 2020, National Electric Power Company (2012, pp. 11–17). The paper contributes to the existing literature because the analysis focuses on a small developing country, Jordan, which has not been studied, from this angle, before.

2. Review of Literature

Many studies have addressed the relationship between energy consumption and economic growth for several countries using different models. The results of these studies reached fairly inconclusive, and sometimes controversial, results concerning the exact nature and direction of the relationship between energy and economic growth. The main differences identified were type of analysis, time span, the time periods examined, the econometric approaches and the variables included in the estimations, level of economic growth in different countries, and method of estimation. Another potential reason for the differences in the results of these studies is the degree of availability of data specific for the country, Inglesi-Lotz and Pouris (2013). This gives rise for further research to guide economic theories and plans to generate economic development. The major part of empirical research that was devoted to test causality and relationship between energy consumption and economic growth could be divided into four categories, hence assuming four hypotheses, Chang and Carballo (2011).

2.1 Neutrality Hypothesis

This hypothesis assumes no causality between energy consumption and economic growth. Its implication is that energy conservation will not lead to economic growth and economic growth is independent from energy use. The neutrality hypothesis is supported by many recent studies including Stern and Enflo (2013), Ozturk and Acaravci (2011), Ozturk and Acaravci (2010), Warr and Ayres (2010), Apergis and Payne (2009c), Halicioglu (2009), Soytas and Sari (2009), Chiou-Wei, Chen and Zhu (2008), Jobert and Karanfil (2007), Lee (2006), Soytas and Sari (2006a), Fata, Oxley and Scrimgeour (2004) and Soytas and Sari (2003).

2.2 Conservation Hypothesis

This hypothesis postulates that a one-way directional causality runs from GDP to energy consumption. This implies that energy conservation policies may be implemented with little or no adverse effects on economic growth. However, it is possible that a growing economy constrained by political, infrastructural, or mismanagement of resources could generate inefficiencies and the reduction in the demand for goods and services, including energy consumption. The running causality from GDP to energy consumption was demonstrated by Baranzini et al. (2013), Damette and Seghir (2013), Ouedraogo (2013), Azlina (2012), Haghnejad and Dehnavi (2012), Adom (2011), Abbasian, Nazary and Nasrindoost (2010), Jamil and Ahmad (2010), Khan and Qayyum (2009), Mehrara (2007), Mozumder and Marathe (2007), Al-Iriani (2006), Tehranchian (2006), Yoo (2006), Hatemi-J and Irandoust (2005), Narayan and Smyth (2005), Jumbe (2004) and Oh and Lee (2004b).

2.3 Growth Hypothesis

This hypothesis supports a uni-directional causality running from energy consumption to economic growth. The implication is that restrictions on the use of energy may adversely affect economic growth while increases in energy consumption may contribute to economic growth. This hypothesis is demonstrated by Damette and Seghir (2013), Javid, Javid and Awan (2013), Ouedraogo (2013), Solarin and Shahbaz (2013), Acaravci and Ozturk (2012), Haghnejad and Dehnavi (2012), Shahiduzzaman and Alam (2012), Kouakou (2011), Mazbahul and Nazrul (2011), Chandran et al. (2010), Chang (2010), Odhiambo (2010), Yoo and Kwak (2010), Apergis and Payne (2009b), Akinlo (2009), Bowden and Payne (2009), Odhiambo (2009a, 2009b), Erdal, Erdal and Esengun (2008), Lee and Chang (2008), Narayan and Smyth (2008), Ang (2007), Ho and Siu (2007), Mahadevan and Asafu-Adjaye (2007), Yuan *et al*. (2007), Zhou and Chau (2006), Lee (2005), Lee and Chang (2005), Yoo (2005), Fatai Oxley and Scrimgeour (2004), Ghali and El-Sakka (2004), Morimoto and Hope (2004), Paul and Bhattacharya (2004), Shiu and Lam (2004), Wolde-Rufael (2004) and Soytas and Sari (2003).

2.4 Feedback Hypothesis

Feedback hypothesis assumes a bi-directional causality between energy consumption and economic growth. It implies that any energy conservation policy will adversely affect the economic output, while an increase in the economic output will increase the level of energy consumption. This hypothesis of causal relation between energy consumption and economic growth was demonstrated by many authors including Belaid and Abderrahmani (2013), Hu and Lin (2013), Tang and Tan (2013), Shahbaz and Lean (2012), Zhang and Yang (2012), Kouakou (2011), Ouédraogo (2010), Apergis and Payne (2009a), Belloumi (2009), Erdal, Erdal and Esengun (2008), Lee et al. (2008), Chen, Kou and Chen (2007), Lee and Chang (2007), Mahadevan and

Asafu-Adjaye (2007), Squalli (2007), Zhang and Li (2007), Soytas and Sari (2006b), Yoo (2006), Zhou and Chau (2006), Fatai, Oxley and Scrimgeour (2004), Ghali and El-Sakka (2004), Jumbe (2004), Oh and Lee (2004a) and Paul and Battacharya (2004).

3. Methodology and Data

The analysis depends on investigating the causal relationship among energy consumption, labour, capital, and economic growth, by using Jordanian annual time series data for the period 1970–2011. Before conducting the cointegration analysis, we conduct a unit root test for the variables of the model. We adopt two different tests, namely those of Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP). For specifying the cointegrating of the equations of the model, we applied Johansen's cointegration test in two forms: linear deterministic trend and no deterministic trend. Finally, to determine the existence and direction of causality among the variables of the model we applied Granger causality test with constant term and no trend.

4. The Model

Following Ghali and El-Sakka (2004), Oh and Lee (2004a) and many others, we start with a modified form of the aggregate output function as follows

$$Y_t = f(K_t, L_t, E_t) \tag{1}$$

Where *Y* is the aggregate output, *K* is capital, *L* is labour, and *E* is energy consumption. Maintaining linearity and following the neo-classical productivity theory, we basically depend on a modified form of production function as follows

$$GDP_t = \alpha_0 + \alpha_1 K_t + \alpha_2 L_t + \alpha_3 E_t + \varepsilon_t \tag{2}$$

The choice of a model which is based on the neo-classical productivity theory is meant to enrich the analysis of the relationship among the aggregate output and its factors of input, considering not only the energy variable but also capital and labor. As noted by Ghali and El-Sakka (2004), whether proposition of neutrality of energy in income determination is true or not, it is best to be tested in a neo-classical aggregated production framework taking capital, labor, and energy as separate inputs. Accordingly, we propose the following model:

$$\Delta GDP_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta K_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta L_{t-i} + \sum_{i=0}^{n} \alpha_{4i} \Delta E_{t-i} + u_1 \tag{3a}$$

$$\Delta K_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta K_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta L_{t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta E_{t-i} + u_2 \tag{4a}$$

$$\Delta L_t = \gamma_0 + \sum_{i=1}^{n} \gamma_{1i} \Delta L_{t-i} + \sum_{i=0}^{n} \gamma_{2i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \gamma_{3i} \Delta K_{t-i} + \sum_{i=0}^{n} \gamma_{4i} \Delta E_{t-i} + u_3 \tag{5a}$$

$$\Delta E_t = \delta_0 + \sum_{i=1}^{n} \delta_{1i} \Delta E_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \delta_{3i} \Delta K_{t-i} + \sum_{i=0}^{n} \delta_{4i} \Delta L_{t-i} + u_4 \tag{6a}$$

For testing cointergration with linear deterministic trends, the above model can simply be written as:

$$\Delta GDP_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta K_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta L_{t-i} + \sum_{i=0}^{n} \alpha_{4i} \Delta E_{t-i} + \alpha_5 t + u_1 \tag{3b}$$

$$\Delta K_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta K_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta L_{t-i} + \sum_{i=0}^{n} \beta_{4i} \Delta E_{t-i} + \beta_5 t + u_2 \tag{4b}$$

$$\Delta L_t = \gamma_0 + \sum_{i=1}^{n} \gamma_{1i} \Delta L_{t-i} + \sum_{i=0}^{n} \gamma_{2i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \gamma_{3i} \Delta K_{t-i} + \sum_{i=0}^{n} \gamma_{4i} \Delta E_{t-i} + \gamma_5 t + u_3 \tag{5b}$$

$$\Delta E_t = \delta_0 + \sum_{i=1}^{n} \delta_{1i} \Delta E_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta GDP_{t-i} + \sum_{i=0}^{n} \delta_{3i} \Delta K_{t-i} + \sum_{i=0}^{n} \delta_{4i} \Delta L_{t-i} + \delta_5 t + u_4 \tag{6b}$$

For simplicity, *n* represents the maximum number of lags which is not necessarily fixed for each variable but determined by the estimation method (Least Squares) based on Schwarz Information Criterion (SIC). Small Greek letters (α, β, γ and δ) are coefficients to be estimated, and u's are stochastic errors.

5. Empirical Results and Discussion

Empirical findings regarding the direction of causality have significant policy implications. If the findings confirm that causality runs one-way from energy to economic growth then this implies that the economy, under study, is an energy-dependent economy. Moreover, energy is a stimulus for economic growth, implying that energy conservation plans may slow down economic growth. On the other hand, a unidirectional causality running from economy to energy consumption provides empirical evidence that the economy, under study, is a less energy-dependent economy. Such findings undermine the theory of energy conservation policies. More precisely, energy rationing may be implemented with little or no impact on economic growth. If there is no causality between energy consumption and economic growth, which is a rare and, probably, an old case, then a country can carry out energy conservation policies with no or little effect on economic growth. For such policies to work in the Jordanian case, this study provides empirical evidence through several tests including unit root test, cointegration and causality test.

5.1 Unit Root Test

In order to have robust results, we conducted two different unit root tests, namely Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP). The results of unit root tests or stationarity properties of all model variables along with the number of lag lengths are presented in Table 1. The unit root tests for both level and first difference forms are performed including a constant without linear trend. A linear trend needs only be included if the variables in level have a second trend. This is not the case for our variables. The null hypothesis that a variable has a unit root is rejected for values of t-statistics greater than or equal to their corresponding critical (or tabled) t-values.

As can be seen, only the t statistics for *GDP* are greater than their corresponding critical values at the 5% level from both ADF and PP tests, suggesting that the variables *K*, *L*, and *E* are nonstationary in their level forms implying the need for stationarity testing for the variables in their first differences. The results of the first differenced variables *K*, *L*, and *E* show that ADF and PP test statistics for all the variables are less than their critical values at 5% levels, notice negative values of t or adjusted t statistics. The results show that all the variables are stationary after differencing once, suggesting that all the variables are integrated of order I(1) except for *GDP* which is stationary at its level which is integrated of order I(0). The two tests almost unanimously indicate that all the variables are non-stationary in their level data except for *GDP* (with or without trend). However, the stationarity property is found in the first difference of the variables (with constant and without trend) at the 5% level.

Table 1. Empirical results of unit root test

Level form	*GDP*	*K*	*L*	*E*
Augmented Dicky-Fuller test statistic	8.499(0)	3.461(9)	0.635(1)	-0.449(0)
Phillips-Perron test statistic	8.224(1)	1.353(3)	1.326(3)	-0.467(2)
Significance level	Critical values	Critical values	Critical values	Critical values
1%	-3.601	-3.654	-3.605	-3.601
5%	-2.935	-2.957	-2.937	-2.935
10%	-2.606	-2.617	-2.607	-2.606
First difference	*GDP*	*K*	*L*	*E*
Augmented Dicky-Fuller test statistic	-0.466(1)	-4.457(0)	-3.549(0)	-5.941(0)
Phillips-Perron test statistic	-2.059(3)	-4.562(4)	-3.519(2)	-5.947(2)
Significance level	Critical values	Critical values	Critical values	Critical values
1%	-3.610	-3.606	-3.606	-3.601
5%	-2.939	-2.937	-2.937	-2.935
10%	-2.608	-2.607	-2.607	-2.606

Note. *GDP* and *K* are in real terms. For Augmented Dicky-Fuller test statistics, the numbers in parentheses are lag length which is selected automatically based on assumed maximum lag length of 9. For Phillips-Perron test statistics, the numbers in parentheses are bandwidths (Newey-West automatic) using Bartlett kernel.

5.2 Co-Integration

Cointegration analysis has been carried out to investigate the long-run cointegration among the variables of the model. In this study, we applied unit root tests to the residuals obtained from OLS estimation. To establish if the variables are cointegrated, the ADF unit roots test was applied on the residuals from the three equations, where *E* was regressed on each of the variables *GDP*, *K* and *L*. Table 2, Table 3, Table 4 and Table 5 present the results from this analysis. When testing for cointegration among the variables using Trace tests with no linear deterministic trend, shown in Tables 2 and 3, we arrive at the conclusion that there is one cointegrating equation using Trace test and two cointegrating equations using Maximum Eigenvalue method, as assumed in equations (2a), (3a), (4a), and (5a).

Table 2. Results for unrestricted cointegration rank test (trace) with no deterministic trend

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.738173	77.85327	40.17493	0.0000
At most 1	0.380375	24.25045	24.27596	0.0504
At most 2	0.089771	5.104784	12.32090	0.5530
At most 3	0.033004	1.342432	4.129906	0.2884

Note. Trace test indicates 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.

Table 3. Results for Unrestricted Cointegration Rank Test (Maximum Eigenvalue) with no deterministic trend

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.738173	53.60283	24.15921	0.0000
At most 1 *	0.380375	19.14566	17.79730	0.0312
At most 2	0.089771	3.762351	11.22480	0.6665
At most 3	0.033004	1.342432	4.129906	0.2884

Note. Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level; * denotes rejection of the hypothesis at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values

As can be seen, the null hypothesis of no cointegrating equations is rejected at the 5% level of significance, as assumed in equations (2b), (3b), (4b), and (5b). The results of both rank tests (Trace and Maximum Eigenvalue) with linear deterministic trend, shown in Tables 4 and 5, indicate that there is one cointegrating equation at the 5% level.

Table 4. Results for unrestricted cointegration rank test (trace) tests with linear deterministic trend

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.743981	80.20033	47.85613	0.0000
At most 1	0.347355	25.70012	29.79707	0.1379
At most 2	0.186548	8.631218	15.49471	0.4006
At most 3	0.009269	0.372508	3.841466	0.5416

Note. Trace test indicates 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.

Table 5. Results for Unrestricted Cointegration Rank Test (Maximum Eigenvalue) with linear deterministic trend

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.743981	54.50022	27.58434	0.0000
At most 1	0.347355	17.06890	21.13162	0.1688
At most 2	0.186548	8.258710	14.26460	0.3530
At most 3	0.009269	0.372508	3.841466	0.5416

Note. Max-eigenvalue test indicates 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.

5.3 Causality Test

The empirical results fully support the existence of a unidirectional causality running from economic growth to energy consumption. This means that reducing energy consumption does not adversely affect GDP. Moreover, neoclassical theory of production is fully supported by Jordanian data as both capital and labor causes economic growth. As can be seen from Table 6, there is only a probability of less than 2% (1.61%) to reject the null hypothesis that capital does not cause GDP growth. On the other hand, we are 96% confident that labor causes output growth. More important to this paper is that energy consumption has no significant effect on economic growth.

Table 6. Pair wise granger causality tests

Null Hypothesis:	No. of Observations	F-Statistic	Probability	Result
K does not Granger Cause *GDP*	40	4.65712	0.0161	Reject
GDP does not Granger Cause *K*		1.32356	0.2792	Do not reject
L does not Granger Cause *GDP*	40	3.53815	0.0399	Reject
GDP does not Granger Cause *L*		1.25031	0.2989	Do not reject
E does not Granger Cause *GDP*	40	1.98693	0.1523	Do not reject
GDP does not Granger Cause *E*		3.64440	0.0365	Reject
L does not Granger Cause *K*	40	8.44389	0.0010	Reject
K does not Granger Cause *L*		0.09062	0.9136	Do not reject
E does not Granger Cause *K*	40	3.16164	0.0547	Do not reject
K does not Granger Cause *E*		5.78664	0.0067	Reject
E does not Granger Cause *L*	40	3.09734	0.0577	Reject
L does not Granger Cause *E*		0.89413	0.4181	Do not reject

Note. GDP is real gross domestic product (million JD), *L* is labour, *K* is capital expressed in real gross capital formation (million JD), and *E* is energy consumption expressed in electricity consumption (kWh).

6. Conclusions

This paper provides new empirical insight into the analysis of the relationship between energy consumption and economic growth for a small developing country considering the traditional factors of production in addition to energy factor. In this context, modeling energy consumption and economic growth in Jordan during 1971–2011 has enabled us to test energy consumption and economic growth relationship in a neo-classical aggregate production model. The empirical findings indicate that there exists long-run cointegration among output, labor, capital and energy use. Granger causality tests indicate that there exists Granger causality running from GDP to energy consumption, but Granger causality running from energy consumption to GDP does not exist. It can also be concluded that conservation hypothesis is applicable to Jordanian data more than the feedback or growth hypotheses.

An important policy implication of the analysis is that conservation in energy consumption is not a significant limiting factor to Jordanian economic growth. Therefore, energy supply constraints could be introduced with little impact on economic growth. This unidirectional causality provides empirical evidence that energy conservation policies are favourable for Jordanian economy. They also support the Government policies that aim at reducing public demand for energy consumption mainly to minimise foreign debt and its services. This should not be interpreted as energy has nothing to do with economic growth but rather there are other factors, such as labour and capital, which are more important to economic growth than energy consumption.

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