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Abstract

Since the 2011 revolution, Egypt has experienced frequent electricity blackouts and severe shortage in energy supplies. The government responded to the problem by reducing the subsidy on energy for heavy industries, and household electricity use. In addition, the government introduced a smart card system that entails a certain quota of fuel for each registered car per month. It appeared to the public that the Egyptian government is attempting to adopt an energy conservation policy to ration energy consumption and manage the deficit in energy supplies. Given that energy is an essential input for many economic activities, there is a concern that a reduction in energy consumption may dampen the growth potentials of the Egyptian economy. This paper investigates the causal relationship between energy consumption and economic growth in Egypt during the period 1980-2012, within a multivariate framework by including measures for capital and labor in the aggregate production function. Causality is tested using a modified version of the Granger causality test due to Toda and Yamamoto (1995). The analyses endogenously controls for potential structural breaks in the time series when conducting the unit root tests. In addition to aggregate energy consumption, the analysis is also segregated by different components of energy use including oil, electricity, natural gas and coal to account for any potential aggregation bias. No causal relationship was found between total primary energy consumption and economic growth, supporting the neutrality hypothesis. When the analysis is stratified by energy type, a one way positive causal relation running from economic growth to electricity and oil consumption was found which is consistent with the conservation hypothesis. The findings of this study provide empirical evidence that energy conservation policy has no negative effect on the growth prospects of the Egyptian economy in the long-run.

Keywords: Energy Consumption; GDP; Cointegration; Causality; Egypt

JEL Classification: C32, F24, F43

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1. Introduction

Sustainable and reliable supply of energy is an essential requirement for economic development. Since the 2011 revolution, Egypt has been experiencing frequent electricity blackouts and severe shortage in energy supplies. The government responded to the problem by reducing the subsidy on energy for heavy industries and household electricity use. In addition, the government introduced a smart card system that entails a certain quota of fuel for each registered car per month. It appeared to the public that the Egyptian government was attempting to adopt an energy conservation policy to ration energy consumption and mange the deficit in energy supplies. Given that energy is an essential input for many economic activities, there is a concern that a reduction in energy consumption may dampen the growth potentials of the Egyptian economy. The objective of this paper is to examine the causal relationship between energy consumption and economic growth in Egypt during the period 1980-2012.

The paper is organized as follows: Section 2 reviews the literature. Section 3 discusses the evolution of the energy sector in Egypt. The data and the econometric methodology are presented in Section 4. Section 5 presents the results which are discussed in section 6. The conclusions and policy implications are summarized in Section 7.

2. Literature Review

The nature of the relationship between energy consumption, or any of its components, and economic growth has received great attention in the energy economics literature due to its implication for the design of energy policies. Since the seminal study of Kraft and Kraft (1978) which found a unidirectional causality from national income to energy consumption in the USA over the 1947-1974 period, a growing literature has emerged to examine the causal relationship between energy consumption and economic growth in a wide range of countries and using different econometric techniques.[2]

Theoretically, four hypotheses have been put forward to explain the direction of causality between energy consumption and economic growth. These include the “neutrality hypothesis”; “conservation hypothesis”; “growth hypothesis”; and the “feedback hypothesis”. The neutrality

[2] For recent surveys of the literature on the causal relationship between energy consumption and economic growth see Ozturk (2010) and Payne (2010).

hypothesis postulates no causal relationship between energy consumption and economic growth. The conservation hypothesis considers a one-way positive causality running from economic growth to energy consumption, while the other direction of causality is asserted by the growth hypothesis. According to the feedback hypothesis there is a two-way causality between energy consumption and economic growth.

Existing empirical evidence on the causal relationship between energy use and economic growth is inconclusive with mixed findings. The neutrality hypothesis has been supported for example by the findings of Menegaki (2011), Yıldırım et al. (2014); while the findings of Ghali and El-Sakka (2004), Belloumi (2009), Apergis and Payne (2012), Shahbaz et al. (2012), Fuinhas and Marques (2012), Mohammadi and Parvaresh (2014), Bloch et al (2015) supports the feedback hypothesis. Among the studies whose findings support the conservation hypothesis include Mozumder and Marathe (2007) and Mehrara (2007); while the growth hypothesis is supported by the findings of Lee (2005) as an example.

The empirical literature on the energy-growth nexus has been largely dominated by cross-country studies and the findings were mixed. For example, using a panel error correction model, within a multivariate framework, Apergis and Payne (2012) investigated the relationship between renewable, non-renewable energy consumption and economic growth for 80 countries, including Egypt, over the period 1990–2007. They found bidirectional causality between renewable and non-renewable energy consumption, and economic growth in both the short- and long-run which is in line with the feedback hypothesis. In another cross-country study, Fuinhas and Marques (2012) examined the nexus between primary energy consumption and economic growth in Portugal, Italy, Greece, Spain and Turkey over the period 1965 to 2009. Using an Autoregressive Distributed Lag (ARDL) approach, they found bidirectional causality between energy consumption and economic growth in both the long-run and short-run, supporting the feedback hypothesis.

In a panel study of 18 developing countries over the period 1975 to 2001, Lee (2005) employed heterogeneous panel cointegration and panel-based error correction models and found evidence of a long-run and short-run causality from energy consumption to GDP, supporting the growth hypothesis. In a multivariate panel framework, Menegaki (2011) examined the causal relationship between renewable energy consumption and economic growth for 27 European countries over the period 1997–2007, using a random effect model, and found no causality between renewable energy consumption and GDP supporting the neutrality hypothesis. In another study, using panel unit-root tests and panel cointegration analysis, Mehrara (2007) examined the causal relationship between per capita energy consumption and per capita GDP in a panel of 11 oil exporting countries. The author found a unidirectional strong causality from economic growth to energy consumption for the studied group of oil exporting countries.

Using data on 17 African countries including Egypt during the period 1971–2001, Wolde-Rufael (2006) found mixed results concerning the causality between electricity consumption and economic growth. For Egypt, Wolde-Rufael (2006) found positive bidirectional causality between electricity consumption and economic growth. In another study, Wolde-Rufael (2009) re-examined the causal relationship between energy consumption and economic growth in seventeen African countries including Egypt during the period 1971-2004, within a multivariate framework by including labor and capital as additional variables. A variance decomposition analysis was used to evaluate the importance of the causal effect of energy consumption on economic growth relative to labor and capital. The causality test rejected the neutrality hypothesis for the energy–income relationship in fifteen out of the seventeen countries. Results of the variance decomposition analyses showed that in eleven out of the seventeen countries, energy is merely a contributing factor to output growth and not an important one when compared to capital and labor. For Egypt, Wolde-Rufael (2009) found a uni-directional causality running from economic growth to energy consumption. Similar mixed results on the direction of causality between economic growth and energy consumption was found by Akinlo (2008) using a multivariate causality test for eleven Sub-Sahara African countries. In a recent cross-country study, Yıldırım et al. (2014) used a trivariate model and a bootstrapped autoregressive metric causality approach to examine the causality between economic growth and energy consumption in 11 countries, including Egypt. The authors found evidence for the neutrality hypothesis of a no casual relationship between energy consumption and economic growth for all countries but for Turkey in which a unidirectional causal link was found from energy consumption to economic growth. In a panel study of 14 oil-exporting countries over 1980–2007, Mohammadi and Parvaresh (2014), examined the long-run relation and short-run dynamics between energy consumption and output using panel estimation techniques - dynamic fixed effect, pooled and mean-group estimators. They found a bidirectional causal relation in both long- and short-run between energy consumption and output which supports the feedback hypothesis.

Similar to the cross-country studies, evidence on the direction of causality between energy consumption and economic growth, based on individual country studies is equally mixed. In a country-specific study, Shahbaz et al. (2012) found a bidirectional casual relationship between renewable, non-renewable energy consumption and economic growth in Pakistan using the ARDL bounds testing approach and within a multivariate framework over the period 1972–2011. A merit of the Shahbaz et al. (2012) study is that it accounted for structural breaks in the time series when checking for the stationarity property of the variables. In another individual country study, and using Johansen cointegration test and a vector error correction model (VECM), Belloumi (2009) found a long-run bi-directional causal relationship between per capita energy consumption and per capita gross domestic product in Tunisia during the period 1971-2004, and a short- run unidirectional causality from energy to gross domestic product (GDP). Using a neo-classical one-sector aggregate production technology, Ghali and EL-Sakka (2004) found a two-way causal relationship between energy consumption and economic growth in Canada. The authors also found that a shock to energy would cause a 15% change in the future growth rates of output. In another study, Mozumder and Marathe (2007), using cointegration and vector error correction model, found a unidirectional causality from per capita GDP to per capita electricity consumption in Bangladesh, which is in line with the conservation hypothesis. In a recent study, Bloch et al (2015) found, using an ARDL technique and a vector error correction model, a long-run bi-directional causality between GDP and oil, coal, and renewable energy consumption in China during the period 1977-2013.

Table 1 presents a brief review for recent empirical evidence, in cross-country and country-specific studies, on the causal relationship between energy consumption and economic growth. As evident from Table 1, studies differed in their sample, econometric methodology, time period covered and level of data aggregation.

In the case of Egypt, little research has been done regarding the causal relationship between energy use and economic growth, especially at the disaggregated level. In addition, pervious cross-country studies that included Egypt such as the study of Wolde-Rufael (2006) and Wolde-Rufael (2009) did not control for the existence of potential structural breaks in the time series when conducting the unit root tests and when estimating the error correction model. Moreover, previous studies have mostly used a bivariate framework without considering other variables that affect economic growth, and accordingly their model could be subject to omission variable bias. These studies have also used either an aggregate energy consumption data or a single component of energy consumption such as electricity.

Table 1 Brief Review of Related Empirical Studies

Study	Study period	Country	Methodology	Finding
Lee (2005)	1975 to 2001	18 developing countries	heterogeneous panel cointegration, and panel-based error correction models	EC → Y
Wolde-Rufael (2006)	1971–2001	17 African countries	ARDL bounds test of cointegration; Toda and Yamamoto Causality test	Egypt, Gabon; Morocco: EC ←→ Y Algeria, Congo Rep, Kenya, South Africa, Sudan: EC— Y Benin, Congo DR, Tunisia: EC → Y Cameroon, Ghana, Nigeria, Sinegal, Zambia, Zimbabwe: EC ← Y
Mozumder and Marathe (2007)	1971 − 1999	Bangladesh	cointegration and vector error correction model	EC ← Y
Akinlo (2008)	1980–2003	Eleven sub-Sahara African countries	ARDL bounds test, VECM; Granger causality test	Gambia, Ghana and Senegal: EC ←→ Y Ghana, Kenya, Senegal and Sudan: EC → Y Sudan and Zimbabwe: EC ← Y Cameroon, Nigeria, Kenya Togo and Cote D'Ivoire: EC— Y
Belloumi (2009)	1971–2004	Tunisia	Johansen cointegration technique, VECM; Granger causality test	EC ←→ Y : in long run EC → Y: in Short run
Wolde-Rufael (2009)	1971-2004	17 African countries	Toda and Yamamoto Causality test, Variance decomposition	Gabon, Ghana, Togo and Zimbabwe: EC ←→ Y Cameroon and Kenya: EC— Y

				Algeria, Benin and South Africa:EC → Y Egypt, Ivory Coast, Morocco, Nigeria, Senegal, Sudan, Tunisia and Zambia: EC ← Y
Menegaki (2011)	1997–2007	27 European countries	random effect model	EC— Y
Fuinhas and Marques (2012)	1965 -2009	Portugal, Italy, Greece, Spain and Turkey	ARDL bounds test approach, VECM	EC ←→ Y
Shahbaz et al. (2012)	1972–2011	Pakistan	ARDL bounds test approach, VECM	EC ←→ Y
Apergis and Payne (2012)	1990–2007	80 countries	panel cointegration test Engle and Granger (1987) two-step procedure	EC ←→ Y
Yıldırım et al. (2014)	1980-2011	Bangladesh, Egypt, Indonesia, Iran, Korea, Mexico, Pakistan and Philippines, Turkey.	bootstrapped autoregressive metric causality approach	EC— Y
Mohammadi and Parvaresh (2014)	1980–2007	14 oil-exporting countries	dynamic fixed effect, pooled and mean-group estimators	EC ←→ Y
Bloch et al (2015)	1977-2013	China	ARDL bounds test approach, VECM	EC ←→ Y

EC and Y refer to energy consumption and real GDP. EC → Y indicates a unidirectional causality from energy consumption to economic growth while EC ← Y indicates that causality runs from economic growth to energy consumption. EC ←→ Y indicates a two-way causality and EC— Y indicates no causality. VAR refers to Vector Auto Regressive model, ECM refers to Error Correction Model, ARDL refers to Auto Regressive Distributed Lag model.

The relationship between energy consumption and GDP could be unstable due to the existence of structural breaks in the time series resulting from an exogenous shock to the regime. Perron (1989) and Zivot and Andrews (1997) showed that failure to allow for structural breaks when testing for unit in the series result in wrong inferences. Accordingly, these authors proposed determining the structural break point ‘endogenously’ from the data.

Previous related studies have mostly used aggregated data on energy use, or a single component of energy use such as electricity or renewable energy, to examine its causal relationship with economic growth. The use of aggregated data could suffer from ‘‘aggregation bias’’ where significant small-level causal relationships might be masked within data series of a larger level of aggregation.

To overcome the limitations of previous studies, the current paper uses aggregated as well as disaggregate data of different components of energy consumption. The level of data aggregation may also affect the direction of causality between energy consumption and economic growth. Using data from Taiwan, Lee and Chang (2005) find different directions of causality between GDP and various kinds of energy consumption. In particular, they find a bi-directional causal linkage between GDP and both total energy and coal consumption while a unidirectional causality running from oil consumption and gas consumption to GDP.

The mixed findings in previous studies could in part be explained by differences with respect to the used econometric technique, time period covered, data sets and level of data aggregation. There are naturally institutional, socio-economic differences between countries. Countries may also differ in their energy-related policies, energy supplies and pattern of energy consumption. Accordingly, it is to be expected that, in practice, the energy consumption-economic growth relationship is country-specific, and varies depending on the period under investigation. While the extant literature is largely dominated by cross-country studies, few individual country studies have investigated the relationship between energy consumption or electricity consumption and economic growth.

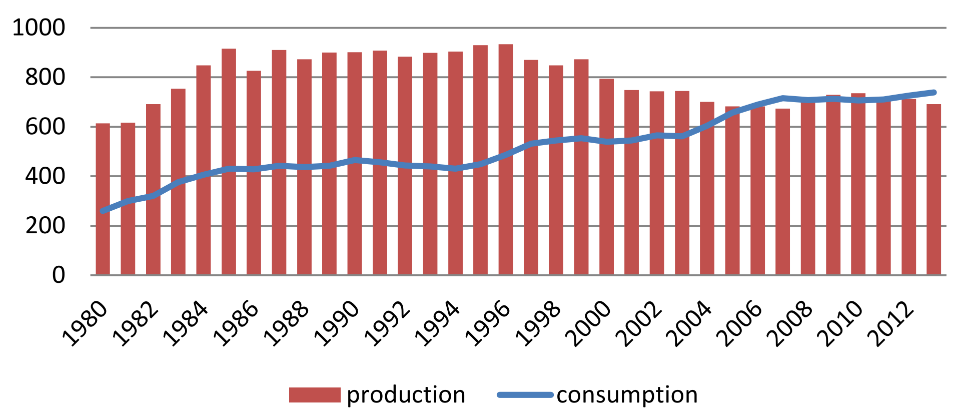
This paper adds to the growing number of individual country studies which investigate the relationship between energy consumption and economic growth by focusing on the specific case of Egypt.

3. Evolution of the Energy Sector in Egypt

Egypt is the largest non-OPEC oil producer and the second largest natural gas producer in Africa. Meanwhile, Egypt is the biggest consumer of oil and natural gas, with over 20% and 40% of total oil and dry natural gas consumption in the continent based on 2013 statistics (Energy Information Administration, 2013). The strategic geographical location helps Egypt to play a prominent role in the international energy markets through operating the Suez Canal and Suez-Mediterranean (SUMED) Pipeline, an important transit points for oil and natural gas shipments from the Arab Gulf countries to Europe.

Over 90 percent of Egypt's energy consumption is currently satisfied by oil and natural gas. Though oil production has been declining in recent years, substantial expansion has been taking place in the production of dry natural gas due to major recent discoveries and substantial investments in that sector. During the last decade, natural gas production has more than doubled, increasing from 646 billion cubic feet (bcf) in 2000 to 2141 (bcf) in 2012 which enabled Egypt to be a net exporter of natural gas since 2003. Nonetheless, Egypt became a net importer of oil since 2012.

Figure 1. Total Oil Production and Consumption in Egypt during 1980-2013



Source: Author compilations based on International Energy Statistics

Figure 1 displays the evolution of oil consumption and production in Egypt during the period from 1980 to 2012. Oil consumption in Egypt has rapidly increased from 260 thousand barrels in 1980 to 738 thousand barrels in 2013. However, oil production has been rising during the 1980's, remained relatively stable during the 1990's, and has dropped since the year 2000. In 1980, oil production was 3.3 times oil consumption which substantially decreased to only 0.93 times in 2013.

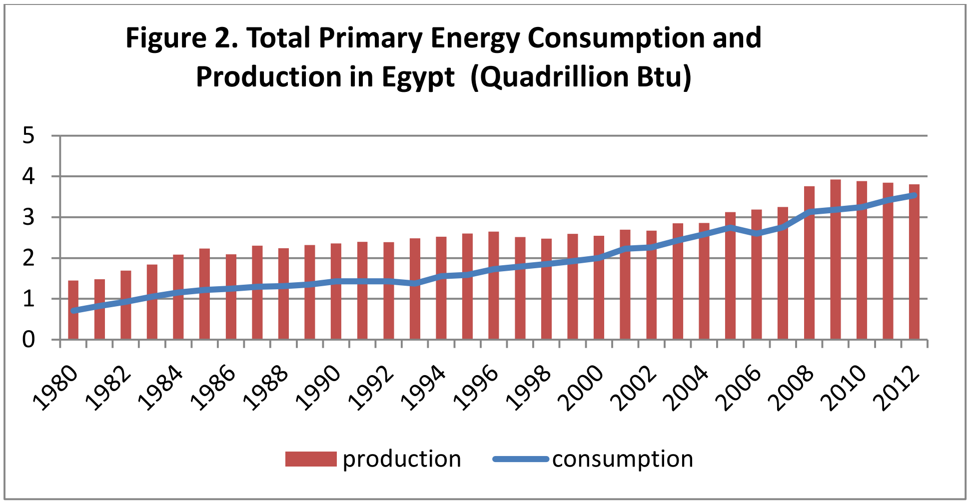


Figure 2. Total Primary Energy Consumption and Production in Egypt (Quadrillion Btu)

Source: Author compilations based on International Energy Statistics

Figure 2 depicts the evolution of total primary energy consumption and production in Egypt over the period 1980-2012. Data shows that Egypt has remained a net exporter of primary energy, though the amount of exports has been declining over time, dropping from 1.1092 in 1993 to 0.269 Quadrillion Btu in 2012. Consumption of primary energy grew at an average rate of 7.4% during the 1980's, 3.5% during the 1990's, and at 5% during the new millennium. On the other hand, primary energy production grew at a slower rate than consumption. During 1980's, the average growth rate of primary energy production was 5.2%, 0.8% during the 1990's, and 3.5% afterwards.

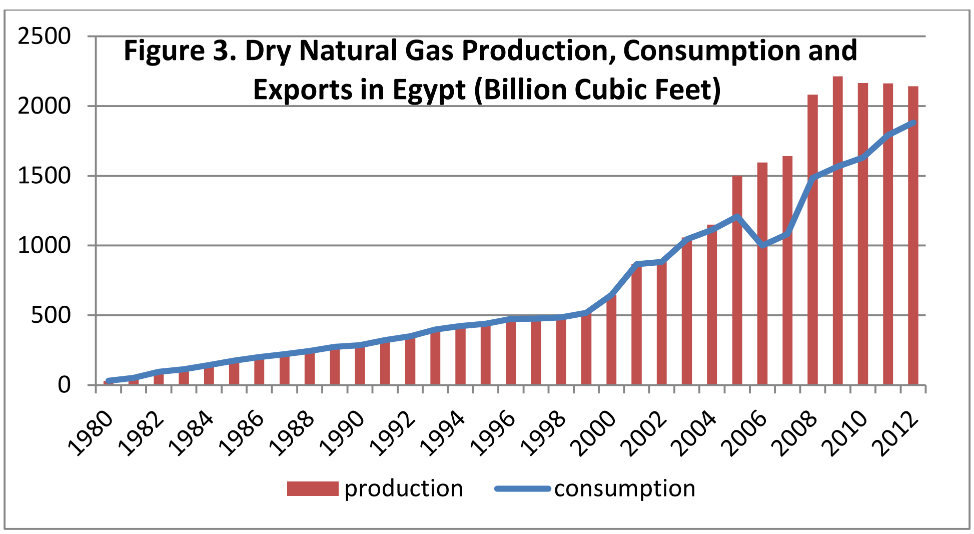
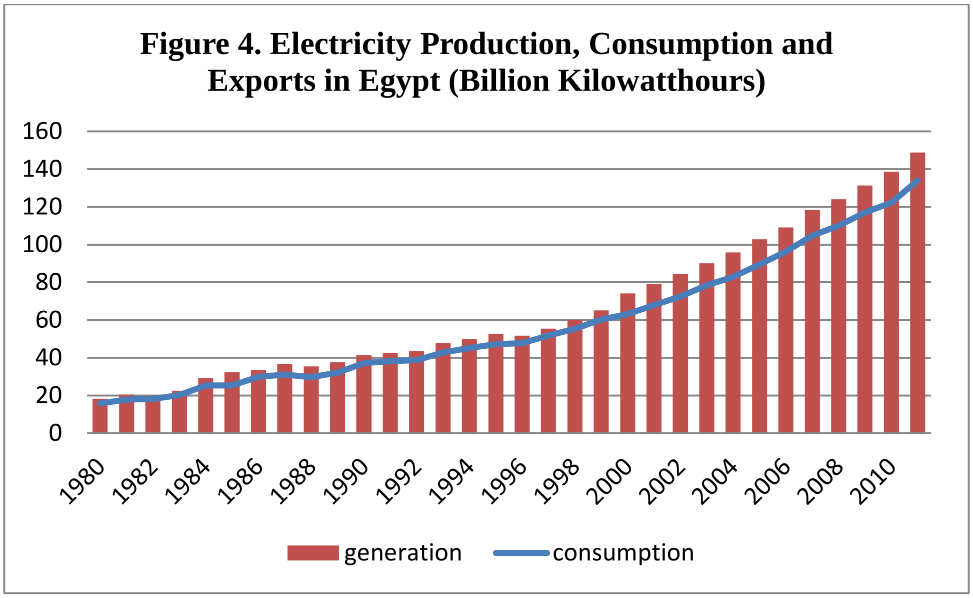


Figure 3. Dry Natural Gas Production, Consumption and Exports in Egypt (Billion Cubic Feet)

Source: Author compilations based on International Energy Statistics

Figure 3 displays the development of dry natural gas production and consumption over the study period and shows that Egypt's natural gas sector has been expanding rapidly, as production has increased substantially from 30 billion cubic feet (bcf) in 1980, to 646 bcf in 2000, reaching 2141 bcf in 2012. Since 2003, Egypt has become a net exporter of natural gas with substantial increase in net exports from 12.36 bcf in 2003 to 647 bcf in 2009 before dropping back to 259 bcf in 2012.



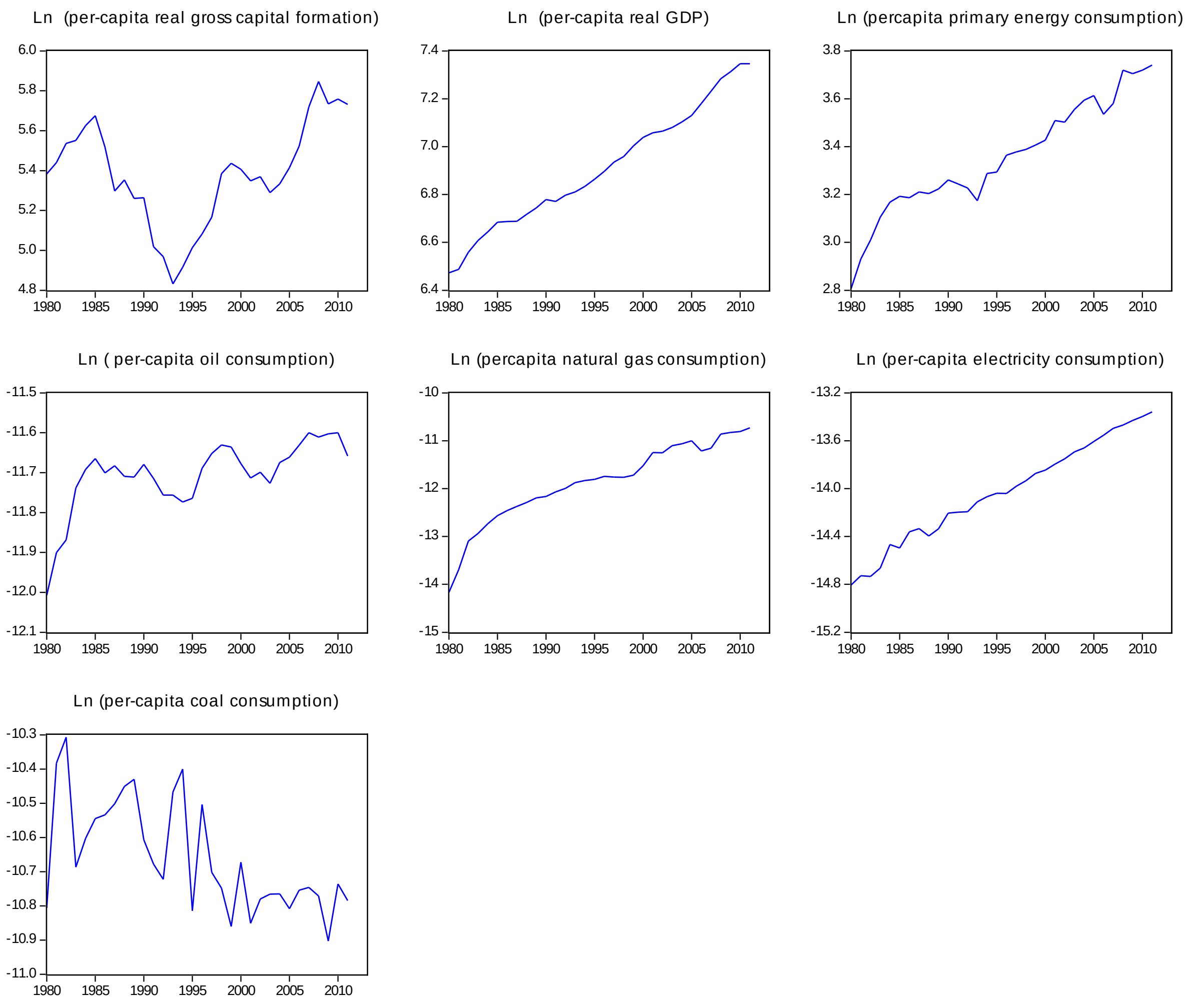
Source: Author compilations based on International Energy Statistics

Figure 4 depicts the evolution of electricity production and consumption over the period 1980 to 2012. Electricity generation has experienced a continual expansion, increasing from 18.3 Billion Kilowatthours (kwh) in 1980 to 74.2 billion kwh in 2000 and 155.3 billion kwh in 2012. The increase in electricity generation was accompanied by a rapid increase in consumption from 15.8 billion kwh in 1980 to over 134 billion kwh in 2012. The excess of electricity generation over consumption enabled Egypt to be a net exporter of electricity to neighbour countries such as Jordon. However, since the 2011 revolution, Egypt has experienced frequent electricity blackouts and severe shortages in energy supplies. Several factors have exacerbated the energy problems in Egypt. These include the rising energy demand, shortages in natural gas supplies, aging generation and transmission infrastructure as well as stagnant investment in the energy sector.

4. Data

Data on energy consumption including primary energy, coal, electricity, oil and natural gas are obtained from International Energy Statistics. Data on GDP (in constant 2000 US dollars) and gross fixed capital formation are obtained from World Development Indicators (WDI) issued by the World Bank (2013). The analysis covers the period from 1980 to 2012. All variables are expressed in real, per capita, and natural logarithmic form. Figure 5 plots the variables under investigation over the study period.

Figure 5. Capital, GDP and energy consumption in Egypt during 1980-2012



Source: Data on GDP (in constant 2000 US dollars) and gross fixed capital formation are obtained from World Development Indicators; Data on energy consumption are obtained from International Energy Statistics.

5. Econometric Methodology

5.1. New-classical production function

To examine the relationship between energy consumption and economic growth, this paper uses a neo-classical one-sector aggregate production function with labour; capital and energy used as separate inputs in the production technology.[3] A new-classical production function that relates output to a set of inputs could be expressed as in equation (1).

$$Y_t = f\ (K_t, L_t, E_t) = A_t\ K_t^{\alpha}\ L_t^{\beta}\ E_t^{\gamma} \qquad (1)$$

In which Y is the real GDP, K is the real physical capital stock, L is labor input and E is energy input. With a constant return to scale Cobb-Douglas production function, $\alpha + \beta + \gamma = 1$, and by taking the natural logarithm, Eq.(1) would be expressed in per-capita form as in Equation (2).

$$Ln\ y_t = \beta_0 + \beta_1\ Ln\ e_t + \beta_2\ Ln\ k_t + u_{1,t} \qquad (2)$$

Where y_t is the per-capita real GDP, $e_t$is the per-capita real energy consumption, and k_t is the per-capita real capital stock. Where: $y_t = \frac{Y_t}{L_t}$; $e_t = \frac{E_t}{L_t}$; $k_t = \frac{K_t}{L_t}$. β_1 and β_2 are the elasticities of per-capita real output with respect to the per-capita real energy and per-capita real capital inputs.

5.2. Unit root tests

The econometric analysis starts with pre-testing all time series for unit root, to ensure a non-spurious estimation, and to have time-invariant estimates. Two traditional unit root tests are used; the Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) test, and the Phillips-Perron (PP) (Phillips and Perron, 1988) test.

One shortcoming of these traditional tests is that they do not account for structural breaks in a time series. Time series data may be characterized by the existence of structural breaks or a shift in the underlying regime. Failing to control for structural breaks in the time series when testing for unit root, could lead to inaccurate hypothesis testing (Perron, 1989). While Zivot and Andrews

[3] This framework has been used by several previous studies such as Ghali and Elsakka (2004) who examined the relationship between energy use and output growth in Canada.

(2002) developed a way that allows for an endogenously determined single structural break, while Clemente et al., (1998) proposed a test to endogenously account for two structural breaks in a series. This test has two versions, one that allows for any gradual shift in the mean of the series known as Innovational Outlier (IO model), and the other version of the test allows for a sudden shift in the time series known as Additive Outlier (AO model). In addition to ADF, and PP tests, the current paper uses both Zivot and Andrews (2002), and Clemente et al., (1998) tests to allow for the possibility of structural breaks in the time series.

5.3. Toda and Yamamoto Granger Causality Test

To test for the existence of a causal relationship between energy consumption and economic growth, a modified version of the Granger causality test due to Toda and Yamamoto (1995) is used. Conducting the Toda and Yamamoto (1995) procedure has a set of steps that will be explained as follows: The first step involves determining the order of integration of all the time series using any of the unit root tests such as ADF, PP and KPSS. Based on the result of these unit root tests, let the maximum order of integration for the group of time-series be m. The second step involves estimating a Vector Auto Regressive (VAR) model of the variables in their levels with optimal lag length P determined based on any of the information criteria, such as Akaike Information Criterion (AIC), or the Schwarz Information Criterion (SIC). In a third step, we add m additional lags of all the variables into the system of VAR equations. Finally, we test for Granger causality using the usual Wald test which is now valid and asymptotically chi-square distributed. The idea behind the addition of m additional lags of each variable in the VAR model is to correct for any 'nuisance parameters' in the asymptotic distribution of the Wald test statistic's if some of the series are non-stationary. It is worth mentioning the additional m lags of the variables are not included when conducting the Wald test.

The Toda-Yamamoto Granger causality test is applied to the following Vector Auto Regressive (VAR) model which is estimated using Seemingly Unrelated Regression (SUR) model.

$$\ln y_t = a_1 + \sum_{i=1}^{p} b_{1i} \ln y_{t-i} + \sum_{i=p+1}^{p+m} b_{2i}\, lny_{t-i} + \sum_{i=1}^{p} c_{1i} \ln e_{t-i} + \sum_{i=p+1}^{p+m} c_{2i}\, lne_{t-i} + \sum_{i=1}^{p} d_{1i} \ln k_{t-i} + \sum_{i=p+1}^{p+m} d_{2i}\, lnk_{t-i} + u_{1t} \quad (3)$$

$$ln\, e_t = a_2 + \sum_{i=1}^{p} f_{1i}\, ln\, e_{t-i} + \sum_{i=p+1}^{p+m} f_{2i}\, lne_{t-i} + \sum_{i=1}^{p} g_{1i}\, ln\, y_{t-i} + \sum_{i=p+1}^{p+m} g_{2i}\, lny_{t-i} + \sum_{i=1}^{p} h_{1i}\, ln\, k_{t-i} + \sum_{i=p+1}^{p+m} h_{2i}\, lnk_{t-i} + u_{2t} \quad (4)$$

$$\ln k_t = a_3 + \sum_{i=1}^{p} j_{1i} \ln k_{t-i} + \sum_{i=p+1}^{p+m} j_{2i}\, lnk_{t-i} + \sum_{i=1}^{p} l_{1i} \ln e_{t-i} + \sum_{i=p+1}^{p+m} l_{2i}\, lne_{t-i} + \sum_{i=1}^{p} r_{1i} \ln y_{t-i} + \sum_{i=p+1}^{p+m} r_{2i}\, lny_{t-i} + u_{3t} \quad (5)$$

Where y_t is the per-capita real GDP, $e_t$is the per-capita real energy consumption, and k_t is the per-capita real capital stock and u_{it} for i=1, 2 3 are white noise error terms. P is the optimal lag length, m is the maximum order of integration for the time-series.

The conservation hypothesis, which asserts a one-way causality running from economic growth to energy consumption, is confirmed if $g_{1i} \neq 0\ \forall i$ in equation 4. Support for the growth hypothesis of a one-way causality from energy consumption to economic growth exists if $c_{1i} \neq 0\ \forall i$ in equation 3. A bidirectional causality between energy consumption and economic growth, i.e. the feedback hypothesis, will hold if both $c_{1i} \neq 0\ \forall i$ and $g_{1i} \neq 0\ \forall i$ in equations 3 and 4, while the neutrality hypothesis holds if both $c_{1i} = 0\ \forall i$ and $g_{1i} = 0\ \forall i$.

6. Empirical Results

6.1.Unit Root Tests

Results of the ADF and PP unit root tests for the variables in levels and in first differences are reported in Tables 2 and 3 respectively. According to the both the ADF and PP tests, both the per-capita real GDP and per-capita real gross capital formation time series are non stationary at level across all specifications of the tests, and they become stationary at their first difference. In other words, both $\ln y$ and $\ln k$ are integrated of order one I(1). For the energy consumption series, both the ADF and PP tests show that the aggregate primary energy consumption, and all its disaggregated components, are stationary in level I(0) in the specification which includes an intercept and a trend which is a relevant specifications since the energy consumption time series shows an upward trend as evident in figures 1 to 4. When unit roots tests are conducted using the first difference of the energy consumption series, all energy consumption series are stationary based on both the ADF and PP tests and across all test specifications.

Results of the Zivot-Andrews structural break unit root test for all variables at level and first difference are presented in Table 4. Results show that time series of GDP, electricity, natural gas, coal and oil are all stationary at level with a single structural break in 1991, 1988, 2006, 1998 and 1991 respectively, while physical capital and total primary energy are non stationary at level with a single structural break in 1991 and 2001 respectively. Results also show that all time series, at first difference, become stationary with structural breaks shown in the table. As shown in Table 4, all t-statistics are statistically significant which imply rejection of the null hypothesis of having a unit root with a structural break.

Results of the Clemente et al., (1998) unit root test are presented in Table 5 for both versions the Additive Outlier and Innovational Outlier versions. Results show that the time series of all variables are non stationary at levels with two structural breaks under the Additive Outlier version of the test. For electricity, natural gas, and coal time series, the first structural break TB1, took place in 1990, and in 1991 for GDP and 1992 for oil and 1988 for physical capital and 1995 for total primary energy consumption. The second structural break TB2 took place in 1999 for physical capital, 2000 for electricity and natural gas, 2001 for GDP and oil and 1996 for coal. Under the Innovational Outlier version of the Clemente et al.,(1998) unit root test, it is only natural gas and coal time series that are stationary at level with two structural breaks in 1998 and 2007 for natural gas and 1988 and 1996 for coal. The structural breaks identified by the unit root tests coincides with the 1990 oil price shock accompanying the first Gulf war and the implementation of the Economic Reform and Structural Adjustment Programme (ERSAP) .

In 1991, Egypt adopted a battery of reform policies under the ERSAP after consultation with the IMF and the World Bank, to restore the internal as well as the external balance. Liberalization of the domestic prices of energy products was an integral part of this program and has resulted in a substantial increase in energy prices in Egypt. As part of the ERSAP, the Egyptian government raised the petroleum prices to 100% of the international prices, and electricity prices to 74% of long-run marginal costs. This was synchronized with an oil price spike after the Iraqi Invasion to Kuwait which was followed by the first Gulf was in 1991.

Table 2. ADF and PP Unit root tests of variables in levels

	GDP		Capital		Total Primary energy		Electricity		Natural gas		Coal		oil	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP
Intercept	-0.19	-0.19	-0.75	-1.15	-1.88	-1.88	-1.73	-1.29	-4.53***	-4.07***	-3.47**	-3.61**	-4.48***	-4.14***
Trend and intercept	-1.72	-1.95	-1.01	-1.19	-3.88**	-3.88**	-3.58**	-3.77**	-5.51***	-11.70***	-6.69***	-7.17***	-3.99**	-3.79**
No trend and intercept	8.88	7.96	0.53	0.40	3.24	3.22	-5.57***	-6.53***	-4.56***	-3.71***	0.43	-0.08	-0.59	-1.15

*, **, *** indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance, respectively. For the ADF test, the hypotheses of interest are H_0: series has a unit root versus H_1: series is stationary. The ADF augments the test using p lags of the dependent variable to ensure that the error terms of the test are not autocorrelated. The Schwarz Bayesian Information Criterion (SBIC) is used to determine the optimal lag length of the ADF test. Three versions for both the ADF and PP tests are used; one version allows for an intercept, a second allows for an intercept and a deterministic trend, and a third version excludes both the intercept and the deterministic trend. The null hypothesis is rejected if the ADF statistic, defined as the t-ratio of the coefficient γ in equation (1), is greater that the critical value from the Dickey-Fuller table. The PP test is similar to the ADF test but it uses a non-parametric correction of any serial correlation and heteroskedasticity in the errors (u_t) of the test regression by directly modifying the test statistics

Table 3. Unit root tests of variables in first difference

	GDP		Capital		Total Primary energy		Electricity		Natural gas		Coal		oil	
	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP	ADF	PP
Intercept	-3.88***	-3.93***	-3.87***	-3.84***	-5.61***	-6.41***	-3.76***	-8.92***	-3.62**	-4.26***	-5.63***	-29.05***	-3.98***	-4.10***
Trend and intercept	-3.55*	-3.76**	-3.96**	-3.93**	-5.52***	-5.80***	-3.59**	-9.67***	-3.16*	-4.05**	-5.51***	-29.25***	-3.90**	-4.23**
No trend and intercept	-1.78*	-1.78*	-3.92***	-3.89***	-4.53***	-4.53***	-2.08**	-4.14***	-3.10***	-3.45***	-8.65***	-14.38***	-4.09***	-4.19***

*, **, *** indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance, respectively. For the ADF test, the hypotheses of interest are H_0: series has a unit root versus H_1: series is stationary. The ADF augments the test using p lags of the dependent variable to ensure that the error terms of the test are not autocorrelated. The Schwarz Bayesian Information Criterion (SBIC) is used to determine the optimal lag length of the ADF test. For the KPSS test, the hypotheses of interest are H_0: series is stationary versus H_1: series has a unit root.

Table 4. Zivot-Andrews structural break trended unit root test.

	At level		At first difference	
	T-statistic	Time break	T-statistic	Time break
GDP	-4.83* (1)	1991	-5.28** (0)	1988
Physical capital	-4.79 (1)	1991	-5.23** (0)	1994
Total primary energy	-4.32 (0)	2001	-7.24*** (0)	1994
Electricity	-6.58*** (0)	1988	-10.03*** (1)	1987
Natural gas	-6.30*** (0)	2006	-5.63*** (0)	1986
Coal	-7.25*** (0)	1998	-6.11*** (2)	1990
Oil	-6.54*** (2)	1991	-4.96* (0)	1986

For Zivot-Andrews structural break trended unit root test, the hypotheses of interest are H_0: the time series has a unit root with a structural break versus H_1: time series is stationary with a structural break. *, **, *** indicate rejection of the null hypothesis at 10%, 5% and 1% level of significance, respectively

Table 5. Clemente-Montanes-Reyes unit root test with double mean shifts

	Additive Outlier			Innovative outliers		
Variable	T-statistic	T_{B1}	T_{B2}	T-statistic	T_{B1}	T_{B2}
GDP	-2.48	1991	2001	-3.68	1993	2004
Physical capital	-3.71	1988	1999	-2.94	1984	2004
Total primary energy	-3.83	1995	2002	-5.41	1992	2006
Electricity	-2.91	1990	2000	-2.84	1996	2001
Natural gas	-4.28	1990	2000	-5.65**	1998	2007
Coal	-3.83	1990	1996	-6.97**	1988	1996
Oil	-4.71	1992	2001	-5.04	1994	2002

T_{B1} and T_{B2} are the dates of the structural breaks and ** indicates rejection of the null hypothesis at 5% level. For the Clemente, Montanes and Reyes test, the hypotheses of interest are H_0: the time series has a unit root with structural breaks versus H_1: time series is stationary with structural breaks.

In the beginning of the new millennium, a worldwide energy crisis took place. At the beginning of 1999 oil price was $10 a barrel. In the second half of 2000 it reached over $30. Since then energy prices have been increasing due to the continued global increases in oil demand coupled with production stagnation and the falling value of U.S. dollar.

6.2. Results of Toda and Yamamoto Causality Test

Results of various unit root tests presented in the previous section show that the maximum order of integration of the time series is one, i.e. $m = 1$. The optimal lag length of the unrestricted

VAR models is one, determined based on the different information criteria, AIC, SBIC. Results of the Toda-Yamamoto causality test are presented in Table 7.

The order of integration of the time series varied across the different unit rot tests. To avoid the problems associated with wrong determination of the order of integration and the cointegration properties among the time series, Toda and Yamamoto (1995) proposed a modified Wald test by augmenting the standard Granger causality test through adding extra lags of each variable in the VAR model to correct for any 'nuisance parameters' in the asymptotic distribution of the Wald test statistic's if some of the series are non-stationary. This modified Wald test statistic could then be used to make valid inferences about causality. Toda Yamamoto approach fits a standard VAR model in the levels of the variables instead of the first differences as in the case of the regular Granger causality test.

Results of the Toda- Yamamoto Granger non-causality test are presented in Table 6. Results show no causal relationship between total primary energy consumption and economic growth, supporting the neutrality hypothesis. As shown in panel A of Table 6, the modified Wald Statistics are not statistically significant. Hence, we fail to reject the null hypothesis that total primary energy consumption does not Granger cause real GDP. Likewise, we also fail to reject the null hypothesis that real GDP does not Granger cause total primary energy consumption. Panel A also shows no causal relationship between primary energy consumption and physical capital. Based on the modified Wald Statistics, which are not statistically significant, we fail to reject the null hypothesis that primary energy consumption does not Granger cause physical capital and we also fail to reject that physical capital does not Granger cause primary energy consumption.

When the analysis is stratified by energy type, a one way positive causal relation running from economic growth to electricity and oil consumption was found which is consistent with the conservation hypothesis. Results depicted in panel B shows no causality between electricity consumption and physical capital. The modified Wald Statistics fail to reject the null hypothesis that electricity consumption does not Granger cause physical capital and we also fail to reject that physical capital does not Granger cause electricity consumption. As for the relationship between electricity consumption and economic growth, a unidirectional causality running from real GDP to electricity consumption is found based on the modified Wald statistics which is statistically significant at 5% significance level. In Panel C, a unidirectional positive causality running from real GDP to oil consumption is found as the null hypothesis that GDP does not Granger causes oil consumption is rejected since the Wald statistic is significant. While we fail to reject the null hypothesis that oil consumption does not Granger cause real GDP. In addition, results show that oil consumption Granger causes physical capital while the other direction of causality does not hold.

Panel D presents results of the Granger non-causality test for natural gas consumption. None of the Wald statistics is significant and hence we fail to reject the null hypotheses of no causal relationship between natural gas consumption, real GDP and physical capital. Similarly, panel E shows no causality between coal consumption and real GDP as we fail to reject the null hypotheses of no Granger causality based on the Wald statistics which supports the neutrality hypothesis.

Table 6 Toda- Yamamoto Granger non-causality test

Null Hypothesis	**Modified Wald Statistics**	**Sum of lagged coefficients**	**Direction of causality**
Panel A: Total Primary Energy Consumption			
Total primary energy consumption does not Granger cause GDP	0.749	-0.083	none
GDP does not Granger cause total primary energy consumption	0.757	0.526	none
Total primary energy consumption does not Granger cause physical capital	0.11	-0.212	none
Physical capital does not Granger cause total primary energy consumption	0.30	0.054	none
Panel B: Electricity consumption			
Electricity consumption does not Granger cause GDP	0.837	0.087	none
GDP does not Granger cause electricity consumption	3.33**	1.159	Y to Electricity
Electricity consumption does not Granger cause physical capital	0.361	0.375	none
Physical capital does not Granger cause Electricity consumption	0.187	-0.042	none
Panel C: Oil Consumption			
Oil Consumption does not Granger cause GDP	0.202	0.048	none
GDP does not Granger cause oil consumption	3.358**	0.929	Y to oil
Oil consumption does not Granger cause physical capital	3.944**	1.27	Oil to K
physical capital does not Granger cause oil consumption	0.001	0.003	none
Panel D: Natural Gas Consumption			
Natural gas consumption does not Granger cause GDP	0.88	-0.034	none
GDP does not Granger cause natural gas consumption	0.012	-0.159	none
Natural gas consumption does not Granger cause Physical capital	1.44	-0.29	none
Physical capital does not Granger cause natural gas consumption	0.20	-0.105	none
Panel E: Coal Consumption			
GDP does not Granger cause coal consumption	0.139	-0.735	none
Coal consumption does not Granger cause GDP	0.029	0.005	none
Coal consumption does not Granger cause physical capital	0.050	0.044	none
Physical capital does not Granger cause coal consumption	0.506	-0.20	none

** indicates rejection of the null hypothesis at 5% significance level.

7. Conclusions and Policy implications

This paper investigated the causal relationship between energy consumption and economic growth in Egypt at the disaggregated level, during the period 1980-2012, within a multivariate framework by including measures for capital and labor in the aggregate production function. To endogenously control for any potential structural breaks when checking the stationarity properties of the energy and growth time series, Zivot and Andrews (2002) and Clemente et al., (1998) unit root tests are used. The causal relationship between energy consumption and economic growth is examined using a modified version of the Granger causality test due to Toda and Yamamoto (1995) to avoid problems resulting from wrong determination of the order of integration of the different time series.

Causality analyses show now causal relationship between total primary energy consumption and economic growth, supporting the neutrality hypothesis. When the analysis is stratified by energy type, a positive unidirectional causal relation from economic growth to electricity and oil consumption was found which is consistent with the conservation hypothesis. In addition, no causal relationship was found between physical capital and any of the energy components, except for oil in which a one way positive causality running from oil consumption to physical capital is found.

The findings of this paper are consistent with those of Wolde-Rufael (2009) who found a unidirectional causality running from economic growth to aggregate energy consumption. But in the current study, economic growth causes only electricity and oil consumption. The finds are also in line with the findings of Yıldırım et al. (2014) who found no casual relationship between aggregate energy consumption and economic growth supporting the neutrality hypothesis. In a previous study, Wolde-Rufael (2006) found positive bidirectional causality between electricity consumption and economic growth. However, in the current study, a positive unidirectional causal relation from economic growth to electricity is found.

Since the 2011 revolution, Egypt has experienced frequent electricity blackouts and severe shortages in energy supplies. Securing a sustainable and reliable supply of energy remains one of the key challenges that face the current Egyptian government. Recent temporary supplies, from some Arab-Gulf oil producing countries have helped mitigate short-term energy pressures.

Nevertheless, these supplies are temporary in nature and are expected to disappear with the recent collapse of oil prices.

Several factors have exacerbated the energy problems in Egypt. These include the expanding energy demand, shortages in natural gas supplies, aging generation and transmission infrastructure as well as stagnant investment in the energy sector. Understanding the nature of these problems is vital for developing appropriate solutions. New investments in the power sector, renovation of existing aging infrastructure, as well as the proper management of energy demand has to be at the core of any energy reform policy in Egypt. To face the high and expanding energy demand, several policy reforms have been recently implemented by the Egyptian government. These include subsidy reform whereby the government reduced the subsidy on energy for heavy industries and household electricity use. The energy subsidies have accounted for a considerable fraction of the government expenditure with a cost of $26 billion in 2012 and have contributed to the rising energy demand and continuous budget deficit. The reduction of energy subsidy was accompanied by the introduction of a smart card system to direct the subsidies toward the poorest people and increase its effectiveness. Expansion of power generated from renewable sources specially wind and solar could also be a promising solution.

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

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