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The Impact of Energy Prices on Electricity Production in Egypt

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ABSTRACT

The paper examines the impact of energy prices on electricity generation by different fuel sources (i.e., oil, gas, and hydropower) in Egypt by employing the autoregressive distributed lag approach and bounds test. Two models are estimated where the first accounts for oil prices only whereas the second include both gas and oil prices. In the first model, oil prices negatively affect the electricity produced from oil in the short-run with no impact in the long-run. Also, hydropower is complementary for oil in electricity production only in the short-term whereas gas is a substitute for oil in both long and short terms. In the second model, both energy prices influence electricity generation from oil in both short and long runs while gas and hydropower are respectively, substitute and complementary to oil in both long and short-run.

Keywords: Energy Prices, Electricity Generation, Fuel, Elasticity of Production
JEL Classifications: Q400, Q430

1. INTRODUCTION

Egypt is the largest non-OPEC oil producer and the third-largest natural gas producer in Africa following Algeria and Nigeria. However, it is also considered as the biggest consumer of oil and natural gas in Africa. In 2010, Egypt consumed around 22% and 37% of petroleum and dry natural gas consumption in Africa respectively (USEIA, 2018). According to (USEIA, 2015), the current energy mix in Egypt is not well-diversified as it heavily depends on fossil fuels that represent about 94.4% of total primary energy use in 2014.

Further, Egypt faces many challenges to ensure energy security given that the Egyptian oil and natural gas proved reserves declined during the last period. According to (BP, 2018), Egypt's proven reserves of oil have dropped from a peak of about 4.5 billion barrels in 2010 to around 3.3 billion barrels in 2017. Also, reserves of natural gas fell from 74 trillion cubic feet (Tcf) during the period (2008-2011) to reach about 64 Tcf over the period (2013-2017).

Egypt has recently witnessed a substantial increase in the demand of all of the energy products compared to the growth in the domestic supply level. This surge in consumption may be justified by the high rate of population growth, the generous subsidy policy as well as economic development. In terms of the supply level, the stagnation of the production is attributed to the maturity of many gas and oil fields beside the departure of foreign investment due to political instability after the 2011 revolution accompanied by external arrears to international energy companies (Hegazy, 2015; IMF, 2015; Rady et al., 2018). Over the period (2005-2017), the compound annual growth rate (CAGR)[1] for generation and use of dry natural gas is estimated at 1.52% and 5.22% respectively whereas the CAGR for production and consumption of oil is valued at −0.15% and 2.36% in that order. As a result, the domestic demand gap of energy demand has been covered through imports of energy products, which led Egypt's to be a net oil and gas importer since 2010 and 2015 respectively.

As indicated by (CAPMAS, 2016), the electricity sector is the dominant consumer of natural gas and oil since it consumes more than 42% of total oil and gas usage in the financial year

1 CAGR are calculated based on (BP, 2018).

2014/2015. According to Egypt's Vision 2030, energy comes as the second most important pillar of sustainable development strategy amongst ten components. Energy-related issues highlighted by the vision report include optimal and domestic use of energy resources, and diversification of the energy supply-mix with the target of generating around 20% of total electricity from renewable resources by 2020 to mitigate CO_2 emissions (Mondal et al., 2019). However, the target of shifting towards increasing the share of renewable energy in electricity generation was then postponed to 2022 due to the political unrest in Egypt after the 2011 revolution (IMF, 2018).

Electricity is an essential input for almost all economic activities in modern economies. Thus, electricity security is a central component of energy security in all countries. However, the determinants of electricity production have been neglected in the literature that extensively investigates the energy (electricity)-economic growth nexus. International policymakers have seriously considered the security of electric power production given the oil supply crisis caused by the Arab uprisings emerged in early 2011 (Sequeira and Santos, 2018). The literature on the energy (or electricity) production is rare. According to the best of our knowledge, the issue of electricity production has been investigated by two studies (i.e., Sequeira and Santos, 2018; Kharbach and Chfadi, 2018).

Since 2011, Egypt has frequently witnessed electricity blackouts accompanied by a severe shortage of energy supplies. Recent supplies provided by some Arab-Gulf oil-producing countries were helpful to alleviate short-run energy pressures. However, these supplies are, in nature, impermanent and are expected to vanish given the sharp decline of oil prices since mid-2014 (Sharaf, 2017). In 2018, the Egyptian government (EGO) approved an automatic fuel price indexation mechanism whereby fuel prices adjust to changes in world prices, the exchange rate, and the share of imported fuel in domestic consumption. This mechanism aims to safeguard the state budget from unexpected increments in the exchange rate and world oil prices taking into consideration the devaluation of the Egyptian pound and fuel price hikes in 2016 (IMF, 2018). Thus, it is of crucial importance to examine the impact of global energy prices on electricity production in Egypt. According to (Kharbach and Chfadi, 2018), oil prices have a significant influence on the choice of electricity generation by different energy sources in Morocco. They proposed a disaggregated approach to quantify the production elasticity of electricity produced by various sources to oil prices in Morocco. Their method is suitable to countries with a traditional single public utility. The electricity generation in Egypt could be investigated using the proposed approach of (Kharbach and Chfadi, 2018) given that Egypt has a regulated energy market where the electricity sector is managed by the state-owned Egyptian Electricity Holding Company (EEHC), that run electricity production, transmission, and distribution sectors (Rady et al., 2018). The paper expands the analysis of (Kharbach and Chfadi, 2018) by incorporating the impact of world prices of gas and oil on electricity generation by different sources (oil, gas, and water) in Egypt. This is done by employing the autoregressive distributed lag (ARDL) approach and bounds test of (Pesaran et al., 2001) over the period (1985-2017). The bounds test method is advantageous in small-sized samples compared to other methods of cointegration such as the Engle and Granger (1987) and Johansen and Juselius (1990). The current paper, to the best of our knowledge, is the first to estimate long and short-run elasticities of electricity production to the world prices of oil and gas and gross domestic product (GDP).

Our results indicate that the price of oil negatively affects the electricity produced from oil in the short -run with no impact in the long-run when the model does not account for gas prices. Additionally, Gas is a substitute for oil over long and short term whereas hydropower is complementary for oil in electricity generation only in the short-term. When the model includes both energy prices, both prices affect electricity generation from oil sources in both short and long runs. Finally, gas is a substitute for oil while hydropower is complementary to oil in electricity supply in both long and short-term.

The paper is structured as follows. Section 1 presents the introduction highlighting the research problem while Section 2 provides a brief review of the existing literature. The third part introduces an overview of the energy sector in Egypt whereas Section 4 presents methodology. Section 5 provides data analysis and empirical results, and finally, Section 6 concludes and draws some policy implications.

2. LITERATURE REVIEW

Energy economics literature has extensively investigated the issue of causal links between energy consumption (EC) (or electricity consumption [ELC]) and economic growth (GDP). However, surveys conducted by Ozturk (2010), Payne (2010) and Bouoiyour et al. (2014) reveal that the empirical testing of this nexus is still controversial providing mixed and conflicting results even for the same country. Results of Balcilar et al. (2010) and Tzeremes (2018) highlight the importance of adopting time-varying framework since the relationship between EC (ELC) and GDP is likely to be subject to structural changes and regime shifts. By applying a bootstrap panel cointegration test onto data of 15 transition countries, Wolde-Rufael (2014) finds that ELC significantly influences GDP in Bulgaria and Belarus; that GDP Granger-causes ELC in the Czech Republic, Lithuania, Latvia; and that bidirectional causation is valid for the Russian Federation and Ukraine. Karanfil and Li (2015) use data from 160 countries over the period 1980-2012. They confirm that the relationship between ELC and GDP is sensitive to regional differences, income levels, urbanization levels, and supply risks. Recently, Shahbaz et al. (2017) apply the cointegration approach onto annual data of 157 countries over the period from 1960 to 2014 to explore the relationship between ELC and GDP by incorporating oil price in the augmented production function. They detect evidence of cointegration between the variables and conclude that ELC stimulates GDP in the full panel and all regions and groups, but the conservation hypothesis is only valid for the lower-middle-income, Middle East and North Africa and South Asia groups. The growth hypothesis is found only valid for North America whereas the neutrality hypothesis is confirmed for the low-middle-income panel, Latin America & Caribbean and Sub-Saharan Africa countries.

Another strand of energy economics literature focuses on estimating price and income elasticities of electricity in both long-run and short-run (see, for example, Narayan et al., 2007; Holtedahl and Joutz, 2004; Blàzquez et al., 2013, Campbell, 2018). A less explored area in the energy economics literature is the determinants of electricity production despite the significant challenges on electricity supply systems. Recently, Sequeira and Santos (2018) apply the error correction approach on a panel dataset of 169 countries, including Egypt, over the period 1970-2014 to empirically investigate the impact of per capita GDP and weighted conflict index on the electricity production per capita. Their results reveal the existence of a significant negative effect of conflict index on electricity production and a positive impact of income on electricity supply, both in short and long-run. Moreover, they analyze the impact of each of the sub-items of the weighted conflict index on electricity production. They detect evidence of a cointegration link between the different items of country-risk, income *per capita* and electric power production. Anti-government demonstrations and riots are found to negatively influence electricity production and significantly both in short and in the long-run. Guerrilla warfare affects electricity supply mostly in the short-run, except when the greatest producers of oil and natural gas are excluded. Nevertheless, purges, strikes, and revolutions seem to have an insignificant effect on electricity production. Kharbach and Chfadi (2018) analyze the relationship between oil price and electricity production by different fuel sources (coal, oil, and water) in Morocco, over the period 1971-2013, using a vector error correction model. They find that the elasticities of the electricity produced by coal and oil to oil prices are similar in the long run. In contrast, significant differences exist in short-term elasticities. Moreover, they conclude that hydropower could substitute the electricity produced by coal in the short-term but not in the long-term.

Regarding the literature on the economics of energy in Egypt, it can be classified into three groups. The first group of papers (e.g., Abouleinein et al., 2009; Elshennawy, 2014; and research cited in Al-Ayouty and Abd El-Raouf, 2015) have studied the impact of the liberalization of energy prices from three different aspects: distributional implications, impact on the consumption of households and the macroeconomy, and the effects on various industries. The second group of research (e.g., Al-Ayouty and Abd El-Raouf, 2015; Atlam and Rapiea, 2016; Mondal et al., 2019) have focused on the right energy mix to achieve energy security and low-carbon emissions. The third group of research papers tests the EC/ELC-economic growth nexus in Egypt, among other countries. Similar to empirical findings for other countries, the direction of causation links is inconclusive for Egypt. Mixed results could be explained by ignoring the presence of structural break by some studies (e.g., Wolde-Rufael, 2006; 2009; Ozturk, and Acaravci, 2011) or by using the aggregate level of EC (e.g., Yıldırım et al., (2014). Sharaf (2017) tested for the causal link between GDP and EC at the disaggregated level (i.e., oil, electricity, natural gas, and coal) to account for aggregation bias, within a multivariate framework by adding measures for capital and labor in the aggregate production function. Moreover, the analysis endogenously controls for potential structural breaks in the employed series when executing the unit root tests. Findings reveal no causal links between total primary EC and GDP. However, a positive unidirectional causality running from GDP to electricity and oil consumption is found. Similarly, Ibrahiem (2018) found two-way causation between ELC and real output in the services sector, a one-way causality running from real output in the industrial sector to ELC but no causation is detected between ELC and real output in the agricultural sector in Egypt over the period 1971-2013.

3. AN OVERVIEW OF THE ENERGY SECTOR IN EGYPT

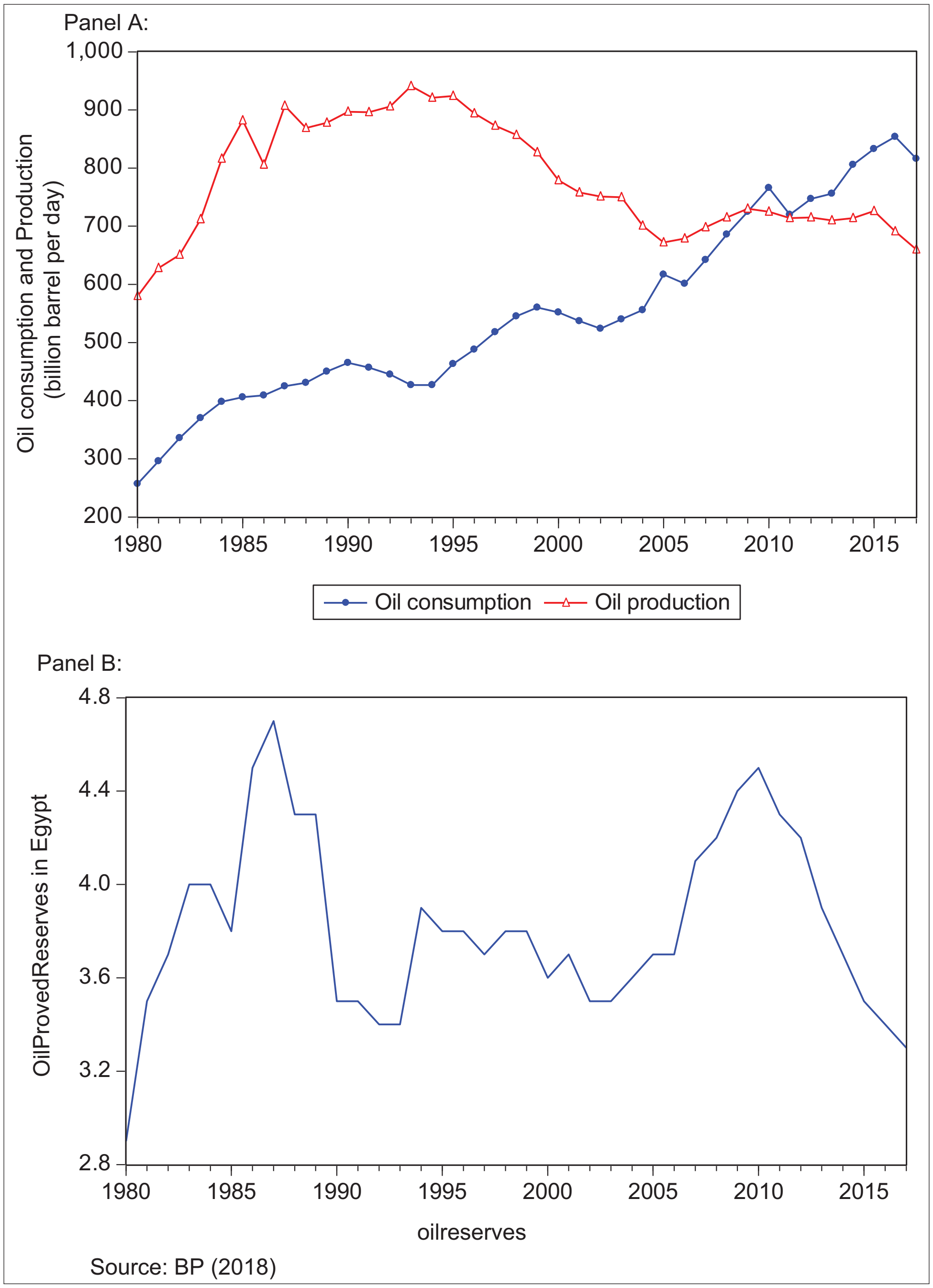
3.1. Oil and Gas Sectors

The petroleum sector in Egypt is controlled and managed by five state-owned enterprises according to Egypt's Ministry of Petroleum. Figure 1 displays consumption, production and proven reserves of crude oil during the period (1980-2017). Panel A of Figure 1 shows that oil production has been steadily declining as a result of the overall decrease in output from its legacy onshore fields. In contrast, oil consumption has surged over the same period due to the inefficient subsidy policy given that the bottom quintiles of the population benefit the least from the petroleum product subsidies (Al-Ayouty and Abd El-Raouf, 2015). Thus, Egypt has turned to a net-importer of oil starting from 2010. Hence, one of Egypt's significant challenges is to satisfy increasing domestic oil demand with the sluggish growth of oil supply. According to (USEIA, 2018), oil consumption is expected to continue growing, even when accounting for the removal of energy subsidies. As presented in Panel B of Figure 1, Egypt's proven oil reserves have declined sharply during the period (2010-2017). Maturing oil fields and lack of discoveries to adequately compensate for the decline could explain this deterioration.

Figure 2 displays consumption, production, and reserves of natural gas in Egypt during the period (1980-2018). Panel A of the graph indicates that gas supply was mainly used to satisfy domestic use until 2004. Starting in 2005, Egypt has become a net exporter of natural gas as its supply exceeds domestic consumption. Thus, the EGO encourages households, firms, and the industrial sector to use natural gas as a substitute for petroleum products and coal. The accelerating growth of gas usage compared to its supply led Egypt to decrease exports of dry natural gas and to import liquefied natural gas to satisfy the domestic market. Consequently, Egypt has become a net importer of natural gas starting from 2015. In 2014, Egypt began to to raise domestic gas prices as a part of the energy prices reform in an attempt to decrease the budget deficit. This reform aims at removing all energy subsidy by 2020. The EGO issued a new law in August 2017 that allows for a more competitive gas market to motivate existing and potential new investors and increase the future production of natural gas (Ouki, 2018).

Panel B of the Figure 2 reveals that Egypt's reserves of natural gas have increased gradually from 4 Tcf in 1980 to reach a peak of 74 Tcf in 2011. This was followed by reserves decline during 2012-2017. Accordingly, Egypt is considered the fourth-largest natural gas reserves in Africa, after Nigeria, Algeria, and Mozambique. According to (USEIA, 2018) the recent natural

Figure 1: Crude oil production and consumption and proven reserves in Egypt



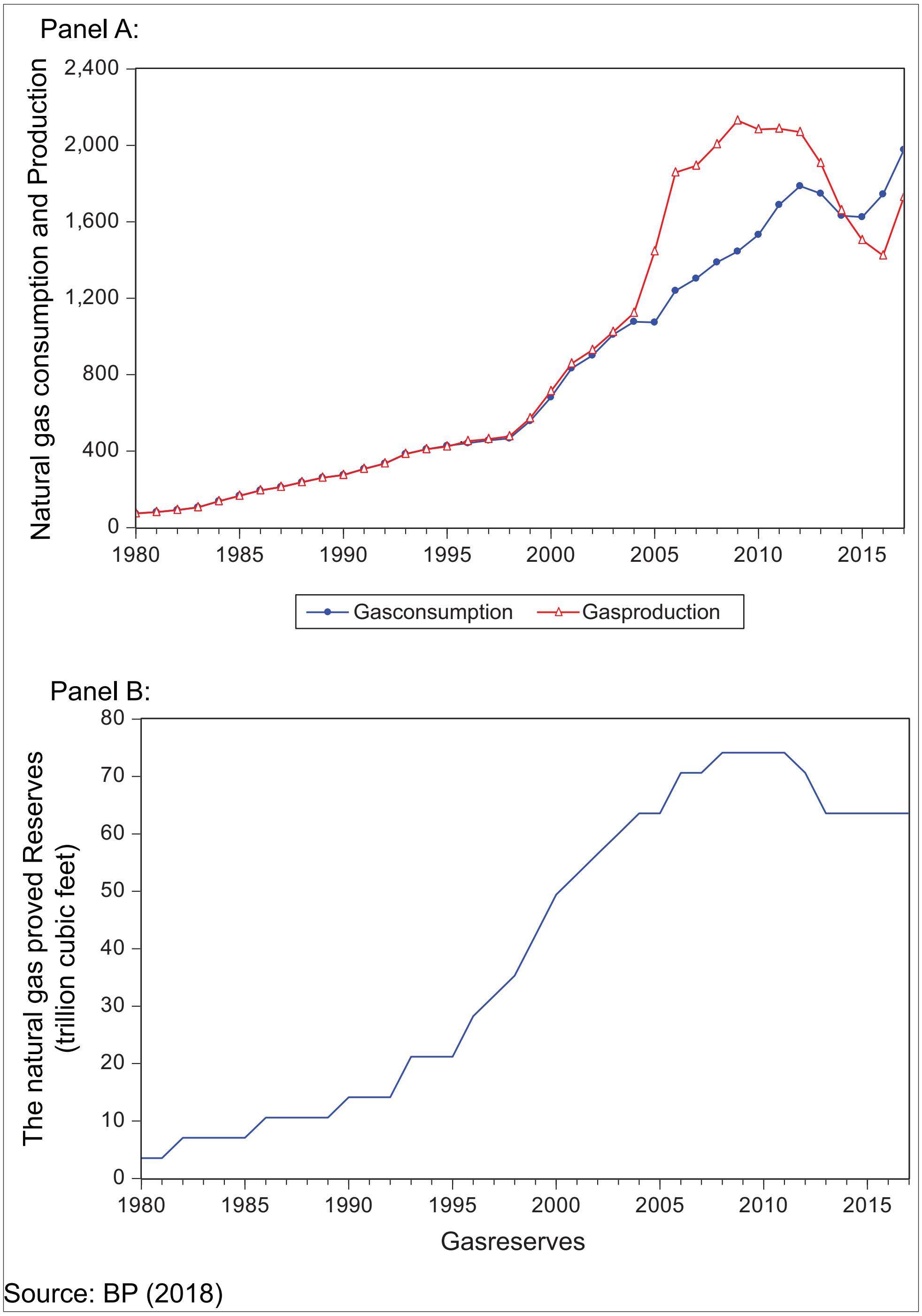
Source: BP (2018)

gas discoveries that started with Zohr field in 2015 are expected to cause a significant rise in total natural gas reserves in the next few years which could allow Egypt to be a net exporter of gas over the medium-term. However (Ouki, 2018) points out that it is unlikely for Egypt to regain its past natural gas export position as the export levels could drop quickly, based on publicly available supply and demand data and information.

In terms of energy use, Egypt is the largest oil and natural gas consumer in Africa. Reasons behind this include the high growth rate of population, the increase of industrial output and economic growth, energy-intensive natural gas and oil industries, the surge of car sales, and energy subsidies. However the phasing out of energy subsidies could lessen consumption growth in the short-run, but the increase in population and the growing transportation sector is expected to induce energy demand in the long-run (USEIA, 2018). Figure 3 shows that the electricity sector is the dominant consumer of natural gas and oil since it consumes around 36.4% and 42.4% of total oil and gas use in 2010/2011 and 2014/2015, respectively. Simultaneously, the share of industry in oil and gas usage has declined from 23.6% to 19.8% over the same period due to the turmoil accompanying the January revolution emerged in early 2011 that led to shutting down of many factories.

According to the Egyptian Ministry of Planning, Monitoring and Administrative Reform (MOPMAR, 2017), the investment of

Figure 2: Natural gas production and consumption and proven reserves in Egypt



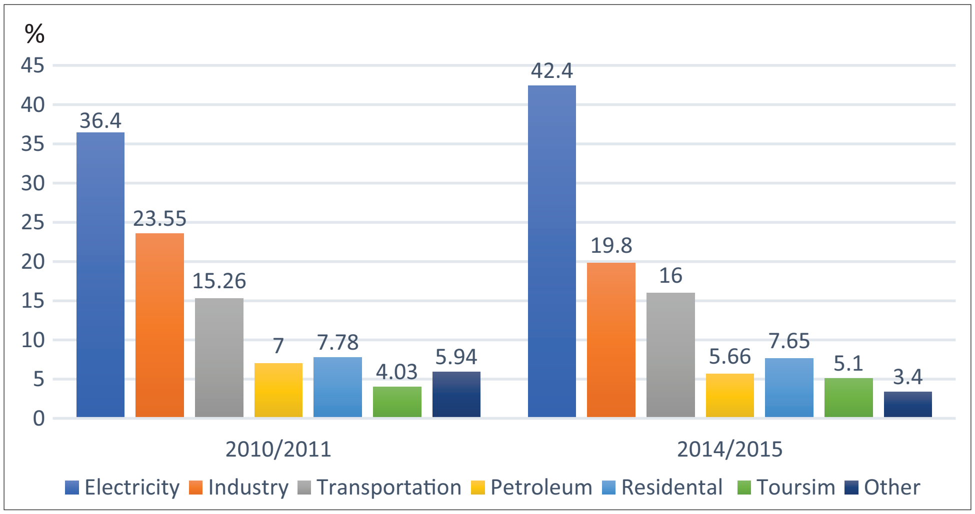
Source: BP (2018)

the extractive sector has grown by 9.1% in 2016/2017 where the foreign investors implemented two-thirds of these investments. Most of the implemented investment was mainly devoted to gas extraction as it accounts for 73% whereas oil investments account for around 10.2%

3.2. Electricity Sector

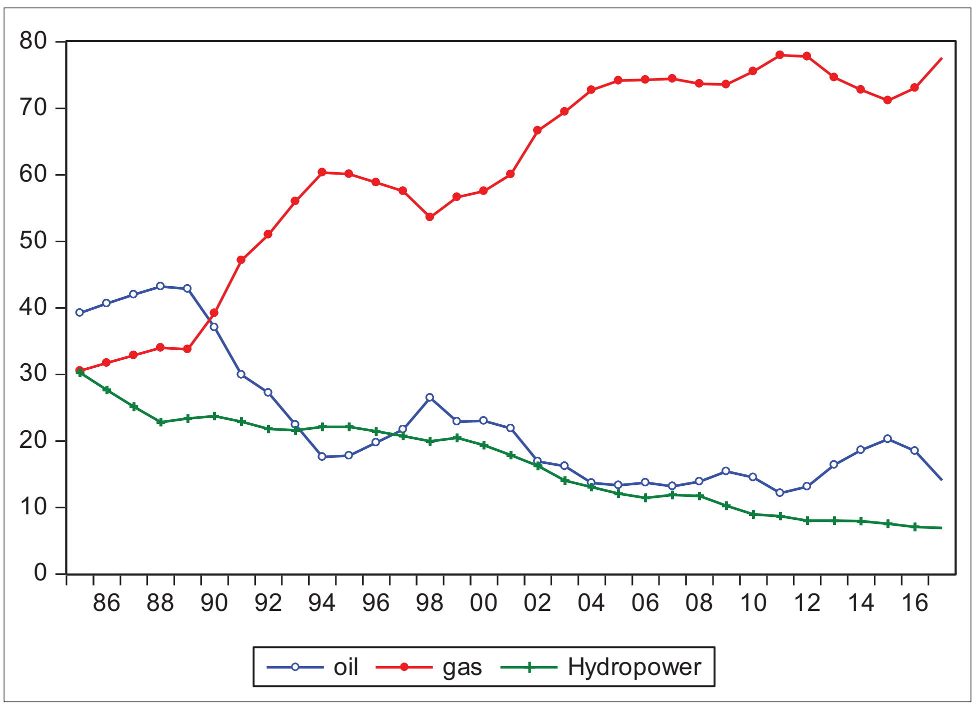
The electricity sector is owned and managed by the state. In 2015, the EGO issued law no. 87 to establish a broad framework to partially deregulate the existing electricity market through the introduction of some competition in an attempt to acquire the required investment from the private sector. In 2015/2016, Egypt had a total installed capacity of 38.86 gigawatts (GW) and generated 186.32-gigawatt hours (GWh) (USEIA, 2018). Electricity production in Egypt depends mainly on fossil fuels. Figure 4 depicts electricity production by different fuels namely oil, gas and hydropower. During the period of analysis, the contribution of these three sources represents more than 98% of the total electricity generation. Throughout the study period, oil share in electricity generation has declined from 39% to 14% between 1985 and 2017 due to the decline in oil production as mentioned earlier.

Figure 3: Oil and gas use by sector



Source: Central agency for public mobilization and statistics, annual statistical yearbook, different issues

Figure 4: Electricity production by different fuel sources (in percentages)



Source: BP (2018)

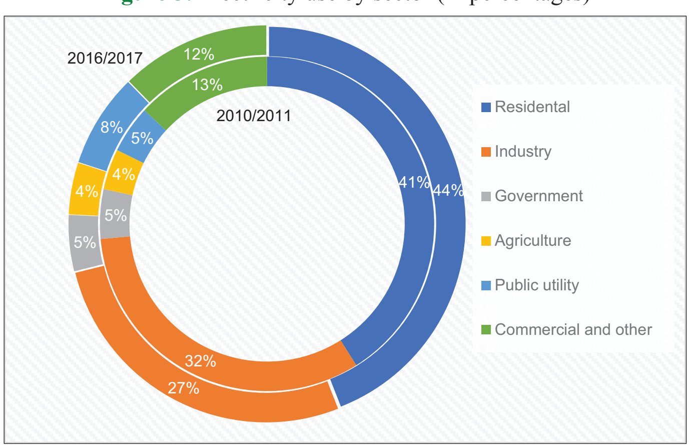
The hydropower is the third-largest energy source in Egypt as it had an installed capacity of 2.8 GW and generated 13.4 Terawatt hours (TWh) of hydroelectricity in 2017 where 69% of the country's hydropower comes from the Aswan High Dam (BP, 2018; EEHC, 2018). Figure 4 indicates that the contribution of hydroelectricity significantly dropped from 30% of total power generation in 1985 to just 7% in 2017 which could be explained by the exploitation of most of the hydropower potential. In contrast, the contribution of gas has substantially risen from 30% to 78% over the same period. Consequently, natural gas has become the dominant fuel in electricity generation in Egypt and it is anticipated to continue given the new gas discoveries. Since the 2011 revolution, electricity sector has experienced many difficulties in satisfying the growing electricity demand which led to regular breakout across the country due to the shortage in natural gas supply, the inefficient power stations, and distribution networks as well as slow growth of investments in the electricity sector (Al-Ayouty and Al-Raouf, 2015).

The electricity sector in Egypt still faces many challenges especially electricity shortages in the summer when consumption levels are highest due to the maturity of infrastructure and inefficient generation and transmission capacity in addition to high temperatures (USEIA, 2018). Another challenge that faces the Hydropower in Egypt is the implementation of the Grand Ethiopian Renaissance Dam (GERD) on the Nile River that raise the concerns about water shortage to Egypt's Aswan High Dam. However Ethiopia, Egypt, and Sudan signed an agreement to conduct studies on the potential impact of GERD on the Nile River in 2015, the negotiation has not produced any significant procedures to handle the economic and environmental effects resulting from the operation of GERD (USEIA, 2018). Accordingly, the EGO has paid attention to increasing the investment in the electricity sector aiming at achieving a diversified energy mix. The executed expenditures in the electricity industry amounted to about LE 70.8 billion during 2016/2017 with a growth rate of 286% compared with the pervious year where most of this investment were public (MOPMAR, 2017).

Concerning renewable resources in electricity production, Egypt has a strong potential for developing renewable energy resources. In 2007, the EGO set an ambitious plan to boost energy production from renewable sources apart from hydro (i.e., solar, and wind) (USEIA, 2018; Al-Ayouty and Abd El-Raouf, 2015). It is planned to raise the share of renewable energy to 20% out of the total produced power in Egypt by 2022. The plan aims at increasing the total installed capacity from wind to 7200 Megawatt (MW) by 2022 based on building wind projects with the involvement of the private sector. According to the plan, the share of hydropower, wind, and other renewable energy sources (mainly solar) would represent 6%, 12 %, and 2% respectively In 2016/2017, electricity generation from wind and solar sources grow by 9.7% and 360%. The surge in solar usage is due to installing 20 new solar plants to reach a total of 87 plants (EEHC, 2013; 2018). Consistent with (BP, 2018), the contribution of wind energy in electricity generation reached a peak of 1.34% in 2016 which is the highest share during the period (2000-2017). However, the contribution of renewable sources in total energy supply is still far from the planned targets.

Figure 5 shows the sectoral ELC in 2010/2011 and 2016/2017. As seen in the graph, the residential sector is the key consumer of electricity in Egypt due to the development of residential compounds and new communities as well as the use of domestic appliances, air conditioners during hot weather. The second sector in electricity demand is the industrial sector despite the decline in its share from 32% to 27% within the two years due to the shutting of many factories as a consequence of the January 2011 revolution.

Figure 5: Electricity use by sector (in percentages)



Source: Author calculation based on the data from the Egyptian Ministry of Planning, Monitoring and Administrative Reform (MOPMAR, 2017)

Over the period 1985-2014, electricity production has exceeded its consumption, allowing Egypt to export electricity to neighboring countries such as Jordan (Sharaf, 2017; Ibrahiem, 2018). Further, Egypt intends to participate in the regional and global electricity networks by 2020. In 2007, the National Democratic Party Congress decreed to establish an integrated Arab electricity network and to connect it with Arab countries in Northern Africa and the European network across Mediterranean countries. The Egyptian transmission grid is connected to Sudan, Lebanon, Jordan, and Libya and it is planned to connect Egypt with Saudi Arabia, that has a different peak load demand profile. Egypt's electricity exports are expected to reach 5000 GWh by 2050 (Rady et al., 2018; Mondal et al., 2019).

In the light of energy policy goals of Egypt's Vision 2030, Mondal et al., (2019) evaluated four scenarios to determine the optimum energy supply-mix and technology selection required to meet the rising electricity demand and to support export opportunities. The four alternative scenarios are compared to a Reference Scenario in which no policy intervention is imposed. Two different scenarios of shifting towards the use of renewable energy; namely, "Renewable Target30" and "Renewable Target40." The first one targets a share of 20% of renewable energy in total electricity generation by 2020 and 30% by 2050 whereas the latter presumes a contribution of 20% and 40%, respectively, over the same years. The third scenario, CO_2 Mitigation, assesses technology choices under the assumption of reducing CO_2 emissions by 5%, 10%, and 25% by 2020, 2030, and 2050, respectively. The fourth scenario, Limited Gas, considers a 2% growth of natural gas production for electricity generation until 2050 instead of the historical increase of 2.8%. The cumulative (2014-2050) renewable-based electricity generation is expected to reach 1270 TWh, 3536 TWh, 4432 TWh, 5465 TWh and 3448 in the Reference, the CO_2 Mitigation, the Renewable Target30, Renewable Target40, and the Limited Gas scenarios, respectively. However, the growth of renewable energy technologies improves Egypt's energy security, solar-based electricity generation requires higher investments, implying that Egypt will import oil for power generation in the scenario that limits gas production.

3.3. Energy Subsidies

Food and energy, including oil, gas, and electricity, have been considered the core of a comprehensive scheme of public subsidies for decades, which was not well-targeted since it benefited the well-off disproportionately rather than the poor. High energy subsidies create a bias toward capital and energy-intensive activities. Thus, they cause resources diversion, including foreign direct investment, towards such industries at the expense of more efficient or labor-intensive sectors (IMF, 2015; 2016). Figure 6 reveals that the subsidies system absorb almost 28.2%, on average, of the government's spending during (2011-2014) where two-thirds of subsidies went to energy. Electricity subsidies in Egypt incorporate both direct and indirect ones. Direct subsidies are those provided by the electricity sector to consumers whereas indirect ones are those that the government provides to oil and natural gas used in electricity generation (Al-Ayouty and Al-Raouf, 2015; Ibrahiem, 2018). Additionally, the Egyptian electricity sector includes two types of cross-subsidization. First, the electricity sector cross-subsidizes users by pricing below the cost of production. Second, the sector cross-subsidize electricity between industrial and commercial sectors, and the residential users (Al-Ayouty and Al-Raouf, 2015).

According to the Ministry of Finance (2018), the direct cost of electricity subsidies has grown from LE 8.6 billion in 2012/2013 to LE 30.5 in 2015/2016 which represents around 7.5% of total subsidies. Total energy subsidies exceeded EGO expenditure on health and education by more than seven and 3 times, respectively, in 2011. Subsidized electricity prices were lower than real marginal costs, implying rigidity in local electricity prices. The distortion associated with electricity subsidies includes rapid increase in energy demand, the misuse of electricity, and chronic budget deficit given that generating electricity relies upon non-renewable resources (e.g., natural gas) characterized by high marginal costs compared to renewable ones (wind and solar) with high fixed costs but almost zero marginal costs. The budgetary cost of untargeted energy subsidies reached around 6% of GDP in 2013/2014 which reflected their universal provision and provision high global oil prices. If budget assumptions were lower than international prices, the Egyptian General Petroleum Company (EGPC) bore the excess cost which negatively influenced its financial performance, resulting in enormous arrears to foreign partners and suppliers (IMF, 2015; Ibrahiem, 2018).

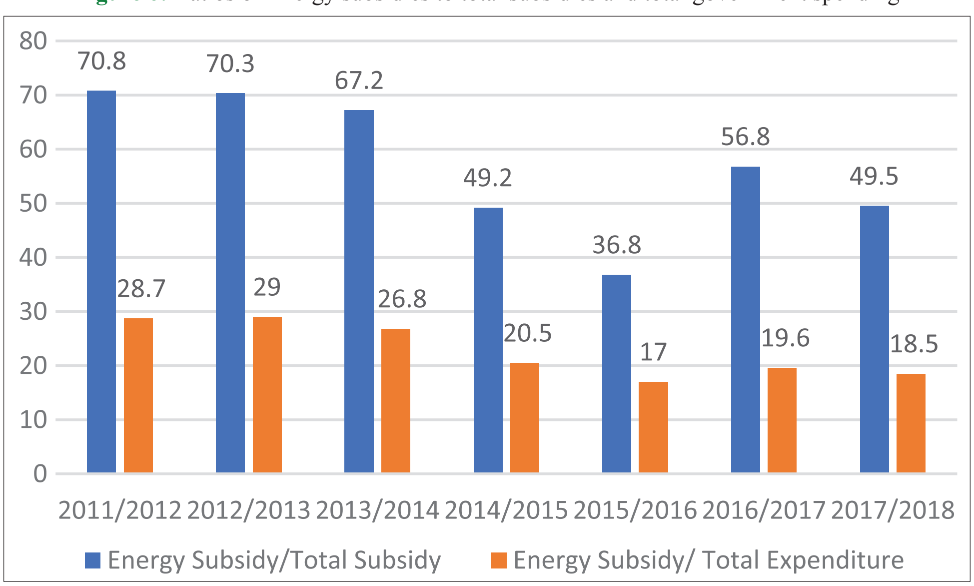
In 2014, The EGO issued decree number 1257 whereby energy subsidy reforms were implemented with the aim of achieving cost recovery in the following five years. Fuel prices were expected to rise by around 20% every year whereas electricity tariffs were planned to gradually increase over the period (2014/2015–2018/2019) by about 47% and 114% for low-consumption and high-consumption households, respectively. The IMF estimates that the expected budget savings from subsidies cut around 2% of GDP annually. Furthermore, the EGO is prepared to periodically adjust fuel prices or take any needed measures to offset any additional costs resulted from an unanticipated depreciation of the Egyptian pound or higher international oil prices with the aim of achieving the targeted price to cost ratios and preventing subsidies levels from being inconsistent with the fiscal targets (IMF, 2016; Al-Salaymeh et al., 2016; Ibrahiem, 2018).

Figure 6 shows that the ratios of Energy subsidies to total subsidies and total government expenditure sharply declined in 2015/2016 due to the combined effect of the adoption of the subsidy cut and the fall in world energy prices. However, the drastic increase in these ratios in 2016/2017 could be attributed to the devaluation of the Egyptian pound that is resulted in increasing the costs of imported energy products (IMF, 2018). In 2014, the EGO launched a comprehensive reform of the energy sector where Strengthening the capacity to guarantee where a more reliable electricity supply is considered as the priority. Moreover, an independent energy regulator is to be created to ensure pricing transparency. According to the ongoing energy subsidies reform, the EGO substantially raised the energy prices for both households and commercial uses. The EGO's strategy also includes introducing smart cards to monitor consumption and combat smuggling. Electricity tariffs were raised by about an average of 40% in July 2016, and by another 40% in July 2017, and by further 26% in July 2018. In June 2018, the EGO raised fuel prices by 44%, on average, for gasoline, diesel, kerosene, and fuel oil. It plans to achieve the objective of full cost recovery by end-2018/2019. Despite the rise of fuel prices in mid-2018, LPG and fuel oil used for electricity generation and bakeries were excluded from this increase.

4. METHODOLOGY

The ARDL model is used to investigate the relationship between electricity produced different fuel sources, income, and energy prices as shown in equation (1).

Figure 6: Ratios of Energy subsidies to total subsidies and total government spending



Source: Author calculation based on the Egyptian Ministry of Finance (2018), Data of FY 2017/2018 is from the budget plan

$$\Delta EPO_t = \alpha_0 + \sum_{i=1}^{m}\alpha_{1i}\Delta EPO_{t\_i} + \sum_{i=1}^{m}\alpha_{2i}\Delta EPG_{t\_i} + \sum_{i=1}^{m}\alpha_{3i}\Delta EPW_{t\_i} + \sum_{i=1}^{m}\alpha_{4i}\Delta GDPC_{t\_i} + \sum_{i=1}^{m}\alpha_{5i}\Delta PO_{t-i} + \sum_{i=1}^{m}\alpha_{6i}\Delta PG_{t\_i} + \beta_1 EPO_{t-1} + \beta_2 EPG_{t-1} + \beta_3 EPW_{t-1} + \beta_4 GDPC_{t-1} + \beta_5 PO + \beta_6 PG_{t-1} + \varepsilon_t \quad (1)$$

Where *EPO*, *EPG*, *EPW* represent electricity produced from oil, gas and water sources respectively, *GDPC* is the GDP per capita, *PG*, and *PO* are global gas and oil prices respectively. The current paper applies the ARDL of Pesaran et al. (2001) cointegration approach which is known as the bounds test. The model is advantageous to other cointegration approaches as it avoids the endogeneity problems and inability to test hypotheses on the estimated long-run parameters associated with the Engle-Granger method. Additionally, the long and short-run parameters of the model are estimated simultaneously. Furthermore, the ARDL approach is applicable regardless of whether the underlying regressors are purely stationary I(0), only integrated of order 1 I(1), or a mix of I(0) and I(1) series. Finally, the model is superior to multivariate cointegration techniques in small sample sized as in the underlying case (Narayan, 2005).

Here, we employ two models; the first one incorporates the oil prices only and is referred to as model 1. In this model, the α_{6i} and β_6 in equation (1) will equate zero. On the other hand, model 2 uses both oil and gas prices and is represented by equation 1.

According to Pesaran et al. (2001), The bounds testing is based on the F or Wald-statistics and is the first stage of the ARDL cointegration method. Accordingly, a joint significance test that implies no cointegration hypothesis, (i.e., H_0: $\beta_1=\beta_2=\beta_3=\beta_4=\beta_5=\beta_6=0$), against the alternative hypothesis, (H_1: $\beta_1\neq\beta_2\neq\beta_3\neq\beta_4\neq\beta_5\neq\beta_6\neq 0$) should be performed for equation (1). The F-test used for this procedure has a non-standard distribution. Thus, Pesaran et al.(2001) compute two sets of critical values for a given significance level with and without a time trend. One set assumes that all variables are I(0) and the other set assumes they are all I(1). If the computed F-statistic exceeds the upper critical bounds value, then the H_0 is rejected. If the F-statistic falls into the bounds, then the test becomes inconclusive. Finally, if the F-statistic is below the lower critical bounds value, it implies no cointegration. This study, however, adopts the critical values of Narayan (2005) for the bounds F-test rather than Pesaran et al. (2001). As discussed in Narayan (2005), given relatively a small sample size in this study (32 observations), the critical values produced by Narayan (2005) are more appropriate than that of Pesaran et al. (2001).

Once a long-run relationship has been established, equation (2) is estimated using an appropriate lag selection criterion. At the second stage of the ARDL cointegration procedure, it is also possible to perform a parameter stability test for the selected ARDL representation of the error-correction model which could be written as follows:

$$EPO_t = \alpha_0 + \sum_{i=1}^{m}\alpha_{1i}\Delta EPO_{t\_i} + \sum_{i=1}^{m}\alpha_{2i}\Delta EPG_{t\_i} + \sum_{i=1}^{m}\alpha_{3i}\Delta EPW_{t\_i} + \sum_{i=1}^{m}\alpha_{4i}\Delta GDPC_{t\_i} + \sum_{i=1}^{m}\alpha_{5i}\Delta PO_{t\_i} + \sum_{i=1}^{m}\alpha_{6i}\Delta PG_{t\_i} + \lambda EC_{t-1} + \varepsilon_t \quad (2)$$

Where λ is the speed of adjustment parameter such that $-1<\lambda<0$ and EC_{t-1} is the residuals that are obtained from the estimated cointegration model.

However, Bahmani-Oskooee and Chomsisengphet (2002) state that the existence of a cointegration derived from equation (2) does not necessarily imply the stability of the estimated parameters. Thus, the present paper tests the constancy of the employed model using CUSUM (i.e., the cumulative sum of recursive residual) and CUSUMSQ (i.e., the cumulative sum of squares of recursive residuals) tests based on the recursive regression of Brown et al. (1975). Both statistics are updated recursively and plotted against the break points of the model. Provided that the plots of these statistics fall inside the critical bounds of 5% significance, one assumes that the coefficients of a given regression are stable. These tests are usually implemented using graphical representation.

5. EMPIRICAL RESULTS

5.1. Data and Preliminary Analysis

The current paper is based on annual data from 1985 to 2017 where data of electricity production and energy prices variables are sourced from BP (2018), whereas data on GDP per capita and population[2] are obtained from World Development Indicators. Thus, the following variables are employed in the analysis: GDP per capita in 2010 real dollar values, Electricity production from gas in kWh per capita (EPG), Electricity production from oil in kWh per capita (EPO), Electricity production from water in kWh per capita (EPW). Both gas prices (PG) and oil prices (PO) are transformed to 2010 real dollar values using Egyptian GDP deflators. Table 1 displays the descriptive statistics of the included variables where all the variables are expressed in logarithmic form. All employed variables have normal distributions as confirmed by the Jaque-Bera test statistics. Table 2 shows the P-values of both ADF and Phillips-Perron unit root test statistics. Some of the variables are integrated of order one while others are stationary at levels which validates the employment of the ARDL model.

4.2. Long-run Relationship

After investigating the integrating order of the employed variables, the next step is to examine the presence of cointegration between them using the bounds testing approach. Given the small size of the sample, we use the critical values provided by Narayan

2 Population is used to generate the per capita production from the three different fuel sources.

Table 1: Descriptive statistics of the included variables

Statistics	*PO*	PG	EPW	EPG	EPO	GDP
Mean	4.499164	2.470821	5.125364	6.478622	5.441117	7.589527
Median	4.496432	2.371458	5.133578	6.523448	5.468179	7.591918
Maximum	6.079346	4.230058	5.313846	7.337326	5.972321	7.932136
Minimum	3.362309	1.174474	4.922613	5.210844	4.912723	7.275582
Standard deviation	0.560774	0.636841	0.099619	0.673763	0.252814	0.224596
Skewness	0.191311	0.632979	−0.171549	−0.371416	0.028581	0.080934
Kurtosis	3.770809	4.374825	2.586961	1.845721	2.708697	1.550537
Jarque-Bera	1.018252	4.802590	0.396436	2.590718	0.121171	2.924824
Probability	0.601021	0.090601	0.820191	0.273800	0.941213	0.231677

Table 2: P-values of unit root tests

Variables	ADF	PP
EPGt	0.3599	0.1886
ΔEPGt	0.0279**	0.0244**
EPWt	0.3568	0.2261
ΔEPWt	0.0001*	0.0013*
EPOt	0.0782***	0.7081
ΔEPOt	0.0295**	0.0016**
GDPt	0.2651	0.3686
ΔGDPt	0.0245**	0.0189**
POt	0.1319**	0.1204
ΔPOt	0.0000*	0.0000*
PGt	0.1744	0.0148**
ΔPGt	0.0002*	0.0003*

Lag length is chosen according to SIC. *, **, *** indicates significance at 1%, 5% and 10% level of significance. All variables are expressed in the logarithmic form

(2005). Table 3 displays the empirical results of the bound test and Narayan's (2005) critical values. Variables included in both models are cointegrated since the computed F-statistics exceeds the upper critical bounds value at 1% level of significance.

Figures 7 and 8 show the plot of CUSUM and CUSUMSQ test statistics. The results of both tests indicate that both models are stable in the long run since the test statistics fall inside the critical bounds of 5% significance.

The next step is to investigate the long-run relationships between electricity production from different sources, GDP per capita and energy prices using the cointegration technique. Table 4 presents the results of the ARDL models. The results of model 1 show that oil prices have no impact on electricity produced from oil in the long-run. The results also reveal that increasing electricity generation from the gas by 1% cause a 1.94% reduction in EPO meaning that both sources are substitutes in the long-run. Finally, the coefficient of electricity production from water is positive but insignificant. Concerning the impact of income on electricity production, it is positive and significant implying that a 1% increase in *GDPC* will lead to a %6.5 increase in electricity produced from oil sources.

Concerning model 2, energy prices are significant with the right signs. Thus, an increase in oil prices by 1% results in a 0.94% reduction in electricity produced from oil while an increase in gas prices by 1% lead to a rise of 1.26% in electricity generated from gas sources. The estimated elasticities of EPG and GDP are higher compared to their counterparts in model 1. As before, gas fuel is a substitute for oil fuel in electricity generation. Finally, a 1% increase in hydroelectricity leads to a 2.94% increase in electricity generated from oil. Based on this result, we can infer that both sources are complementary inputs in electricity supply.

Panel B of the Table 4 presents the diagnostic tests of the estimated models. The lagrange multiplier test (LM) for serial correlation and the Jarque-Bera test for the normality of the residuals as well as ARCH LM test for heteroscedasticity and Ramsey RESET Test for model specification confirm that there is no significant departure from the standard assumptions.

4.3. Error Correction and Short-term Dynamics

Table 5 displays the short-term parameters along with the error correction term (ECT) in both models. In model 1, the error-correction term is −0.27 with the expected sign, suggesting that about 27% of any movements from disequilibrium are corrected for within the same year (i.e., the full convergence process to its equilibrium level takes around four years). When gas prices are included in model 2, the error-correction term equals −0.23, implying that around 23% of the deviation from the long-run relationship is adjusted in the same year.

Concerning the short-term elasticities, the oil price has a negative influence on electricity production in both models where the impact is higher in model 2. Thus, a 1% increase in oil prices leads to a decrease of % 0.11, and 22% in electricity generated from oil in models 1 and 2 respectively. Additionally, the results of both models show that gas and oil are substitutes while water and oil are complementary sources. Thus, a 1% increase in EPG leads to 1.78% and 2.08% decrease in EPO in models 1 and 2 respectively. On the other hand, a rise of 1% in EPW results in an increase of 0.75% and 0.69% in models 1 and two respectively. As expected, short-term elasticities are lower than their counterpart long-term as authorities could modify the mix of different sources over the longer periods compared to short periods as well as the role played by technology changes in the long-term.

5. CONCLUSION

The objective of the current paper was to investigate the production elasticity of electricity generated by different fuel sources (gas, oil, and water) to energy prices and GDP per capita in Egypt. The generation of electricity has been heavily depended on non-renewable energy resources due to the substantial subsidies on fossil energy. Comprehensive reforms of the energy sector reforms implemented in 2014 with the aim of ensuring a more reliable

Table 3: Bounds test for cointegration

Dependent variable	Computed F-stat.	Sample size	1% critical values		5% critical values	
			I0 bound	I1 bound	I0 bound	I1 bound
Model 1 (k=4)	6.742452*	n=30	4.768	6.670	4.537	6.370
		n=35	4.590	6.368	3.276	4.630
Model 2 (k=5)	6.719435*	n=30	3.354	4.774	3.125	4.608
		n=35	4.257	6.040	3.037	4.443

Table 4: Long-run elasticities using ARDL models

Dependent variable: ΔEPO_t	Model 1		Model 2	
Panel A: long-term elasticities				
	Coef.	P-value	Coef.	P-value
EPG_t	−1.946237	0.0010*	−2.457236	0.0007*
EPW_t	2.808122	0.1401	2.940237	0.0729***
GDP_t	6.509177	0.0010*	8.573443	0.0012*
PO_t	0.255200	0.2309	−0.943758	0.0716***
PG_t			1.257757	0.0596***
C	−46.35034	0.0208**	−56.80917	0.0109**
Panel B: Diagnostic tests				
ARCH (2) LM	1.603748	0.2054	2.010293	0.3660
Jarque-Bera	0.992907	0.608685	1.1111	0.5737
Breusch-Godfrey test	0.897204	0.6385	2.222418	0.3292
Ramsey RESET test	0.282097	0.6012	0.810900	0.3786

−lag length is chosen according to SIC. − *, **, *** indicates significance at 1%, 5% and 10% level of significance

Figure 7: Plot of CUSUM and CUSUMSQ Stability tests for model 1

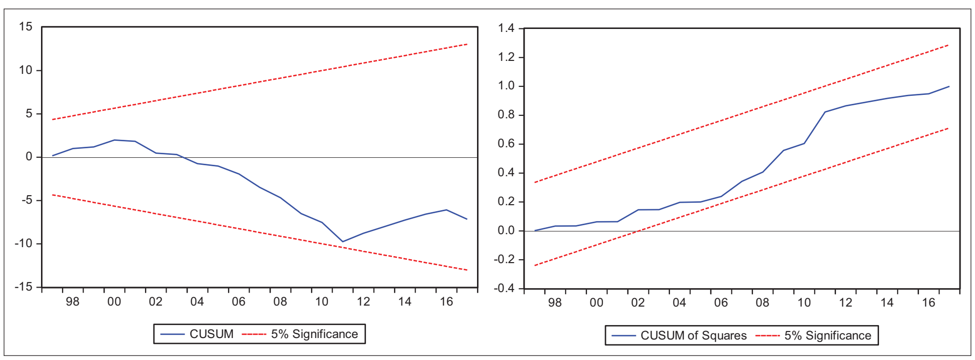
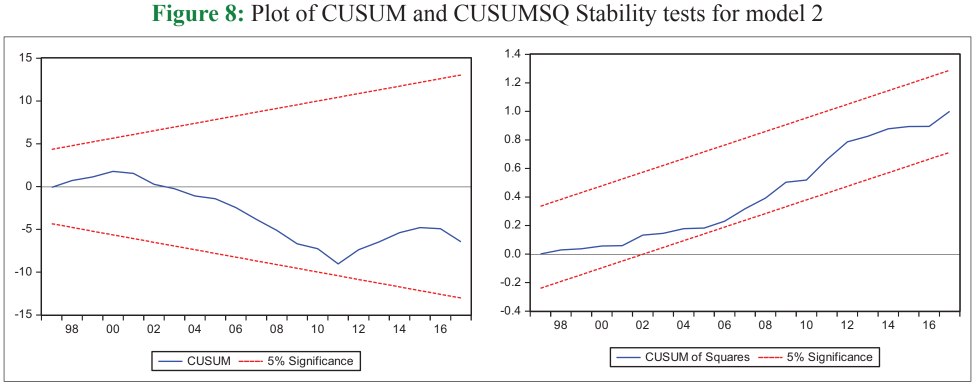


Figure 8: Plot of CUSUM and CUSUMSQ Stability tests for model 2



electricity supply and achieving cost recovery by 2018/2019. In June-2018, a new mechanism of adjusting domestic fuel prices to changes in international fuel prices and the exchange rate has been introduced. Moreover, Egypt's Vision 2030 highlights the importance of raising the share of renewable energy in electricity generation and targeting CO_2 emissions' mitigation.

We estimated two models. The first model excludes the gas prices whereas the second model accounts for it. We found evidence of a long-term relationship between the GDP per capita, oil prices, gas prices and electricity production from different sources. Results of model one revealed that in the long run, gas is considered as a substitute for oil in electricity production and GDP per capita

Table 5: Short-run elasticities using ARDL models

Dependent variable: ΔEPO_t	Model 1		Model 2	
	Coef.	P-value	Coef.	P-value
ΔEPG_t	−1.789505	0.0000*	−2.077117	0.0000*
ΔEPW_t	0.747453	0.0041*	0.690350	0.0019*
ΔGDP_t	2.063836	0.0896***	2.120572	0.0997***
ΔGDP_{t-1}	−3.106459	0.0147**	−3.668448	0.0501***
ΔOP_t	−0.109350	0.0965***	−0.221589	0.0202**
ΔPG_t			0.295314	0.0038*
EC_{t-1}	−0.266175	0.0488**	−0.234794	0.0127**

positively influences EPO. Further, oil prices negatively affect the EPO in the short-run only. Additionally, gas fuel and hydropower are considered as a substitute and a complementary to oil in the short-term, respectively. Finally, the ECT indicates that around 27% of any disequilibrium is adjusted within the same year.

Findings of model two showed that oil prices have a negative impact on EPO over long and short terms. Concerning the cross elasticity of EPO to gas prices, it is found that gas prices have a positive and significant impact on EPO in the short-run and long-run reaching 0.295 and 1.25, respectively. Similar to results obtained from model one, GDP per capita has a positive impact on EPO and gas is a substitute for oil in electricity supply in all terms. Moreover, EPW is complementary for EPO in both the short and long terms. Finally, the ECT implies that about 23% of deviation from the long-run relationship is corrected in the same year.

In both models, long-term coefficients are higher than short-term elasticities which could be explained by the flexibility to accommodate any shock in the longer term. Also, technology and demand changes could play a significant role in explaining the differences between EPG and EPW elasticities between short-term and long-term.

These findings reflect the partial success of the EEHE strategy regarding the use of gas as the primary source of electricity production. However, this strategy was unsuccessful in increasing dependence on renewable energy. Thus, Egypt needs to make more efforts to boost the renewable component in electricity generation. However, choosing the energy supply mix must be carefully weighed in terms of the growth of electricity demand, environmental targets, optimal usage of indigenous resources of energy, total cost including oil imports bill, gas discoveries and potential electricity exports given the growing trade and inter-connections of electric grids. The ongoing offshore explorations confirm the presence of significant gas reserves in Egyptian territorial waters in the Mediterranean. According to IMF (2018), negotiations with international gas exploration companies, to develop these new fields to reach production sharing agreements, are at an advanced stage.

Taking into consideration the findings of Sequeira and Santos (2018), the massive waves of anti- EGO demonstrations starting from 2011, and the repeated clashes between demonstrators and riot police, it is highly advised to ensure government accountancy (e.g., improving the democratic and the rule of law standards) to avoid these disturbances that negatively affect electricity production. Moreover, policies aiming at eliminating poverty and inequality are of crucial importance. In this regard and given the budget savings realized from subsidy cut, cash transfers to the poorest two quintiles of the rural and urban population are highly recommended by many scholars (e.g., Al-Ayouty and Al-Raouf, 2015). In other words, up to 50% of these savings should be earmarked to the cash transfers, mainly in the domains of health, education and social protection. Meanwhile, the EGPC is highly encouraged to reduce existing arrears (exceeded $6 billion in 2014) to international oil companies, the main suppliers of fuel, and not accumulate new net arrears.

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